DYKE'S
AUTOMOBILE
AND
GASOLINE ENGINE
ENCYCLOPEDIA

C.R.E. 10-15-24

Dyke's Automobile
and Gasoline Engine
Encyclopedia

The
Elementary Principles, Construction, Operation *and*
Repair *of* Automobiles, Gasoline Engines *and*
Automobile Electric Systems; including
Trucks, Tractors, *and* Motorcycles

Simple, Thorough *and* Practical

By
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Electrical Engineer
St. Louis, Mo., U.S.A.

Thirteenth Edition
Enlarged and Entirely Rewritten, Rearranged
and brought down to date

THIRD RUN

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St. Louis, Mo.

Dyke's "Automobile and Gasoline Engine Encyclopedia" has passed through more than 25 editions and impressions, and is recognized as the standard authority throughout the English-speaking world.

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PREFACE TO THE THIRTEENTH EDITION

This book has been compiled with three general classes of readers in mind, i.e., the **student,** the **repairman,** and the **car owner.**

Uppermost in the mind of the author has been the needs of the **student**—the man who is seeking to master the many mechanical and scientific principles involved in the completed automobile. The plan of the book is to present this information in the form of Instructions, in place of the conventional chapters. If the student will proceed systematically through the book, digesting each Instruction before passing to the next, and if, in addition, he can have a car available for practical demonstration and experiment, he should emerge at the end with a mind stored with all the necessary facts and principles to make of him a fully equipped car mechanic.

The one great aim of the author has been to make the book **practical.** Fundamental principles are necessarily discussed in every case, but always in the light of their practical relation to the subject involved. Mere technical discussions are entirely avoided.

To make the book as practical as possible, the **underlying principles** involved in each subject are first discussed. The truck and the tractor are each related to the automobile, and hence they are given full space in the general scheme of the book. The scientific principles embodied in the highly developed cars of today underlay the earlier designs, now discarded. Hence many of the old designs are illustrated and discussed, in order that the developed designs of the modern type may be thoroughly understood.

When once the student has mastered the **fundamental principles,** he will understand the various developments now on the market, no matter how diversified they are. And, by way of additional assistance, the book undertakes to point out the differences in method employed by the different makes of cars now in use.

The **Index** is so complete as to enable the reader to put his finger on any subject, even though it is discussed on several different pages or is illustrated at different points. Familiarity with the Index is urged as a means of greatly increasing the usefulness of the book. The Table of Contents and the Index, used intelligently, will quickly lead the reader to any subject on which information is sought. It may be well, however, to add that the book embodies thirteen principal sections:

I. ASSEMBLY OF THE AUTOMOBILE
II. THE AUTOMOBILE ELECTRIC SYSTEMS
III. THE STORAGE BATTERY
IV. WIRING DIAGRAMS
V. IGNITION AND CARBURETION
VI. TIRES
VII. GARAGE AND SHOP EQUIPMENT
VIII. REPAIRING AND OVERHAULING ENGINE AND CAR
IX. OXY-ACETYLENE WELDING
X. COMMERCIAL CARS
XI. TRACTORS
XII. FORD CAR, TRACTOR, ETC.
XIII. DATA; SPECIFICATIONS; HORSEPOWER; USEFUL INFORMATION

These are supplemented by special instructions and illustrations on the Ford car and the Ford wiring circuits; the Aeroplane and the Liberty engine; the Continental engine; the Dixie magnetos; Engine Construction.

In short, the student will find the entire field so comprehensively covered that, no matter what may be his need for information, it can be found.

And, since every student is a potential **repairman,** it has been the serious endeavor of the author to make the book a complete book of instruction embodying all the accumulated knowledge of car builders, engineers, and master mechanics engaged in the automotive industry.

If the book is used by the **repairman** as it should be used, he will have it always available for immediate **reference,** at the bench as well as at home. If he will use the book intelligently, in the light of what has been said, he will find practical suggestion and advice covering every question that he will encounter in the shop, in the garage, or on the road. The book will save him from errors of judgment and from overlooking the real cause of trouble in a car; and it will serve to teach him things that he does not know, or methods that are time-saving and economical.

The average **car owner** is in much the same situation as the student, in his need of the necessary knowledge to enable him to meet emergencies with intelligence, and to maintain his car without relying on advice from others.

Every driver of a car should realize that in an emergency his trouble may be any one of a possible thousand or more. How is he to detect the nature of his trouble, or to tell what must be done? This book enables him, without loss of time and without annoying experiment, to put his finger on the specific defect, and tells him what to do as permanent repairs or as a temporary remedy. A free use of the book makes him "master of his fate."

Extremely few car owners attempt even the simple repairs needed on their cars. They lack the information necessary to decide what is wrong and how it should be remedied. To this class the advantage of this book lies in telling them what work ought to be done on the car, and, if done by a repairman, whether it has been done right. A study of the book at spare intervals will give the car owner information by which to diagnose his own car troubles, and to determine the extent of the repairs needed. The advantage to the man who knows these things is incalculable.

This, the 13th edition, has been completely re-written. Moreover, the thousands of illustrations have been assembled with a view to showing graphically every point discussed. Many of these are not drawn to scale; the exaggerations that they show are intentional, in order to bring out clearly the point discussed and the principle involved.

The author has drawn freely on the accumulated knowledge of that highly intelligent body of men who together represent the many branches of the automotive industry. He is glad to take the opportunity afforded here of expressing his profound gratitude for the generosity and co-operation with which each one of them has placed his own special knowledge at the author's disposal.

The author is equally under heavy obligations to the several trade journals of the automotive industry. His warm personal relations with the various editorial staffs and the free drafts that he has made on their pages are appreciatively and gratefully recognized. The present is an opportunity that is gladly availed of to enable him to express his sense of gratitude and friendship covering personal relations of many years' standing. Specifically, the author is indebted to *The Automobile* (New York), *Motor Age* (Chicago), *Motor World* (New York), and *Automobile Dealer and Repairer* (New York). While credit is given in the following pages wherever it is due, it is a pleasure to the author to express his obligations in a comprehensive manner.

A. L. Dyke

St. Louis, Mo.
September 15, 1922

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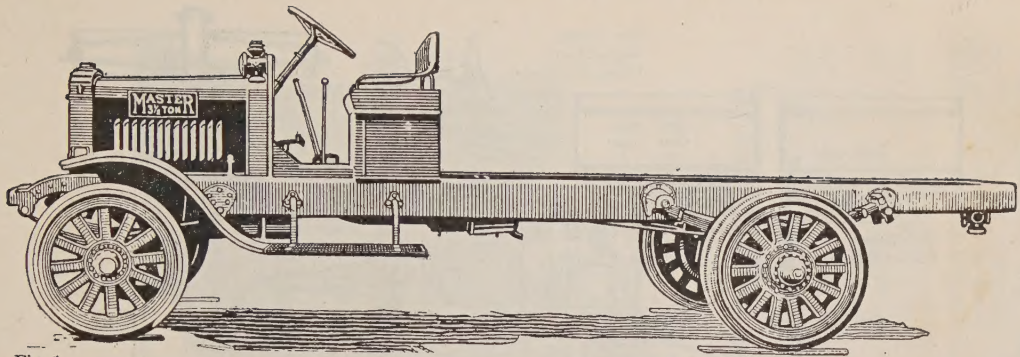


Fig. 1

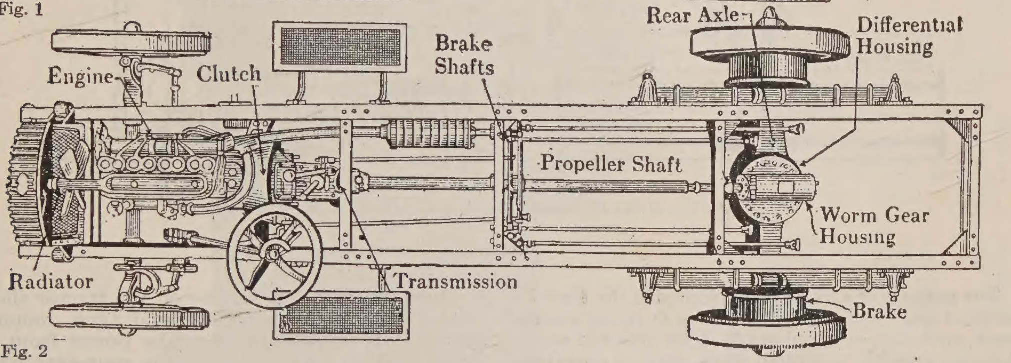


Fig. 2

A Truck

The principle of the truck is similar to the principle of a passenger car type of automobile.

The engine is usually a four-cylinder type of engine, for reasons explained under the Truck Instruction. (See Index.) The truck engine is a slower-speed engine than the automobile engine. The average maximum speed of a truck engine is 900 to 1,000 r.p.m. The engine speed is controlled by a hand throttle and foot accelerator, as in the case of the automobile engine, but **a governor is employed,** for reasons stated under the Truck Instruction, which is to prevent undue "racing" of the engine when changing gears or releasing the clutch.

By governing the engine speed, the car speed is also limited. For instance, the governor can be set to govern the engine speed at 950 r.p.m., which gives a maximum car speed of 14 m.p.h., which is the average speed of a heavy-duty truck.

The speed of a passenger type of automobile varies from 1½ m.p.h. to 50 or 60 m.p.h., and a governor is not employed. The engine speed of a passenger type of automobile varies from 150 r.p.m. to as high as 2,500 to 3,000 r.p.m. The truck, however, being designed for commercial use, must necessarily be more efficient; hence the employment of a governor.

All complicated devices are eliminated on a truck, for the sake of efficiency. For instance, the electric starting motor is seldom used. Instead, the engine is cranked by hand in connection with an "impulse starter" (see Index). Instead of a coil, battery, generator, cut-out, timer, and distributor being used for **ignition,** a high-tension magneto is usually employed. The gravity fuel-feed system is used instead of a vacuum or pressure feed. The tubular type of radiator for **cooling** is used instead of the cellular type. The cellular type, as generally used on automobiles, is more artistic in appearance, but the tubular type has larger openings, is less liable to clog, and is easier to repair.

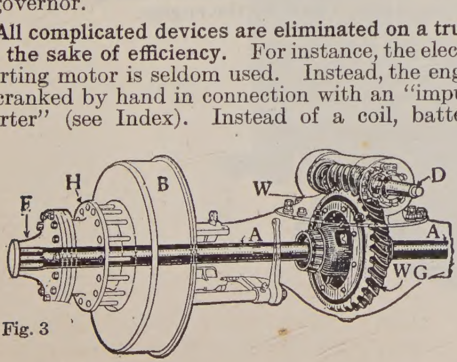


Fig. 3

The drive method usually depends on a propeller shaft connected with (**D**) to a worm gear (**W**) to a worm-driven gear (**WG**) on the differential. The worm gear gives a greater reduction and is silent and possesses enormous strength.

The rear axle is usually a full-floating "live" axle. Axle shafts (**A**) are split and the inner ends are connected to differential gears and the outer ends to the hub flange (**F**).

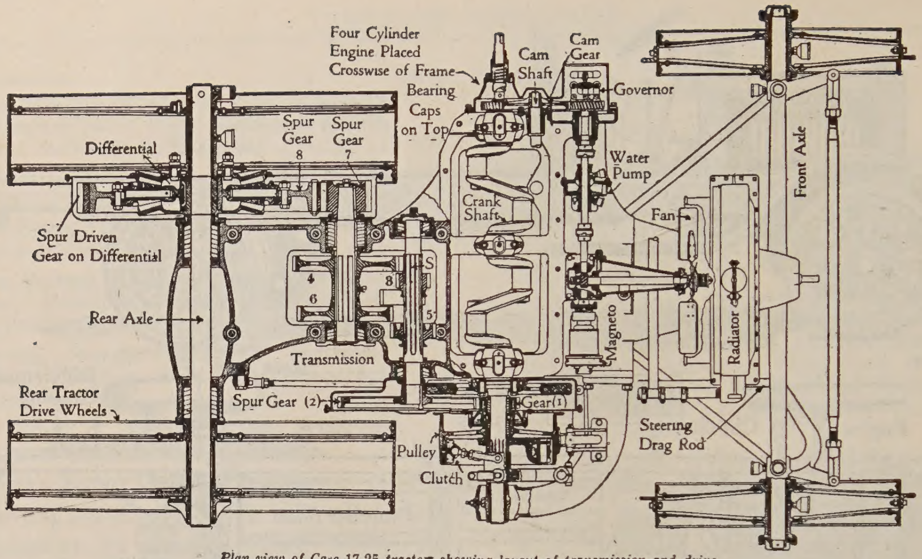
The transmission is usually a three-speed forward and reverse, and is similar to an automobile transmission, but of heavier construction. **Gear ratios:** On the truck shown above: **on first speed,** rear wheels make 1 revolution to every 24 of the crank shaft of the engine; **on second speed, 1 to 13.6; on high speed, 1 to 8.**

The clutch used on the truck shown above is a dry-plate multiple-disk type. The disk type of clutch is extensively used, as is also the cone type of clutch.

The tires on the truck illustrated are solid 34″ x 4″ single, in front; 36″ x 7″ in rear. The "dual" solid tire, also the "pneumatic cord" truck tire is also extensively used.

The steering gear used on the truck shown above is the Ross; see Index under "Steering devices."

From the foregoing specifications of a truck and after a study of this book, it will be noted that a truck differs only in a few details from the principle of the passenger-car type of automobile.



Plan view of Case 17-25 tractor, showing layout of transmission and drive

A Tractor

The purpose of a tractor is explained in the Tractor Instruction. Note that in addition to doing **tractor work,** such as pulling plows or other drawbar work, it is also possible to do **belt work,** such as operating threshing machines, etc.

The illustration above is that of a four-cylinder engine tractor. Most all tractor engines are four-cylinder, for reasons explained under the Tractor Instruction.

The construction of a tractor differs considerably from that of an automobile or truck, but the same underlying principles of the engine and drive system are employed.

The engine used on a tractor is a slow-speed engine, and has usually a long stroke. This particular tractor engine has a bore of 4½ in. and a 6 in. stroke. **A governor** is employed for the purpose explained under the subject of "Governors." The speed of the engine is governed to 900 r.p.m.

The ignition is usually a high-tension magneto, with an "impulse starter" (see Index for explanation of an impulse starter). Most tractor engines use magneto ignition for reasons stated in the Tractor Instruction.

The tractor engine operates for long periods of time at full power. Therefore it must be built heavier and more substantial than the automobile engine, as, for instance, in the bearings, etc.

The fuel is usually gasoline to start with and kerosene to run on after the engine is started and thoroughly heated. **The heating** of a tractor engine, in order to use kerosene or low-grade fuels, is a very important factor.

Drive system: The engine on the tractor shown above is a four-cylinder, vertical type, mounted transversely on the frame. The power from the crank shaft is transmitted to the **spur-gear transmission** by means of a clutch. From the transmission, power is transmitted to the rear axle by means of a spur-gear drive. The differential is employed as shown in the illustration. Power is transmitted to both rear wheels, which are 52 in. in diameter and have a 12-in. face.

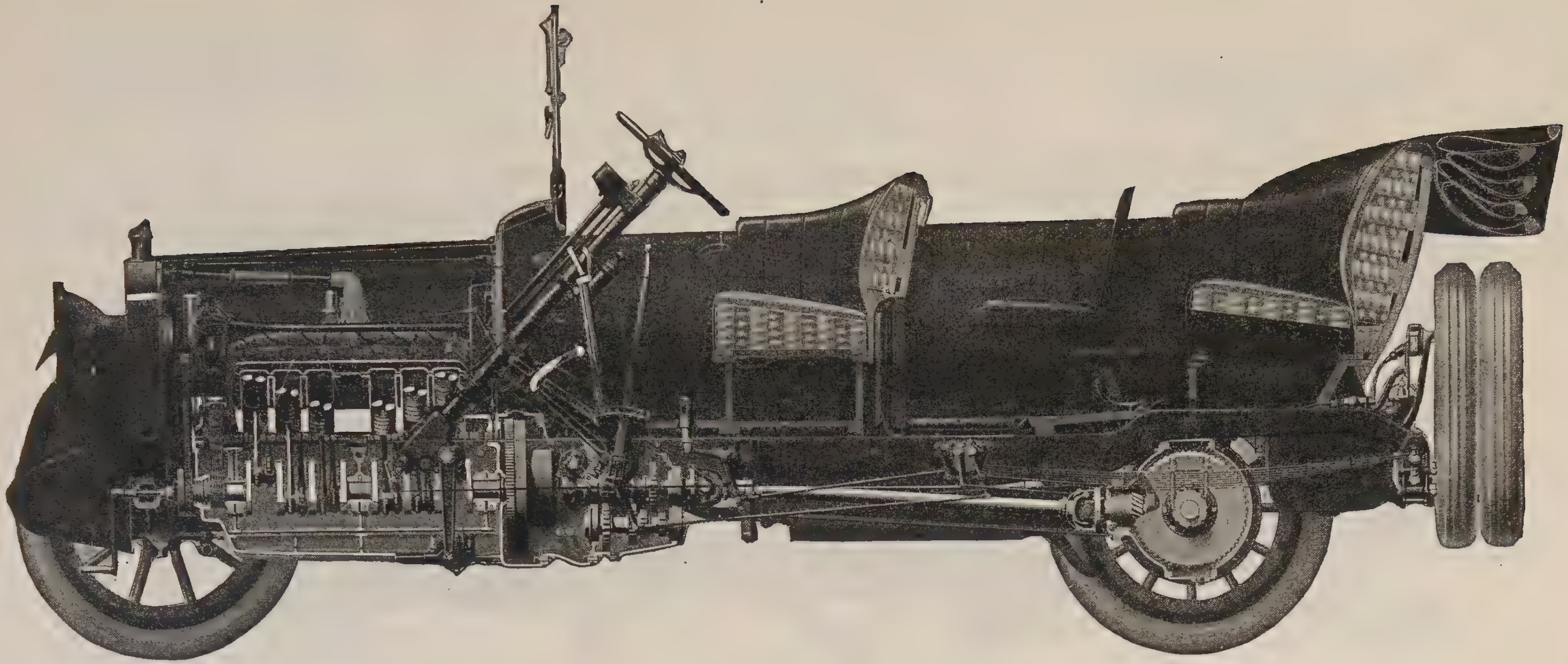
The speed of the average tractor is 2 m.p.h. on slowest speed, and 2¾ m.p.h. on high speed (see also Index under "Tractors").

The belt power is obtained from a 16-in. pulley mounted on an extension of the engine shaft, and runs therefore at engine speed—900 r.p.m.

The tractor illustrated (the Case 15–27 h.p. tractor) has a wheel base of 76½ in., and its overall dimensions are: length, 126 in.; width, 72 in.; height (without exhaust pipe), 68 in. The shipping weight is 5,500 lbs.

The tractor pulls three 14-in. plows in tough sod, or four plows under usual conditions. It is also adapted for other drawbar work, requiring a similar amount of power, and it will operate either a 20 x 36-in. or a 26 x 46-in. thresher (belt work).

It will be observed that the tractor, while it differs widely in construction, from that of the truck or passenger car automobile, is, in many respects, similar in principle, the main difference being in the drive system and fuel used by the engine.



A Twelve-Cylinder Automobile

The modern automobile employs either a four, six, eight or twelve-cylinder engine. The illustration above shows a twelve-cylinder car.

The engine, clutch, and transmission are housed in one unit, called a "unit-power-plant."

The drive on the car shown above is a propeller shaft with a spiral or helical drive pinion which meshes with a spiral-driven ring gear on the differential of the rear axle. Straight-tooth bevel gears are also used on many makes of cars.

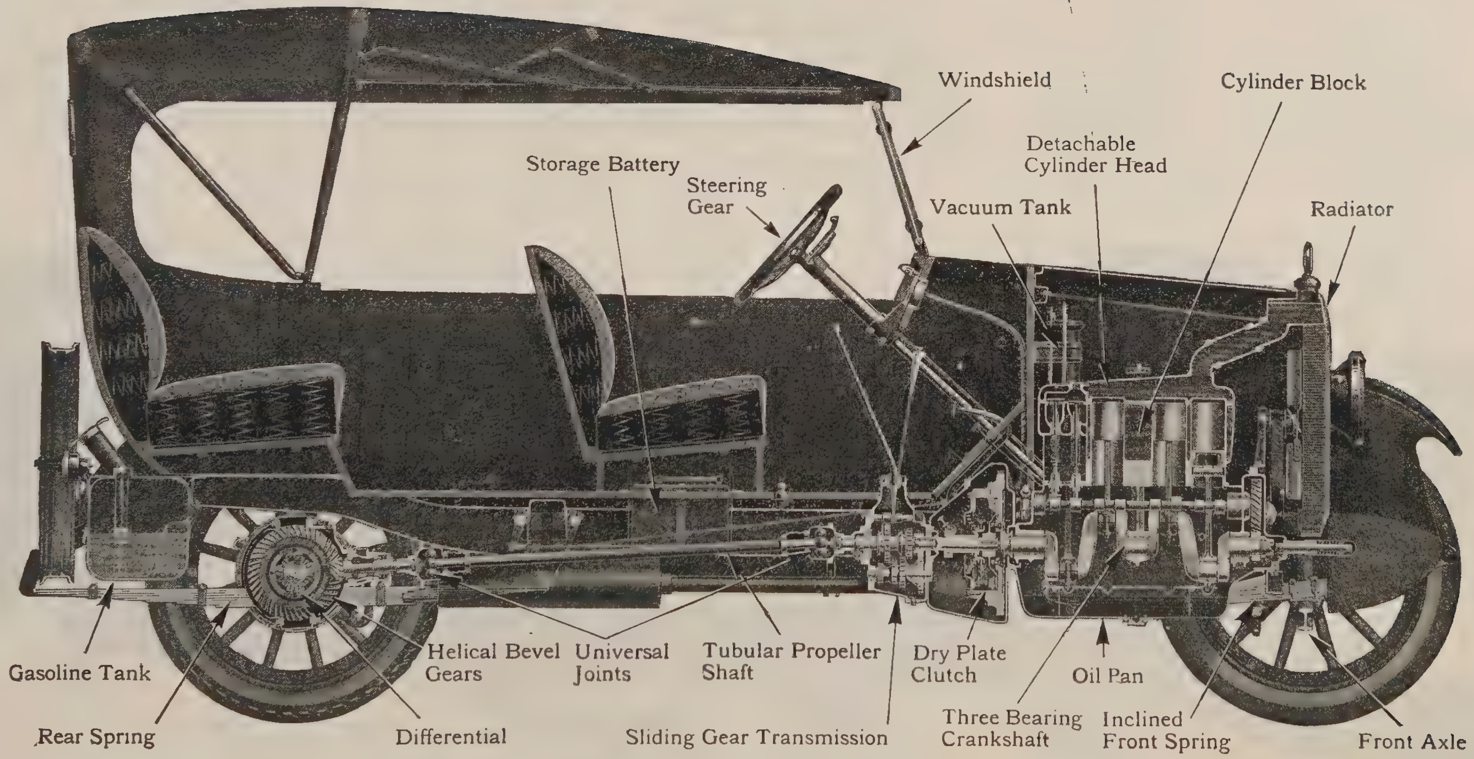
The engine is started by an electric motor, which derives its electric current supply from a storage battery. The storage battery is kept charged by a dynamo or generator, driven from the engine.

The gasoline feed is from the gasoline tank in the rear of the car. In this instance, the gasoline is fed to the carburetor by air pressure. On many other modern cars the vacuum principle is extensively used.

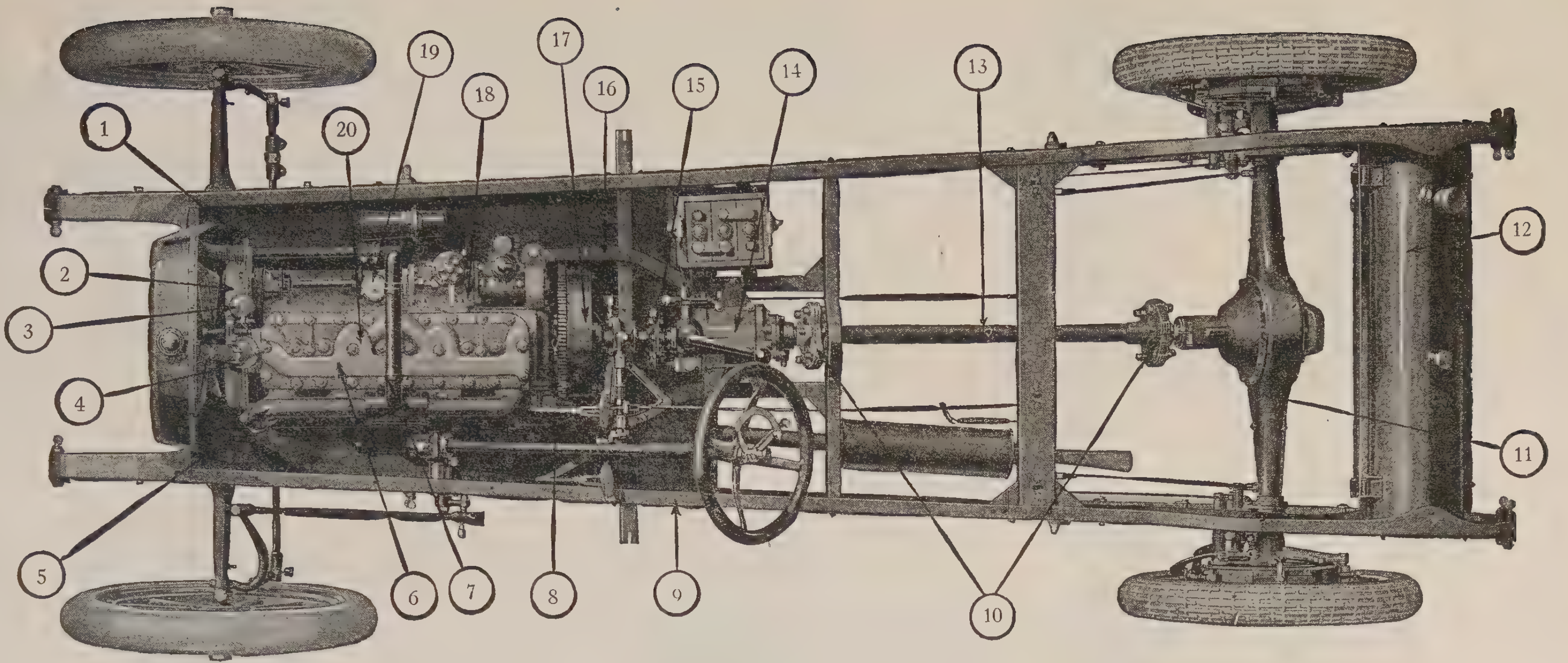
The speed of the engine is controlled by a foot accelerator and hand throttle. Owing to the great variations of speed, the governor is not employed on passenger-car automobiles. The speed of automobile engines varies from 150 to 2,500 r.p.m., and is sometimes as high as 3,000 r.p.m.

The ignition, in most instances, and in the car shown, is of the coil, battery, timer, and distributor type, but many use the high-tension magneto.

Cooling is a forced circulation, by means of a water pump. A sylphon or water thermostat is used for reasons stated in the discussion on the subject of "Cooling." The cellular type of radiator is used.



A Four-Cylinder Automobile (Allen)



A Six Cylinder Automobile (Studebaker Light-Six)

1. Silent chain adjusting nut.
2. Aluminum timing-gear case.
3. Oil-filler pipe.
4. Thermostatic water regulator.
5. Exhaust manifold.
6. Aluminum detachable head.
7. Warm-air stove and pipe leading to carburetor.
8. Starter motor and Bendix drive.
9. Deep-channel section straight-side frame.
10. Flexible-disk universal joints, requiring no lubrication.
11. Pressed-steel rear-axle housing.
12. 15-gallon gasoline tank with protecting shield.
13. Tubular propeller shaft.
14. Transmission suspended at three points on subframe.
15. Flexible-disk coupling between clutch and transmission.
16. Sub-frame carrying engine, clutch, and transmission.
17. Flywheel containing single-plate dry-disk clutch.
18. Accessory unit containing generator, water pump, oil pump, distributor, coil, and relay.
19. Horizontal carburetor.
20. Horizontal intake manifold, water manifold, and detachable head.

Specifications: five passenger; 112-inch wheel base; 40 h.p. 6-cylinder engine; 3⅛ in. bore x 4½ in. stroke; weight of car complete, 2,500 lbs.; 32 x 4 in. tires. **See** Index for other parts of this car.

ASSEMBLY OF THE AUTOMOBILE

The automobile is made up of four component units: the running gear, the power plant, the drive system, and the control members.

These parts are subdivided into other units, and each of these will be treated separately farther on. Although the construction of the different makes of cars may vary, the principle or purpose of the parts remains the same.

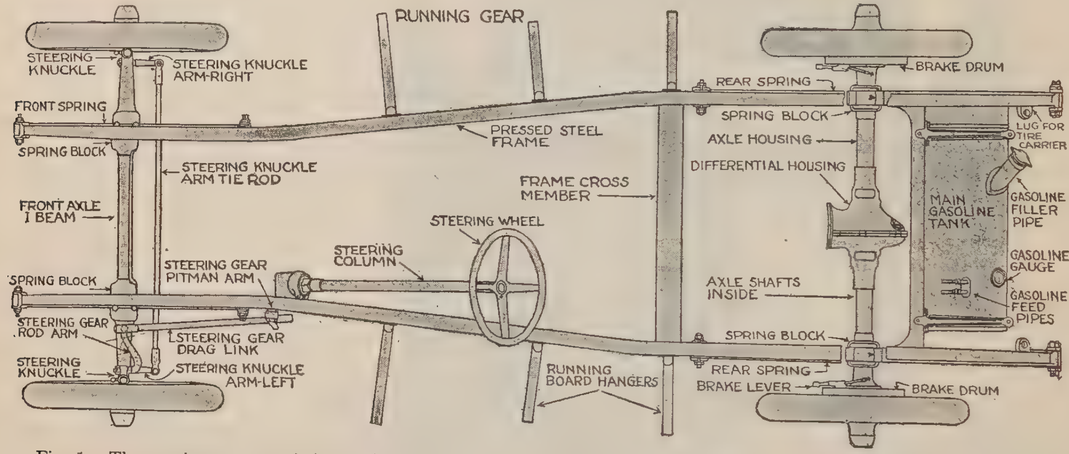


Fig. 1. The running gear, consisting of the front and rear axles, springs, pressed steel frame, and steering device. The main gasoline tank is shown attached.

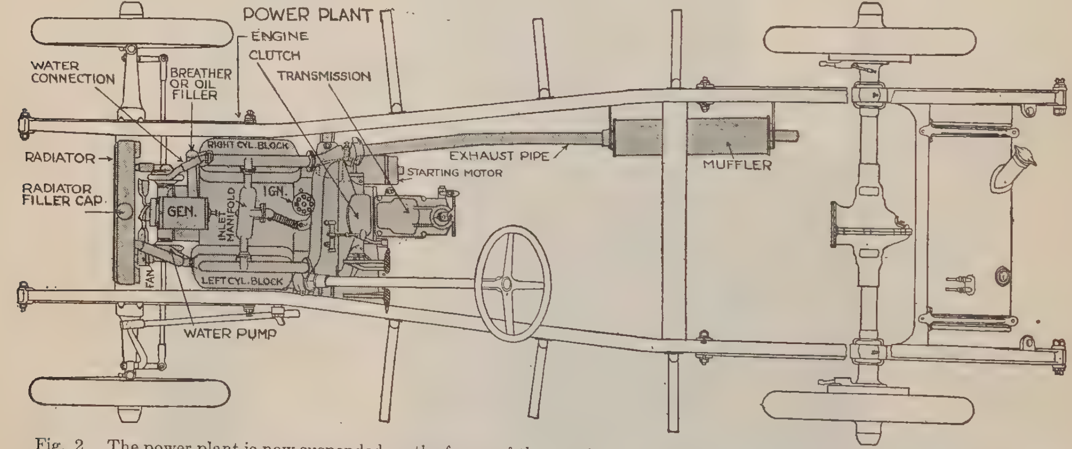


Fig. 2. The power plant is now suspended on the frame of the running gear. The power plant in this example consists of an eight-cylinder V-type engine with the clutch, clutch housing, and transmission all mounted as one unit. It is, for this reason termed a "unit power plant."

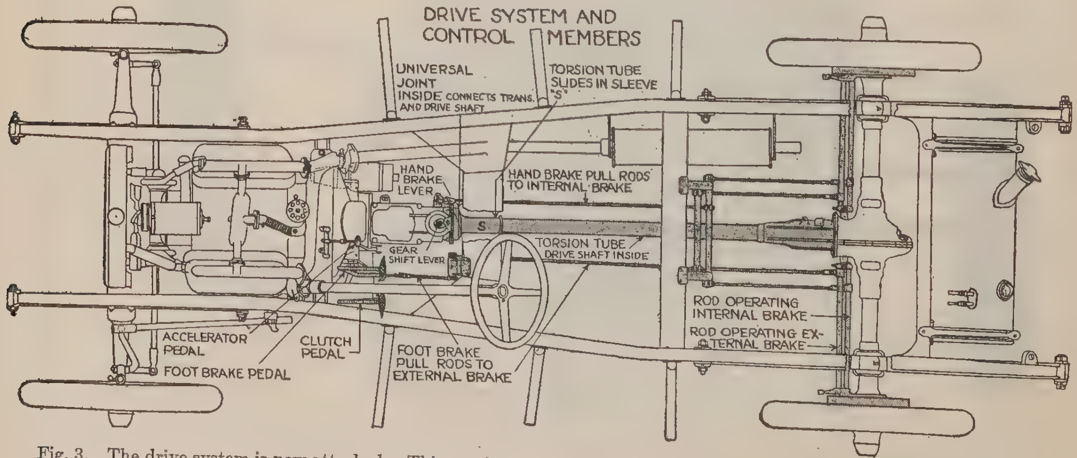

DRIVE SYSTEM AND CONTROL MEMBERS
UNIVERSAL JOINT INSIDE CONNECTS TRANS. AND DRIVE SHAFT
TORSION TUBE SLIDES IN SLEEVE "S"
HAND BRAKE LEVER
HAND BRAKE PULL RODS TO INTERNAL BRAKE
S
GEAR SHIFT LEVER
TORSION TUBE DRIVE SHAFT INSIDE
ACCELERATOR PEDAL
FOOT BRAKE PEDAL
CLUTCH PEDAL
FOOT BRAKE PULL RODS TO EXTERNAL BRAKE
ROD OPERATING INTERNAL BRAKE
ROD OPERATING EXTERNAL BRAKE

Fig. 3. The drive system is now attached. This consists of a propeller or drive shaft encased with a universal joint inside of the torsion tube. On many cars the drive or propeller shaft is not encased. The above is termed the *chassis.*

INSTRUCTION No. 1

ASSEMBLY OF THE AUTOMOBILE

GENERAL EXPLANATION

The Kinds of Motor Cars

There are three different kinds of motor cars: first, the gasoline motor car; secondly, the steam car; thirdly, the electric car.

The gasoline motor car is by far the most popular and it is with this that we are mainly going to deal.

The steam car, silent, smooth, and easy on tires is comparatively seldom seen.

The electric car, almost invariably in the form of a brougham or coupé, is heavily handicapped by being unable to run for more than a few hours without a fresh charge of electricity from its headquarters, and is in less general use. Our attention will be devoted to the car with the gasoline engine for the motive power.

The Component Parts of a Motor Car

A car may be made up as a whole of two distinct parts, the body and the chassis.

The body, which is the work of the body builder and which has been brought by him to a wonderful pitch of perfection, hardly concerns us, so we will unscrew the half-dozen or so bolts that secure it to the frame of the chassis and stand it to one side —for the present, at least—so that we can examine the chassis underneath.

The chassis is the entire car (Fig. 3, opposite), with the exception of the body. The chassis, for our purpose, must also be divided into its main parts as follows: the running gear, the power plant, the transmission system, the control system, the equipment and accessories.

The running gear consists of parts as follows: front and rear axles, wheels, springs, frame.

The power plant (Fig. 2, opposite), consists of parts as follows: the motor with its fuel system, the carburetion system, the ignition system, the cooling system, and the lubrication system.

The drive system consists of parts as follows: the clutch, the change-speed gears, the drive shaft with its universal joints, and the differential.

The control system consists of parts as follows: the steering device, the throttle and spark control, the hand levers, the foot pedals, and the brake system.

The construction of the parts of a motor car may vary, but their purpose is the same. While it is true there are hundreds of different firms making automobiles, they all employ in the construction of their cars the parts enumerated under the various headings. For instance, one manufacturer may suspend the power plant on the main frame, others use a sub-frame; some use a clutch of the cone type, others use a clutch of the multiple disk type—but they all use frames and they all use clutches. Farther on we shall explain the different constructions involved in these parts; but bear in mind that the fundamental principle or purpose of each part does not change.

As we progress, the reader will gain an idea of the different constructions of the component parts now in general use. For instance, there are two kinds of front axles in general use: the tubular type and the solid type. There are two types of construction of rear axles in general use: the live axle which revolves and is driven by a bevel gear and pinion, and the dead axle which does not revolve, but on which the wheels are driven by chain and sprocket; and so on, throughout the whole construction of a car.

It is now clear that if the reader masters the principle and purpose of these parts, it will be no difficult matter to understand the variations in construction, and when he has completed the study of the various constructions he will have gained sufficient knowledge to enable him to understand the construction of all cars.

Purpose of the Parts of the Running Gear

The **front wheels** run free on the axle, and guide the car. They are called the guiding wheels and are moved from side to side by means of a steering device, and the direction of the car is controlled in this manner. The rear wheels are revolved by the engine and drive the car.

The **front axle** is fitted with **steering knuckles** on which the guiding wheels run. These steering knuckles are moved by means of a rod which connects to the steering device. The front axle is fitted with **spring blocks** and spring clips which hold the springs in place.

The **rear axle** revolves. The housing over the axle is fitted with spring blocks and clips similar to the front axle, that is, if it is a "live" axle.

The **springs** act as a cushion and protect the machinery and the occupants of the car from undue vibration and shock. They also hold the frame.

The **frame** of an automobile is made of pressed steel and is the foundation which supports the power plant, change gears, levers, steering device, fuel tank, body, etc. Each part is bolted to the frame and is kept in proper relation to each of the other parts. The frame is usually hung, with the springs resting on the axles, as shown in Fig. 1, and is called the "overslung" method of frame suspension. Sometimes the springs are fastened below the axles, called the "underslung" method.

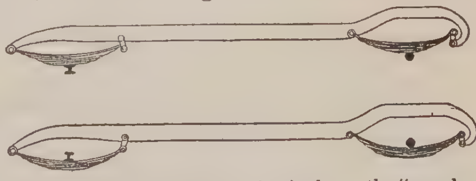


Fig. 1. In the upper illustration is shown the "overslung" spring suspension which is used on the majority of the cars today. Note that here both front and rear springs and also the frame are above the axles. In the lower illustration is shown the "underslung," a form of spring suspension in which the frame is above the axles, but with the springs below, a method seldom used. A popular spring system is the cantilever.

A sub-frame is sometimes placed inside of the main frame to support the power and drive plant.

The **steering device** is usually attached to the frame. By turning the steering wheel, the car is guided through the control of the direction of the front wheels.

Brakes are fitted to automobiles for stopping or slowing down, and are usually fitted to a drum on the hubs of the rear wheels.

Purpose of the Parts of the Power Plant

The **engine** furnishes the power that drives the car. It is usually located in the front part of the frame, if it is a multiple-cylinder type of engine.

Suspension. Multiple cylinder engines usually have four, six, eight, or twelve cylinders. If of the double-cylinder opposed type, it is usually placed across the frame. If a multiple cylinder, "single-unit power plant," it is usually suspended at three or four points. This is called "three-point" or "four-point" suspension.

The **carburetor** mixes air with gasoline, and is connected direct to the intake pipe on the engine. The carburetor is connected to the feed pipe from the gravity tank.

The **gasoline tank** is usually placed under the seat or at the rear of the car, and gasoline is fed to the carburetor through a small pipe or by the vacuum system (as explained under Carburetion).

The **exhaust pipe** connects to the exhaust manifold and runs to the muffler, which is usually placed at the rear of the car. The exhaust pipe permits the burned gases to escape. The muffler, placed at the extreme end of the exhaust pipe, silences or muffles the noises from the explosions in the engine cylinders.

The **ignition system** is a part of the electric plant. It consists either of a storage battery and coil, dry cells and coil, a generator, or a magneto. The coil and battery electric system was formerly placed on the dash, while the magneto or generator is placed on the engine and is run by the cam shaft or crank shaft, through the medium of silent chains. The modern coil and battery system with a timer and distributor is now placed on the engine.

The **cooling system** consists of the radiator, water pipes, circulating pump and fan. The object of the cooling system is to keep the engine from getting too hot when the explosions take place inside of the cylinders.

The **lubrication system** of the engine is for the purpose of keeping the bearings and rings and other moving parts from wearing. This subject as well as the others mentioned will be treated separately, farther on.

Purpose of the Transmission and How the Rear Axle Shafts Are Revolved

The **transmission,** or the speed-change gears, is that part which transmits the power from the engine to the driving wheels through a system of speed-change gears.

A **clutch** is placed between the engine and the transmission; this permits the engine to run free, or, when "thrown in," connects the engine to the change-speed gears and drives the car. The clutch is operated by a foot pedal and is thrown "in" or "out" by the driver.

In a locomotive, the piston rods are connected direct with the wheels, through the medium of the cross-head, and connecting rod, so that when steam is applied the locomotive moves. **In an automobile,** the engine may be disconnected from the transmission by means of the clutch, so that the motion of the transmission or of the entire car may be stopped without stopping the engine.

Change-gear principle: When a bicyclist wants to race on a level track he gears his wheel up high, so that one revolution of the crank takes him the greatest possible distance. Yet if he takes this wheel on the road and encounters a hill, he must get off and walk or exert an extra lot of power—he needs a wheel geared lower.

In the same way, when an engine is required to do more than ordinary work, as climbing a hill, the transmission or change-speed gear contains from two to four changes of gears and helps out the engine by changing to the gear ratio requiring less motive power. It allows the car to move at various speeds while the speed of the engine is unchanged.

When in low gear, the engine makes quite a number of revolutions (10 or 15), while the wheels revolve once, which makes the car move forward slowly, but with considerable force, so that it can go up a steep hill or through sand or mud.

When in second or intermediate gear, the engine makes from 7 to 12 revolutions to one revolution of the wheels, which moves the car faster than the low or first change of gears, but with less force.

When in third or high gear, the engine makes from 3 to 5 revolutions to one revolution of the wheels, which gives the car high speed over good roads.

If the car should be going up a steep grade while on high gear, the work would be more than the engine could do, and it would stop unless one of the lower speeds were shifted in. There would then be considerably more pull on the wheels.

The operation of the change of gears is effected by means of a side or center lever. Change of gears can be made instantly. The transmission also contains a set of reverse gears, which, when thrown in, will reverse the motion of the car without reversing the motion of the engine.

The **transmission** may be connected so that it drives the wheels by the following methods: First, by a **driving shaft** (Fig. 2) connected to the rear axle, which it revolves by means of bevel gears, the wheels and axle turning together. This axle revolves and is called a "live" axle. Second, by a **single chain** (Fig. 3) connected to a "live" rear axle, the wheels and axle turning together (now obsolete).

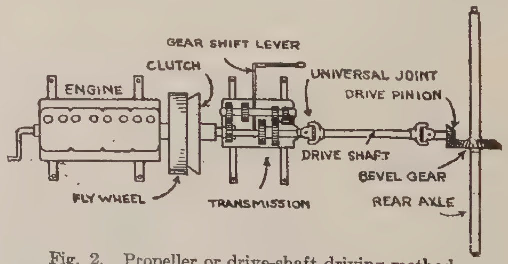


Fig. 2. Propeller or drive-shaft driving method.

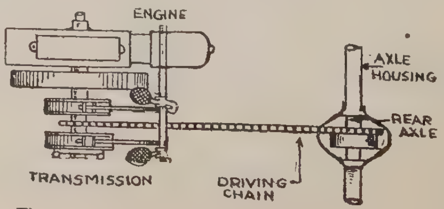


Fig. 3. Single-chain driving method (obsolete).

Third, by **two chains** (Fig. 4), one connected to each rear wheel, which run free on the axle, like a buggy. This is called a "dead" axle because it does not revolve.

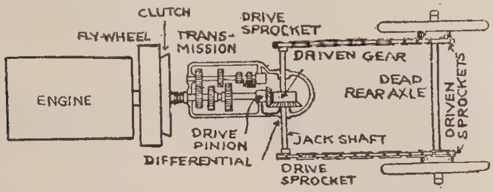


Fig. 4. Double-chain drive method. Seldom used on passenger-car automobiles, but used on trucks to a limited extent.

Drive System

The connection between the engine and the wheels is called the "drive system."

The **drive shaft** connects with the end of the transmission shaft by means of a universal joint. A universal joint is usually at the rear end connecting with the differential drive pinion shaft.

The **universal joints** permit the parts mounted on the rear axle to move up and down, thus preventing the movement of the axle from interfering with the drive of the car.

The **torque rod** is usually placed between the housing on the rear axle and the transmission case. The object of the torque rod (or torque arm, as it is now called) is to prevent the axle housing from twisting when the power or brakes are applied.

The **drive pinion** connects to the rear end of the drive shaft and drives the large bevel gear, which is connected to the differential.

The **front wheels** on an automobile run free on the axle. For this reason the outside wheel is able to revolve faster than the inside wheel when the car is turning a corner.

When a vehicle turns a corner, the outside wheels revolve faster than the inside wheels, because they travel a longer distance.

The **wheels in the rear** must do the same thing; if they were forced to revolve at the same speed, one would slide because it could not keep pace with the other.

When they run free on the axle, they would take care of this themselves, but as both are driven by the engine, the transmission or rear axle is fitted with a **differential,** at times erroneously called a **compensating gear.** This device is automatic, and permits the wheels to revolve at variable speeds, although both are driven by the engine.

Wheels

Tires made of rubber are fitted to the wheels to take up the vibrations that are too sudden for the springs to absorb.

The wheels of an automobile are smaller in diameter than horse-drawn vehicles, due principally to the fact that at the high speed the automobile travels, the wheels would have to be built entirely too heavy to sustain the strain. Automobile wheels must be very strong, because of the weight that they must support, and the strain that they are under. They are made of wood or wire (see illustrations, Figs. 5, 6, and 7).

Wheels are divided into three classes (Figs. 5, 6 and 7): wood, wire, and disk wheels, the latter type being made of wood or metal.

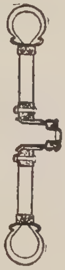


Fig. 5

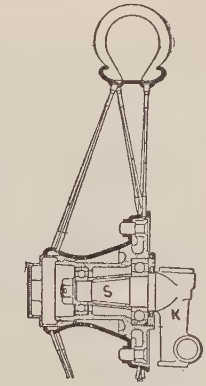


Fig. 6

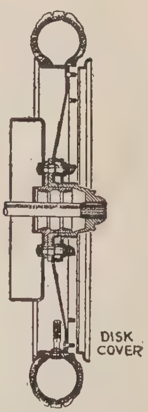


Fig. 7

Fig. 5. Sectional view of a "wood artillery" type of wheel.
Fig. 6. Sectional view of a wire wheel.
Fig. 7. Sectional view of a disk wheel.

Wood Wheels

The wood wheel predominates, but does not possess the lasting qualities of metal, and costs less. It is usually termed the "artillery type" (see Fig. 5). A steel rim is fitted over a wood felloe which holds the tire.

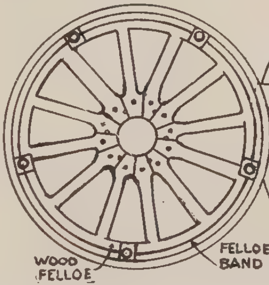


Fig. 8

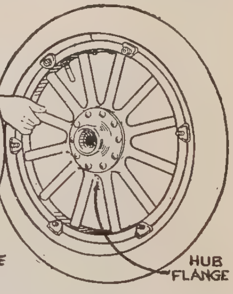


Fig. 9

Fig. 8. Wood wheel without hub flanges, but with rim mounted.

Fig. 9. Wood wheel with hub complete, rim and tire mounted.

The artillery type of wood wheel is shown in Figs. 8 and 9. Note that the spokes meet at the center and are bolted between the metal hub flanges. Wood felloes are shrunk on to the wooden spokes to carry a steel felloe band, and on the steel felloe band, a steel rim is fitted to take the tire.

Easy riding qualities always have been claimed for the wire wheel, and this is largely due to the fact that the weight is centered in the hub and that the car weight is suspended from the top spokes, whereas in the wood wheel the weight is taken on the spokes at the bottom. Road shocks, therefore, are more readily transmitted through the wood spokes to the hub of the wheel than in a wire wheel. With a wire wheel, it is claimed, acceleration is much improved because the wheel is set in motion more easily by virtue of the lighter rim. In other words, the hub of a wire wheel, wherein is centered the weight of the wheel, literally wraps the spokes about it, and the spokes in turn pull the light rim after them.

If wood spokes become loose and squeak the cause is usually due to dryness, from lack of washing. To remedy, swell the spokes by soaking well with water. When wood spokes break, new ones can be fitted.

Wire Wheels

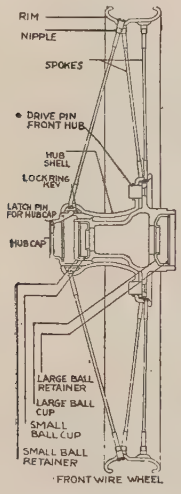
Wire wheels are lighter and are generally of the demountable type, that is, the wheels are demountable, but not the rim. The triple-spoke construction is the favored type.

When wire wheel spokes break or become loose, new ones can be inserted or loose ones tightened, similar to the treatment given to bicycle spokes. Hub caps on wire wheels must be tight, otherwise there will be an intermittent clicking noise.

The parts of a wire wheel are shown in Figs. 10 and 11. The rim on this wheel is of the clincher type. It could be, and usually is a straight-side type of rim. The "Ford," "Overland Four," and "Maxwell 25" use 30 x 3½ clincher rims, but most all other cars use straight-side rims.

Rims are not demountable on wire wheels (see Index under "Wire wheel rims").

Wire wheels usually come in sets; five detachable and interchangeable wheels and five hubs make a set—four on the car and one spare, all detachable at the hub. All are usually interchangeable, front or rear, right or left. Unscrewing and replacing the hub cap is all that is necessary in changing the wheels. The spare wheel may be carried with the tire inflated ready for immediate attaching to any of the hub mountings. Wheels of this type are usually equipped with a built-in locking device, which adds safety without interference to the quick-change feature. See also Index under "Wire wheels."



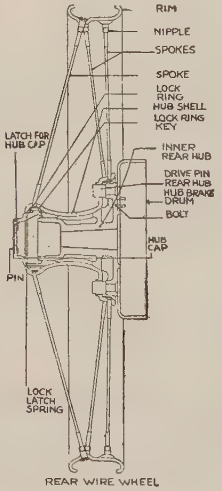


Fig. 10. Rear wire wheel with 30 x 3½ clincher rim for a Ford. Note the brake drum attached to the hub flange.

Fig. 11. Front wire wheel with 30 x 3½ clincher rim for a Ford. The parts are shown in the illustration.

Disk Wheels

Disk wheels are now popular and add considerably to the appearance of a car. The steel disk is usually dished and welded or bolted to the felloe, or the wheel is made in one piece with demountable rims. The hub is usually bolted to the disk. Disk wheels are also made of wood.

Easier riding qualities, rapidity of wheel change, and the ability to keep them clean are some of the major things claimed for the disk wheel.

The wood disk wheel is made from the same grade of wood as used for airplane propellers and is laminated in such a way that the grain in each lamination runs in a different direction. These wheels are claimed to be of about the same weight as spoked wheels, but to have four times the lateral strength.

With many of the disk wheels it is not necessary to carry a spare, only a rim being necessary. On others the entire wheel is changed. See Index under "Disk-wheel rims."

Mud guards or fenders are always fitted over the wheels, to protect the car and occupants from the mud thrown by the wheels.

Meaning of Wheel Base and Tread or Track

The wheel base of an automobile is the distance (in inches) between the rear axles and the front axles. The long wheel base rides easier than a short wheel base. The frame must be sufficiently stiff, however, to prevent sagging from the weight resting on it. The wheel bases vary from 80 inches on runabouts to 144 inches on larger cars.

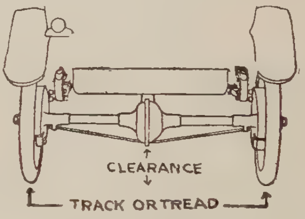


Fig. 12

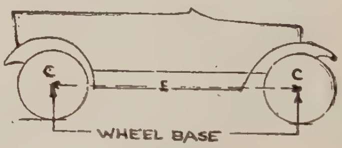


Fig. 13

The tread (also called track) is the distance the two wheels are apart measured parallel with the axle. The standard tread is 56 inches, measured from center to center.

The treads of wagons and carriages vary in different parts of the country. In the Southern states it is 60 inches; in the West 48, and in most of the other parts of the country 56 inches. Small, light cars are sometimes made with a smaller tread than 56 inches, but this is exceptional.

The road clearance is the distance from the lowest point of the car to the road. For rough roads, a greater clearance is required than for smooth roads, as a high place in the road would strike parts of the machinery that hung too low. The front axle, which is solid and heavy, is usually curved down in the center, so that it will be the first part of the car to strike a high place, thereby protecting the delicate parts behind it.

The Body

The automobile frame, with all parts of the running gear, the transmission, engine, and other parts of the mechanism, when it is without the body, is called the **chassis**. Different types of bodies may be attached to a chassis, and are generally fastened down with bolts.

Although there are many special makes of bodies which are given special names, the illustrations that follow will give the reader the names of the standard type of bodies.

Body Nomenclature

The following descriptions of the various types of bodies, illustrations of which are shown below, are those proposed and recommended by the Passenger-Car Body Division as the standard recognized by the S. A. E. (Society of Automotive Engineers).

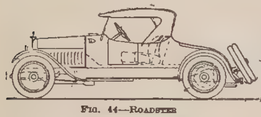


Fig. 44—Roadster

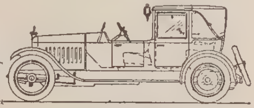


Fig. 52—Landaulet

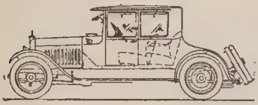


Fig. 45—Coupe

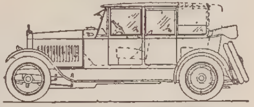


Fig. 53—Sedan-Landaulet

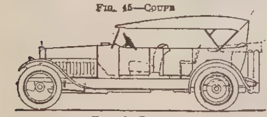


Fig. 46—Phaeton

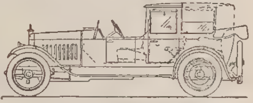


Fig. 54—Brougham-Landaulet

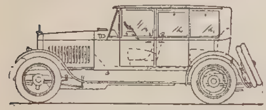


Fig 47—Sedan

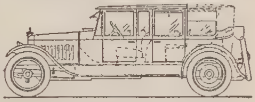


Fig. 55—Berline-Landaulet

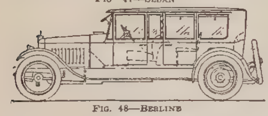


Fig. 48—Berline

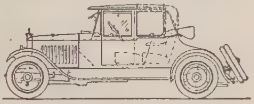


Fig. 56—Coupe Landaulet

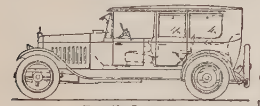


Fig. 49—Limousine

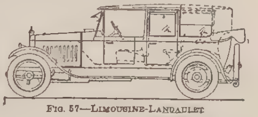


Fig. 57—Limousine-Landaulet

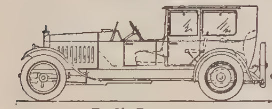


Fig. 50—Brougham

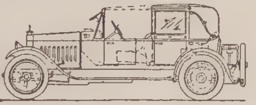


Fig. 58—Cabriolet

Roadster (Fig. 44): A small open-type body, having one fixed cross-seat for two passengers and a space or compartment at the rear for carrying luggage. Folding seats fitting into the luggage compartment are sometimes used. The conventional type has two doors and a folding roadster top with emergency side-curtains that are removable.

Coupe (Fig. 45): An enclosed single-compartment body, with one fixed cross-seat. This seat may be straight and accommodate two persons, or be staggered and accommodate three persons. With the latter arrangement, a folding seat may be placed beside the driver's seat, thus making it a four-passenger body. The conventional body has two doors and two movable glass windows on each side; the roof is permanent; and there is a luggage compartment at the rear.

Phaeton[1] (Fig. 46): An open-type body, with two fixed cross-seats for four or five passengers. Folding seats in the tonneau for two additional passengers are sometimes used. The conventional body has four doors and a folding phaeton-top with emergency side-curtains that are removable.

Sedan (Fig. 47): An enclosed single-compartment body, with two fixed cross-seats for four or five passengers. Sometimes the front seat is divided by an aisle. Folding seats in the tonneau for two additional passengers are sometimes used. The conventional body has four doors, but some models have only two. There are three movable glass windows on each side and the roof is non-collapsible.

Berline (Fig. 48): A body of the same general description as the sedan, except that there is a partition at the rear of the driver's seat that makes it an enclosed two-compartment body. Generally one glass window in the partition is made so that it can be moved horizontally or vertically.

Limousine (Fig. 49): A partially enclosed body, with a non-collapsible roof that extends the full length of the body and is attached at the front to the windshield standards. Only the rear portion of the body up to the partition at the rear of the driving seat is fully enclosed. Forward of this partition, the sides are enclosed only from approximately the belt downward. There are two low doors and one fixed cross-seat for two in the forward section. In the rear section there is one fixed cross-seat for two or three. Folding seats for two additional passengers are sometimes used. There are two doors in this section, and two movable glass windows on each side.

Brougham (Fig. 50): A body of the same general description as the limousine, except that the non-collapsible roof extends only over that portion of the body that is entirely enclosed.

Landaulet (Fig. 52): A body similar in appearance to the brougham, except that the enclosed section is shorter from back to front, and the roof is fully collapsible up to the partition at the back of the driver's seat. The body has one fixed cross-seat in the rear section for two or three passengers, two doors made with either flappers or hinged upper parts, and glass windows in the doors only. The rear quarters, back and top, are covered with leather or fabric. There are outside joints to support the top.

Sedan-Landaulet (Fig. 53): A body of the same general description as the sedan, except that the top back of the rear doors is collapsible. Forward of this point the roof is non-collapsible, and the windows are the same in number as in the sedan. The rear quarters, the back above the belt, and the roof are covered with leather or fabric.

Brougham-Landaulet (Fig. 54): A body that bears the same relation to the brougham as the sedan bears to the sedan-landaulet.

Berline-Landaulet (Fig. 55): A body that bears the same relation to the berline as the sedan-landaulet bears to the sedan.

Coupe-Landaulet (Fig. 56): A body that bears the same relation to the coupe as the sedan-landaulet bears to the sedan.

Limousine-Landaulet (Fig. 57): A body that bears the same relation to the limousine as the sedan landaulet bears to the sedan.

Cabriolet (Fig. 58): A body similar in appearance to the brougham and having the general characteristics of the landaulet, except that the falling pillar-hinge is set back from the pillar-line and shows the curved parting line through the leather. The rear section is therefore longer than that of the landaulet. The body has one fixed cross-seat for two or three, and folding seats on the partition for two additional passengers.

The distinction between the **Delivery Wagon** and **Truck** is in size and weight. The delivery wagon is usually a shaft-driven solid, or pneumatic-tired car, whereas the truck is a double-chain or shaft-driven solid or pneumatic-tired, heavier machine.

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[1] The principal reason for recommending the use of the term "phaeton" instead of the term "touring" is that the latter has lost its significance as applying to any particular type of body, as all types are used for touring. The term "phaeton" is used extensively in Europe, and to a considerable extent in America, in connection with passenger-cars; it is the name of a horse-drawn prototype; it is inelegant and in a technical sense is not distinctive of any particular type of motor vehicle body.

INSTRUCTION No. 2

DRIVE METHODS: Drive-Gear Reduction

VARIOUS DRIVE METHODS

The power from the engine is transmitted through the transmission; and is applied to the propelling of the car by those parts called the drive.

There are three methods of transmitting power to rear-axle shafts: **the double-chain drive,** requiring a "dead" rear axle; **the single-chain drive** (seldom used); and **the shaft or propeller-shaft drive,** which requires a "live" rear axle.

There are seven drive methods: single chain (obsolete); **double chain; internal gear** (page 929); **double reduction** (page 925); **double reduction internal** (page 933); **worm** (pages 17, 914, 920, 954, 956); **bevel gear** (Fig. 3 below). The last mentioned is the type generally used on passenger cars.

Double-Chain Drive

The double-chain drive is seldom used on pleasure cars, but is used quite extensively on trucks. Trucks use chains, because trucks carry heavy loads and often have solid "dead" axles.

When, as is usual in cars of this type of drive, the engine is in front, the crank shaft is parallel to the sides of the car, and therefore at right angles to the rear axle. The power developed at the crank shaft must therefore be turned at right angles in order to apply it to the wheels (see Fig. 1). This is done by means of bevel gears, which are in the transmission case.

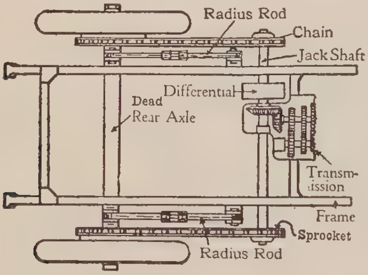


Fig. 1.

The power is transmitted from the crank shaft of the engine to the square shaft of the change-speed gear by gears, as explained farther on. The square shaft carries a bevel gear that meshes with another bevel gear carried on the jack shaft (Fig. 1).

The jack shaft passes across the car, running in bearings in the gear case and on the frame. It is held so rigidly that while it is free to revolve, its bevel gear is always in correct relation to the bevel gear on the square shaft of the transmission.

The jack shaft is in two sections, between the inner ends of which the differential is placed, the differential, of course, being beside the bevel gear that drives the jack shaft.

At each end of the jack shaft, outside of the frame, is a sprocket which is in line with a corresponding sprocket on the rear wheel of that side (Fig. 2). Over each pair of sprockets passes a chain that transmits the revolutions of the jack shaft to the wheels which run loose on the ends of the dead axle.

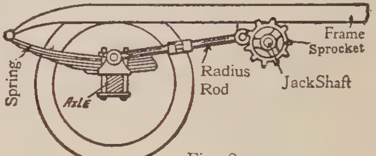


Fig. 2.

The chain most commonly used for automobiles is called a "roller chain." It consists of side pieces in pairs, each pair being secured to the adjoining pairs by rivets passing from side to side. On these rivets are steel rollers which revolve as they touch the sprockets. These rollers fit the space between the teeth of the sprockets, and as the chain bends around the sprockets the rollers are stationary, while the rivets turn inside of them.

To give the best service, the chain must run true; that is, the sprockets over which they run must be in line, the links of the chain must fit the teeth, and the sprockets must be exactly circular. If the sprockets are out of line, the chain will be forced to bend sideways. If the links do not fit the teeth, there will be a grinding that will cause rapid wear, and there will be danger of the chain jumping off. If the sprockets are not exactly circular, during one part of the revolution the chain will be slack, and during the other part will be drawn tight, stretching it.

The double-chain drive has advantages on heavy cars. By its use the weight of the car is carried by a "solid" or "dead" axle, which is lighter than a divided "live" axle of the same strength can be. If a solid axle is bent, it can be straightened easily, while it requires an expert mechanic to straighten a bent live axle.

The disadvantages of double-chain drive are the difficulty of properly lubricating the chains, their rapid wear in consequence, and the liability of chains to stretch and jump off the sprockets.

The worm-gear drive for trucks, with substantial axles of the "live" type, are now considered superior to the double-chain drive.

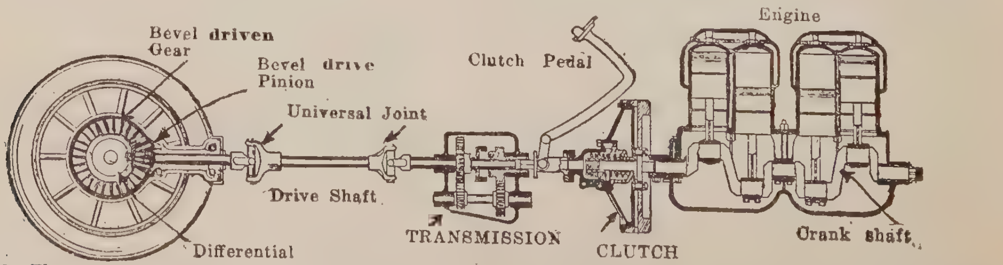


Fig. 3. The modern method for driving the rear axle is by means of a propeller type of drive shaft with a bevel drive pinion and bevel-driven gear on the differential on the rear axle. Commercial cars with shaft drive instead of double-chain drive often use the worm drive.

Propeller or Shaft Drive

In this type, a shaft connects with the square main shaft of the transmission and is extended to the rear axle, where it ends with a small bevel gear called the **drive or driving pinion.** See Figs. 3, 4, p. 28.

This driving pinion meshes with a bevel gear on the differential housing that is mounted between the inner ends of the two parts of the live rear axle, called the **axle-driven gear,** or differential "ring gear," or "master gear," "crown wheel," etc.

The propeller or driving shaft always has one, and sometimes two, universal joints in between the gear box and drive pinion on rear end, so that the moving of the rear end, as the axle receives the jolts of a rough road, does not affect its driving.

The drive and driven gears are contained within a casing or housing that supports the bearings for the parts of the axle and also the end of the driving shaft, so that the bevels are held in the same relation to each other, regardless of the moving of the axle.

The advantages of this type of drive are that all of the moving parts are enclosed and protected from dust, and run in grease or oil, which means perfect lubrication.

Radius Rods

Radius rods, also called "distance rods" and "strut rods," are mostly used on commercial cars using a double-chain drive. They extend from a point alongside of the frame in line with the jack shaft, thence to the rear axle. Thus they keep the chain at the proper tension and the distance from sprocket to sprocket the same, no matter how rough the road. A **turn buckle** is provided to insure adjustment. Radius rods are not used on propeller-shaft-driven cars in the manner described above, but on two or three propeller-shaft-driven cars they are used as shown in Fig. 7. Many worm-drive trucks are equipped with radius rods.

The Torque Member

Torque means turning movement, or twist. The **torque arm, torque tube, radius rod,** or the **rear springs** represent four different methods of preventing torque reaction. The torque arm, or radius rods extend from the cross-member near the transmission to the housing on the rear axle (construction varies).

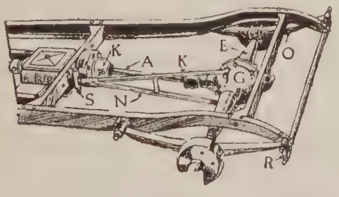


Fig. 4. One type of construction of a torque arm is shown in the illustration. Note the arm (**N**), extending from the rear axle housing to a spring arrangement or torque pillar attached to a cross member, in line with the drive shaft. See illustration (**S**) (**N**).

The tendency for the driving pinion to climb the ring gear when starting or driving a car causes the rear axle housing to twist in the opposite direction to the road wheels. So it is **torque reaction** which the torque member prevents.

What is known as the **"Hotchkiss drive method"** is where the torque and the drive are taken through the semi-elliptic rear springs. The main leaf of each of these is made strong enough for this added duty, and the construction does away with torsion tube, torque arm, and radius rods.

A torque tube is often used instead of a separate torque arm. The propeller or drive shaft revolves inside of the tube (see Fig. 6).

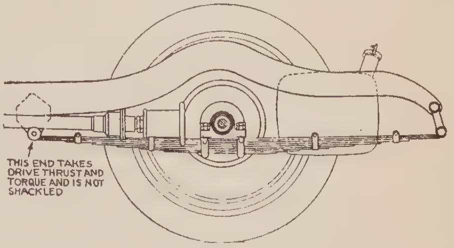


Fig. 5.

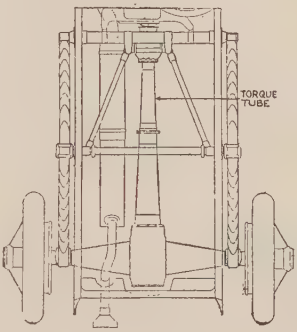


Fig. 6.

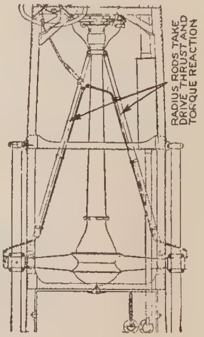


Fig. 7.

Fig. 5. "The Hotchkiss drive." A semi-elliptic spring is used to take the thrust. The forward end of the spring is not shackled, but oscillates on a pin, and this takes the thrust and torque. The rear end is shackled and is free to move under stress.

Fig. 6. A torque tube, which takes both the drive and torque; Rolls-Royce rear axle. See also **Fig. 7, page 16.**

Fig. 7. Radius rods on the Dusenberg, which take both the drive and torque (illustrations from *Motor World*).

Gears and Chains

Spur gears are noisy and are not used very much except for the transmission. They were formerly used for driving the cam shaft. The **helical,** or spiral tooth gear or silent chain, is now used to a great extent for driving the cam shaft.

The worm and worm gear are used extensively as a final drive on the rear axle of trucks.

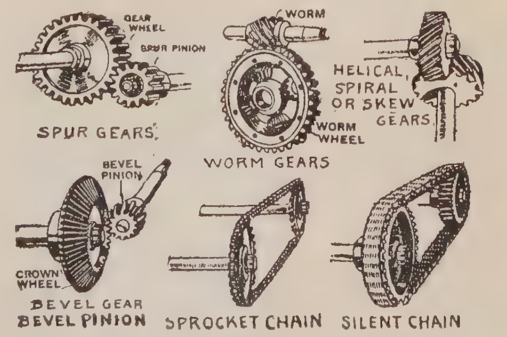


Fig. 8

The helical or spiral gear with straight face can be placed as shown in the illustration above, and may thus be used to drive pumps and distributors. **The bevel helical tooth gear** is used extensively for the final drive on rear axles of automobiles, and is termed a bevel gear with a helical or spiral tooth.

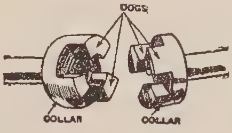
The bevel gear with straight teeth, as shown, is used for final drives, but the helical tooth bevel gear, being more quiet, has taken its place to a large extent.

The worm and worm gear make a wiping contact and the helical, more of a rolling contact. When accurately made, worm gears run with great smoothness and silence. The worm may engage either from above or below the gear wheel. The angle of the worm and gear may be as much as 45 degrees. The worm is made of hard steel and the worm gear of bronze. See Index under "Adjusting of the worm gear on a truck rear axle."

The sprocket chain is used on double-chain-driven trucks. See Index under "Chains for trucks," showing the roller-type sprocket chain.

The silent chain, with special sprockets to take the chain, is used extensively for driving the cam shaft, generator, etc., especially on "V"-type engines. See Index under "Silent chains."

The setting of bevel gears so that they will mesh properly without noise requires careful adjustment, as there must be as little play as possible without having the teeth bind. See Index under "Adjusting drive pinion."



DOG CLUTCH
Fig. 9.

The dog clutch is used in the transmission and can be used for couplings for various driving purposes, as for instance, with the magneto, etc.

When the "dog clutch" is used in the transmission, one dog is placed on the clutch shaft and the other on the square main transmission shaft. On modern transmissions, gears with internal teeth are used instead of the "dog clutch."

Drive Pinion and Driven Ring Gear

The drive pinion (R3) is shown in the illustration below (Fig. 10). This pinion is attached to the end of the drive shaft.

The differential ring gear (N3) is also shown in Fig. 10. This gear is attached to the differential housing, and is driven by gear (R3). Thus the drive is transmitted to the rear-axle shafts through the differential.

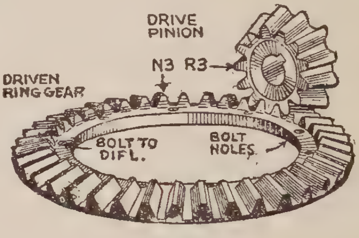


Fig. 10.

Note that both gears (R3) and (N3) have beveled teeth which are straight. The type of gears in general use have beveled teeth which are not straight but helical or spiral shaped.

DRIVE-GEAR REDUCTION

The speed of the crank shaft is reduced so that the road wheels turn once while the crank shaft revolves from three to five times with the high-speed gear engaged.

On cars with single-chain drive (now obsolete) this is done by having the transmission sprocket smaller than the axle sprocket. If the reduction is to be three to one, that is, if the crank shaft revolves three times to one revolution of the axle, the axle sprocket will have three times the number of teeth that the transmission sprocket has.

The reduction on side-chain-driven cars is sometimes made at the bevel driving the jack shaft, but usually at the sprockets.

On shaft-driven cars, the reduction is made at the rear axle-drive gears. The driven gear (N3) (Fig. 12) on the rear axle is given as many more teeth than the drive pinion (R3) on the driving shaft as is necessary for the reduction that is required.

In the worm drive, the reduction is governed as explained under "Worm-gear ratio"; see Index. In other words, the size of the worm could be changed without its changing the speed. (The angularity of course would have to be the same in both cases.)

To make the point clear as to just how the speed reduction is brought about in the worm drive, imagine the screw thread on a vise shaft which draws the jaws together. If that thread is coarse, with only a few to the inch, the jaws would move toward each other rapidly and of course it would take some power to move it; if, on the other hand, there were quite a number of threads to the inch, the jaws would move more slowly but it would take less power to exert the same pressure.

When the "gear ratio" of a car is spoken of, it is often referred to as the reduction between the engine crank shaft and rear axle. Thus, for instance, a "gear ratio of 4 to 1" is where the drive shaft makes four revolutions to one revolution of the road wheels on the high gear.

This term, "gear ratio," should be termed "total gear reduction," as the term "gear ratio" could be applied to the transmission, or to the rear axle. Thus a distinction is made as is explained below.

Difference Between "Rear-Axle Gear Ratio," "Transmission-Gear Ratio" and "Total-Gear Reduction"

Rear-Axle Gear Ratio

"Rear-axle gear ratio" refers to the number of times the rear axle turns over to one revolution of the propeller shaft (P), Figs. 11, 12.

To find the rear-axle gear ratio on any car, divide the number of teeth in the driven gear (N3) on the differential, which in this instance has 71 teeth, by the number of teeth on the drive gear, which in this instance has 16; thus $71 \div 16 = 4.437$, revolutions of the propeller shaft (P), to one of the axle shafts or wheels.

Transmission Gear Ratio

"Transmission-gear ratio" refers to the ratio between the engine crank shaft and the propeller shaft **P**.

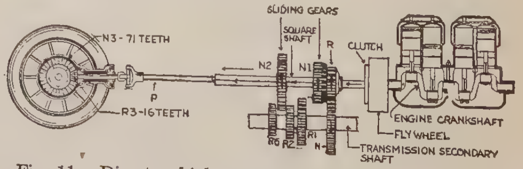


Fig. 11. Direct or high gear. Note that the drive is direct from the engine crank shaft to the drive pinion (R3), to the driven ring gear (N3). Gears (R) and (N) are meshed at all times.

On direct or high gear (Fig. 11), the ratio is 1 to 1, meaning that the engine crank shaft turns over one revolution to one of the propeller shaft (P), because the engine crank shaft is connected direct through the transmission to the propeller shaft **P**. Thus it is termed "direct drive."

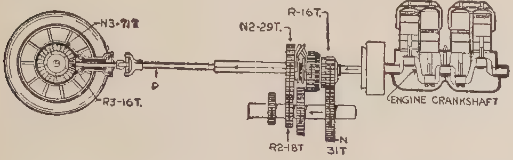


Fig. 12. Low or first gear. Note that the drive is from the crank shaft to the drive gear (R), to the driven gear (N), to the drive gear (R2), to the driven gear (N2), to the drive gear (R3), to the driven gear (N3).

On first or low speed (Fig. 12), the ratio is 3.121 to 1, meaning that the engine crank shaft turns over 3.121 times to 1 of the propeller shaft (P).

To find the transmission-gear ratio, multiply all of the driven gears together and all the drive gears together and divide the product of the driven gears by the product of the drive gears as follows:[1]

N,31teeth×**N2**,29t÷**R**,16t×**R2**,18t=3.121 obtained thus: 31×29=899, the product of the **driven** gears and 16×18=288, product of the **drive** gears, therefore, 899÷288=3.121.

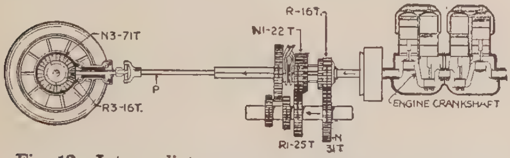


Fig. 13. Intermediate or second gear. Note that the drive is from the engine crank shaft, to the drive gear (R), to the driven gear (N), to the drive gear (R1), to the driven gear (N1), to the drive gear (R3), to the driven gear (N3).

On second speed (Fig. 13), the transmission ratio in this example is 1.705, meaning that the engine crank shaft makes 1.705 revolutions to 1 of the propeller shaft **P**. This transmission ratio is found by following the same rule:

N,31t×**N1**,22t÷**R**,16t×**R1**,25t=1.705.[1]

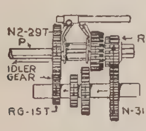


Fig. 14

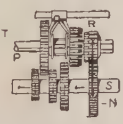


Fig. 15

Fig. 14. Reverse gear. Note that the drive is from the drive gear (**R**) to the driven gear (**N**), to the drive gear (**RG**), to the idler gear, to the driven gear (**N2**), to the drive shaft (**P**), to the rear axle. The idler gear gives a reverse motion to shaft (**P**).

Fig. 15. Neutral gears. Note that the drive is from the drive gear (**R**) to the driven gear (**N**). Gears (**R**) (**N**) and shaft (**S**) revolve independently of shaft (**P**). Thus the rear axle is not connected with the crank shaft of the engine.

On reverse speed (Fig. 14) the transmission ratio in this example is 3.74 to 1, meaning that the engine crank shaft turns over 3.74 times to 1 revolution of the propeller shaft (**P**). This transmission ratio is found by following the same rule.

N,31t×**N2**,29t=899÷**R**,16t×**RG**,15t=240,

thus:

899÷240=3,74.

Note: Sliding gear (N2) is pushed over to the extreme left and meshes with an "idler gear" behind gear (RG). The idler gear then meshes with (N2) and reverse gear (RG). This gives a reverse motion to propeller shaft (P). The teeth on the "idler gear" are not considered, as it is both a driven and a drive gear.

Total Gear Reduction

"Total gear reduction" refers to the number of times the engine crank shaft turns over to one revolution of the axle shafts or rear wheels. This is governed by the diameter of any gear transmitting power to the rear-axle shaft.

To find the total gear reduction, multiply the "transmission-gear ratio" by the "rear-axle ratio."

To find the total gear reduction when in first or low speed, multiply 3.121, the transmission ratio, by 4.437, the rear-axle ratio, and we have 13.847. Thus the engine crank shaft turns over 13.847 times to 1 of the rear-axle shafts or rear wheels.

To find the total gear reduction when in second speed: 1.705×4.437=7.565 revolutions of the engine crank shaft to 1 of the rear wheels.

To find the total gear reduction of third or high speed: 1×4.437=4.437 revolutions of the engine crank shaft to 1 of the rear wheels.

To find the total gear reduction of reverse: 3.74×4.437=16.594 revolutions of the engine crank shaft to 1 of rear wheels.

The foregoing examples of ratios are those used on the Cadillac Type 59 car. The Cadillac sometimes gives a 14-tooth drive pinion (R3) on the heavy closed cars and for touring cars used in hilly countries. The rear-axle ratio would then be: 71÷14=5.071 rev. of propeller shaft **P**, to 1 of the rear wheels.

Miscellaneous Ratios

Ford: Rear axle ratio N3, 40 teeth÷R3, 11 teeth=3.636. Transmission ratio, 1st speed 2.75; 2nd speed 1; reverse 4.

Overland 4: Rear axle ratio, N3, 45 teeth÷R3, 10 teeth=4.5, transmission ratio, 1st speed, 3.62 to 1; 2nd, 2.03 to 1; high, 1 to 1; reverse, 4.83 to 1.

Dodge: the rear-axle ratio is 4.17 to 1.

On some cars, for instance the Locomobile model 48, Mercer Series 5, and Pierce-Arrow Models 31 and 51, there are 4 speeds and on 4th the transmission ratio is 1 to 1. On Locomobile 48 and Pierce-Arrow 51, first speed transmission ratio is 4 to 1. On the Mercer, 3.75 to 1.

On some cars with four speeds, the 4th speed is higher than 1 to 1; for instance the Wasp with 4 cylinders 4¾×5½, the 4th speed transmission ratio is .73 to 1. The rear-axle ratio is 3.7, therefore the total gear reduction would be .73×3.7=2.701 revolutions of engine to 1 of rear wheels. On 3rd speed the Wasp transmission ratio is 1 to 1; on 1st or low, 2.69 to 1. The total gear reduction on 1st speed is 2.69×3.7=9.953 revolutions of the engine crank shaft to 1 of the rear wheels.

Truck-Gear Ratios[1]

Federal 2-ton truck: Rear-axle ratio, 9.25, transmission ratio, 1st speed, 4.40; 2nd, 3.08; 3rd, 1.76; 4th, 1; reverse, 5.28.

Federal 5-ton truck: Rear-axle ratio, 13.66, transmission ratio, 1st speed, 4.99; 2nd, 3.16; 3rd, 1.79; 4th, 1; reverse, 5.78.

Replacing a Drive Pinion

When replacing a drive pinion (R3) with one of a different diameter, it is always necessary also to replace the driven ring gear (N3), because the teeth will mesh too tight at either the big end of the tooth or the little end of the tooth, due to the fact that the teeth are cut at a different angle. See Index: "Differential gear, how to replace."

Relation of Engine Crank Shaft to Periphery of Road Wheels

If the rear axle ratio on a certain car is **4.437 to 1**, and say for instance, high gear is being used, then the rear wheels, no matter how large or how small the wheels or tires may be, will revolve 1 revolution to 4.437 revolutions of engine crank shaft.

It is then clear that the larger the rear wheels or tires, the harder will be the pull on the engine, and that the smaller the rear wheels or tires, the easier will be the pull by the engine.

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[1] Driven gears are designated in the illustrations as (N), (N1), (N2), etc. Drive gears are designated as (R), (R1), (R2), etc.

[1] See Index under "G. M. C. 'two-range' truck transmission."

INSTRUCTION No. 3

STEERING; SPRINGS; BRAKES

STEERING PRINCIPLE

Principle of Steering

The steering device is placed on the left-hand side of the car. On early model cars it was placed on the right-hand side.

The principle: In steering a wagon, pulling on one of the reins swings the horse to that side. The shaft or pole is attached to the axle, and the axle is pivoted to the king pin, and all swing with the horse.

If you go straight ahead, the front and rear wheels of any vehicle move in straight lines. To make a turn to one side or the other, the front wheels are swung so that they are at an angle with the rear wheels.

Whenever the front wheels stand at an angle with the rear wheels, the vehicle will turn, and it will continue ~~to~~ turn until the front wheels are swung back to a straight line again.

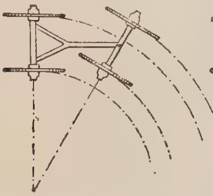


Fig. 1

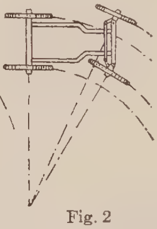


Fig. 2

Fig. 1. Showing how a front axle of a horse-drawn vehicle gives the direction in which a horse-drawn vehicle runs.

Fig. 2 Showing how the front wheels of an automobile give the direction in which the car runs. See next column, giving the meaning of **"turning radius."**

In a horse-drawn vehicle, the front wheels are square with the axle, for wheels and axle swing together. (See Fig. 1.)

In an automobile, the front axle does not swing, but each wheel swings on a pivot at the end of the axle, known as the **Ackerman principle.** (See Fig. 2.) See also page 910.

It would not be practical to steer an automobile as a horse-drawn vehicle is steered, for the axle would have to be very heavy to support the weight, and besides, it would be so hard to swing it that steering would be difficult. Another reason is that the body would have to be raised up high, so that the wheels could go under it in making a short turn.

A fixed front axle is always used on automobiles. The pivots on which the front wheels swing must be as close to the hubs of the wheels as possible, for the closer they are, the less leverage there will be to overcome, and the easier it will be to steer, with less liability to break.

When a wagon or automobile turns a corner, it moves in the arc of a circle.

In a horse-drawn vehicle, the front axle, because it swings on the king pin, always points to the center of the circle (Fig. 1). Notice that both wheels are perpendicular to the same radius of the circle and to the axle in Fig. 1.

The front axle of an automobile is fixed and cannot turn, and therefore only its pivoted ends point to the center of the circle (Fig. 2). Notice in Fig. 2, that the axle does not move, but that each wheel moves.

When running straight ahead, the front wheels of an automobile are square with the axle. When turning, the front wheels are not square with the axle, but at an angle with it.

Because each wheel is square with its axle end, and both axle ends point to the center of the circle, each wheel is square, or perpendicular to, a radius of the circle. If both were perpendicular to the same radius, which they are not, the wheels would be parallel with each other.

Thus, while the front wheels of a horse-drawn vehicle are always parallel to each other, the front wheels of an automobile turning a corner are not parallel to each other on the same radius.

The steering mechanism must be so arranged that the front wheels are parallel when the car is running straight ahead, but stand at an angle with each other when turning a corner.

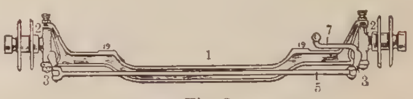


Fig. 3

Each of the pivoted axle ends (2, Fig. 3), which are called "steering knuckles," has a steering arm (3), projecting from it.

The ends of these two arms are connected by a rod called a "drag link, or tie rod" (5). When the drag link is moved endways, both wheels move with it.

The two steering arms are not parallel, but incline a little toward each other. If they were parallel, the two wheels would be parallel, no matter how the drag link was moved. As they are not parallel, moving the drag link moves one of the wheels through a greater angle than the other, depending on the direction in which the drag link is moved.

Turning radius: The radius in which a car can turn. For example, a turning radius of 15′ would mean that the car could be turned in a circle measuring 15′ from its center or 30′, or can be turned in a street 30′ wide if on one side of the street. If the steering device is on the left, a car can usually be turned in less space by turning to the right and vice versa.

Factors determining the turning radius are: (1) wheel base; (2) maximum angle at which the front wheel can be turned from the front. The average turning radius is 12½′ to 15′, or a circle of 25′ to 30′ dia. See Fig. 2, page 10, which will no doubt make the explanation clearer.

Steering Methods

There are two methods in general use: (1) the "fore and aft" method; (2) the "cross method."

The "fore and aft" method is shown in Fig. 4. With this method the reduction gearing is usually in the bottom of the steering device and the connecting rod (B) is usually behind the front axle.

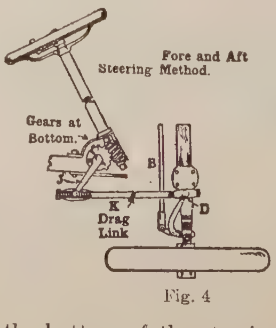


Fig. 4

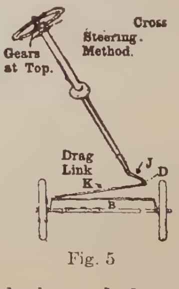


Fig. 5

The "cross steering" method is shown in Fig. 5. With this method the reduction gearing can be either at the top or bottom, and the connecting rod (B) can be either in front or behind the front axle.

The Ford and model "Four" Overland and Chevrolet "Four Ninety" employ planetary gears for reduction. The Ford gears are at the top of the steering column (Fig. 9), and on the Overland model "Four" and Chevrolet, the planetary gears are at the bottom.

Types of Steering Gears

There are a number of methods for reducing the ratio of movement of the steering column shaft to that of the arm (J).

(1) **Pinion and sector type** (see Fig. 6).

(2) **Worm and sector type** (Fig. 7). Note that the teeth are only on a section of the sector.

(3) **Worm and worm-wheel type** (Fig. 8).

(4) **Planetary type.** Note that the gears are at the top of the device on the Ford (Fig. 9), and at the bottom on the Overland model "Four," and Chevrolet.

(5) **Screw and nut type** (Fig. 10). Movement of this nut is up and down which moves the arm (J).

(6) **Screw and half-nut type** (Fig. 11). This is the Lavine steering gear. Adjustment is at the bottom of this device.

The breaking of any part of the steering connections is more likely to cause a wreck than the breaking of any other part of the car, and must be watched carefully. The parts must be kept tight enough to prevent play, but must not be so tight as to make steering hard. All parts must be kept well lubricated.

(See Index for "Steering gears, adjusting.")

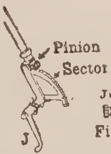


Fig. 6

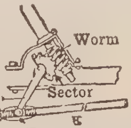


Fig. 7

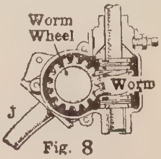


Fig. 8

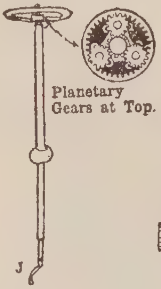


Fig. 9

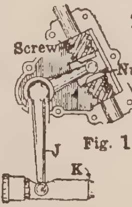


Fig. 10

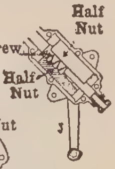


Fig. 11

SPRINGS

All vehicles intended to move at more than a very slow speed must be provided with springs. Springs not only protect the occupants from the vibrations of a rough road, but also keep the machinery from being shaken to pieces.

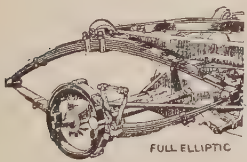


Fig. 12

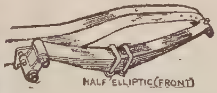


Fig. 13

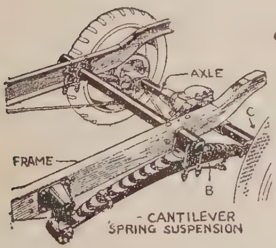


Fig. 14

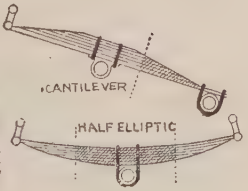


Fig. 15 (upper)
Fig. 16 (lower)

The size and strength of the springs depend on the weight of the vehicle. Springs that are too weak will not give sufficient protection, and if they are too strong they will not have enough resiliency.

Types of springs in general use are: Full elliptic, half or semi-elliptic, quarter-elliptic, three-quarter elliptic, and cantilever.

The full-elliptic was formerly used on a great many cars for the rear, as in Fig. 12. In some instances it was used in front.

The cantilever spring system (Figs. 14 and 15) is probably the most popular present-day practice. The illustration shows how it compares with the ordinary half-elliptic principle shown in Fig. 16.

In the cantilever spring the forward end is shackled and the axle is attached to the rear end. The center of the spring is attached to a trunion or bearing on the frame. Thus the spring has a certain amount of movement about its center. One good feature of this form of spring is that it reduces the unsprung weight of the axle. The shaded parts of the respective springs show the comparative amount of the unsprung weight. In the cantilever form of spring the heaviest part of it is supported by the frame. See also Fig. 5, page 7 (Hotchkiss drive).

The half-elliptic spring (Fig. 16) is used for the rear and, to a great extent, for the front, as in Fig. 13.

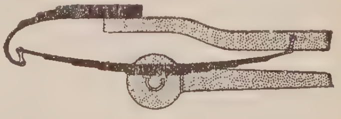


Fig. 17. Three quarter elliptic.

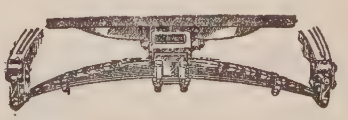


Fig. 18. Half elliptic-end supsension.

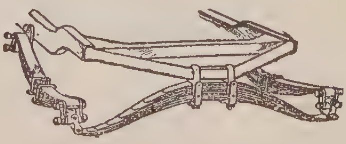


Fig. 19. Three half elliptic spring-coach style of suspension.

Other arrangements of half-elliptic springs for the rear are shown in Figs. 17, 18, and 19.

Breakage of a spring means breakage of one or more of the leaves. Breakage almost always occurs in the expansion that follows a heavy compression, and not during the compression. In other words, it is the **rebound** that breaks the spring.

Because the leaves slide on each other, they will wear and squeak if not properly lubricated.

To lubricate between the leaves it is necessary to relieve them of the weight they carry. This may be done by jacking up the body, or taking the springs apart, and spreading heavy grease or graphite on the leaves. This is quite a job and is seldom done.

SHOCK ABSORBERS

Breakage of springs usually occurs during a rebound. Devices called shock absorbers are attached to the springs to check their up movement. There are two types of shock absorbers in general use: the friction type, and the air or plunger type.

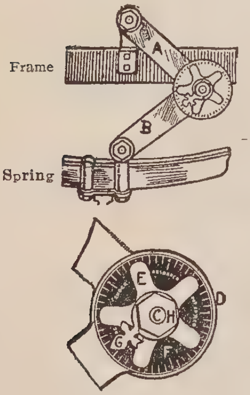


Fig. 20.

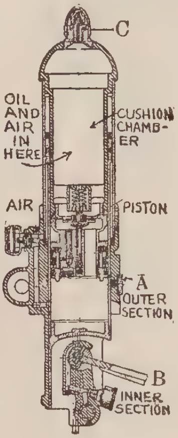


Fig. 21.

The friction type is shown in Fig. 20. All these movable frictional parts offer a constant resistance to the vibration of the spring both ways. It is easy to see that when the wheel strikes an obstruction, the arms come together, but instead of flying back, as does the free spring, it is retarded by the friction and moves gradually to its normal position, since the friction is always the same, while the tension of the spring diminishes as it approaches its normal position.

An adjustment dial (F) and indicator (G) provide means of securing the correct tension for the car. A spider compensating spring (E) takes up any little wear automatically, keeping the friction uniform after the adjustment has been made.

The arms (A) and (B) are joined to the frame and axle by two frictional joints, which also can be regulated.

The air or plunger type is shown in Fig. 21. It consists of an air chamber made up of two sections, one of which telescopes into the other. The outer section is attached to a bracket on the frame of the car, (**A**). The inner section is attached to one end of one of the springs, (**B**).

The chamber is partly filled with oil, through the filling-plug hole under the cap (C). The filling plug is fitted with an ordinary Schrader-tire type of air valve through which the chamber may be charged with air at any desired pressure, by means of an ordinary tire pump.

BRAKE CONTROL AND CONNECTIONS

Automobiles are fitted with two sets of brakes, called the "running service" or "foot brake," and the "emergency" or "hand brake," the terms "foot brake" and "hand brake" being the correct terms.

The foot brake is applied by pressing on a foot pedal, and is the one most in use because of its convenience, and is used most when running. Because it is used most, it requires more attention.

The usual method of connecting the foot brake is by a contracting band on the outside of the brake drum on the rear wheel hubs, called the "external contracting band brake."

The hand brake is usually applied by a lever at the side (or center) of the driver's seat, so placed that he may apply his whole force to it. This brake is seldom used while running. It is usually applied when the car is left standing, in order to keep the car from rolling down an incline. The hand-brake connects in almost every instance with the internal expanding brake inside of the brake drum on the rear wheel hubs, but occasionally will be found connected by a contracting band over a drum mounted on the main transmission shaft.

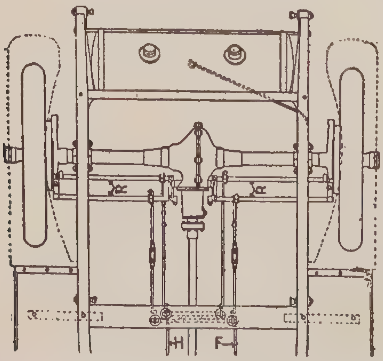


Fig. 22. Method of connecting the two brakes in rear. The adjustment for equalizing the pull on each rod, can be made at the turn buckles.

The foot-brake pedal is the right pedal and the left pedal is the **clutch pedal,** on almost all cars.

Brake Equalizers

When the foot-brake pedal or hand-brake lever is applied, the pull should be the same on each brake on each wheel. If one brake rod is longer than the other the brake effect is not equal on both wheels, and this has a tendency to make the car skid.

To overcome this, a brake equalizer is used, the principle of which is shown in Fig. 22. The rods (R) are placed in bearings; the rod (F), connects with the foot brake, and rod (H) with the hand brake.

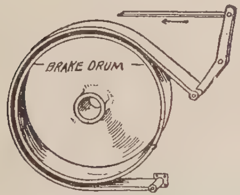
If a brake squeaks, it is an indication that it is dirty and needs cleaning. The dirt clogs the pores in the surface of the lining and glazes it over. Gasoline or, better, kerosene, will remove the dirt. The wheel should be removed and the linings cleaned with a stiff brush, such as a tooth or nail brush.

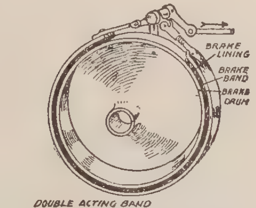
Types of Brakes

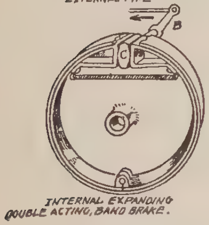
There are two distinct types of brakes in general use: the **external contracting** and the **internal expanding** type.

The **external band brake** is a flexible steel band faced with an asbestos or fabric composition, called "Raybestos" or "Multibestos," etc. Setting the brake causes friction between the brake drum and the linings, hence the use of asbestos composition.

Band brakes are of two kinds: **Single acting** and **double acting**, the latter being an improvement over the former.







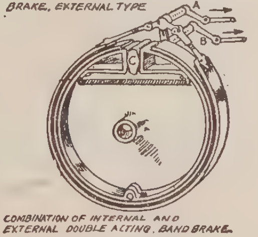

A
B
C
COMBINATION OF INTERNAL AND EXTERNAL DOUBLE ACTING. BAND BRAKE.

Fig. 23 (upper)
Fig. 25 (lower)

Fig. 24 (upper)
Fig. 26 (lower)

The single-acting band brake (Fig. 23) binds only when the drum is revolving in one direction, having very little grip when the drum is revolving in the same direction in which the band is being pulled. This form is going out of use for automobiles, for it cannot be depended on to hold the car from running down hill backward.

The double-acting band brake (Fig. 24) is more practical, for it holds with the drum revolving in either direction. In this form, both ends of the brake are attached to the lever or pedal, and are so arranged that while one end is being pulled in one direction, the other end is being pulled in the opposite direction. This binds on the drum so tightly that it may be depended on to hold the car in any position.

The brake band may either be drawn around the outside of the drum, called the "external brake band," or expanded within it so that it bears against the inside wall of the drum, called the "internal expanding brake." Sometimes the internal brake is made of metal.

The external type of brake is usually of the double-acting contracting type, and is always placed on the outside of the brake drum attached to the hub of the rear wheels as at **OB** (Fig. 27).

A combination of internal expanding and external contracting brakes are shown in Fig. 26. Lever **(A)** operates the external brake and lever **(B)** the internal brake. See also Fig. 27, below.

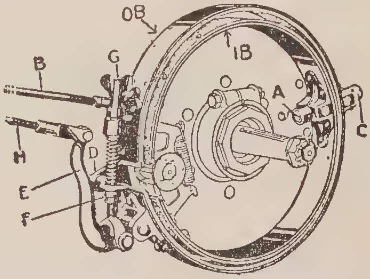


Fig. 27. A combination of an internal expanding and external contracting brake on brake drum of rear-wheel hub. **OB** is the outer or external and **1B** is the inner or internal. **B** is the hand-brake rod operating the internal brake. **H** is the foot-brake rod operating the external brake.

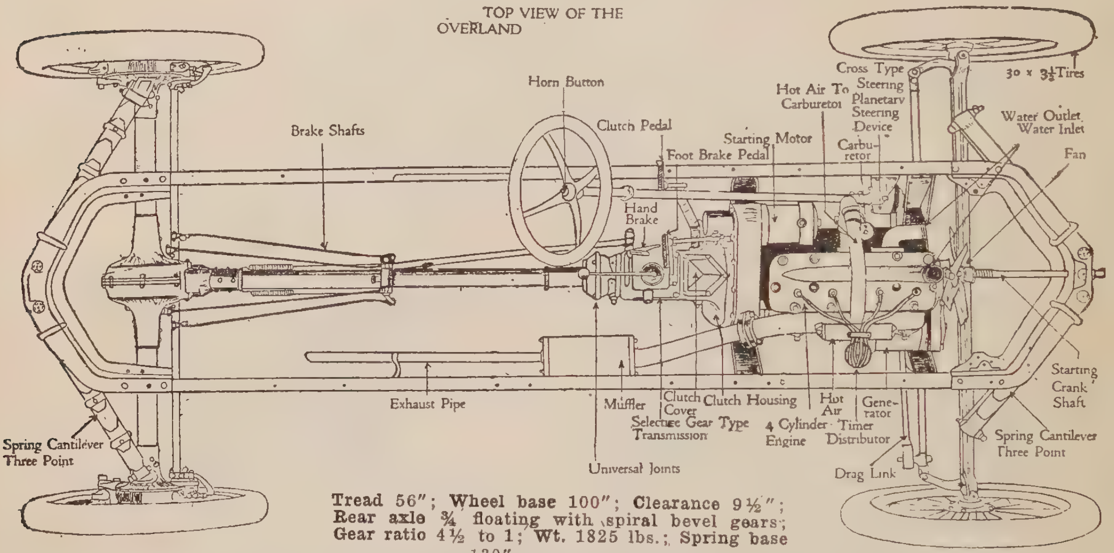
Adjustment of external brake is made at **F**, **G**, and **C**. Adjustment of the internal or hand brake is at **A**. It is turned up or lowered so as to have 1-64 inch clearance between the brake drum and brake.

The internal or hand brake formerly consisted of two shoes of metal, but the modern form is shown in Fig. 27. This is a double-acting, expanding type, and which acts internally against the inside of the drum. This brake shoe is lined with Raybestos, Thermoid or some similar material.

For the method of adjusting and relining brakes, see Index. This subject is treated in the Repair Section of this book.

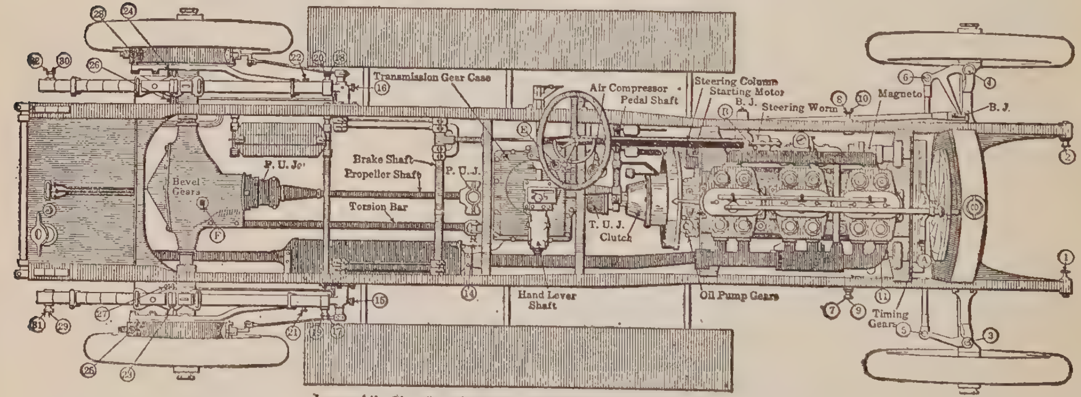
TYPICAL EXAMPLES OF A LIGHT CAR AND A HEAVY CAR

Illustrations and specifications of the two well-known cars shown below will give a comparison of the relative difference between a light car and a heavy car.



Tread 56"; Wheel base 100"; Clearance 9½"; Rear axle ¾ floating with spiral bevel gears; Gear ratio 4½ to 1; Wt. 1825 lbs.; Spring base 130"

Fig. 28. Example of a 4-cylinder car (Overland 4). Note the spring suspension used on this make of car, which is termed "triplex suspension," meaning that there are three points of contact on suspension. Engine, 4 cylinders; bore, 3-⅜", stroke 4"; actual h. p., 27; crank-shaft main bearing, 3; wheel base, 100"; tread, 56"; rear-axle ratio, 4½ to 1; rear-axle shafts, ¾ floating; transmission sliding gear, three speeds and reverse; clutch, lubricated single-plate type; unit power plant; tire sizes, 30" x 3½"; water capacity, 3¾ gal.; weight, approximately 1825 lbs.; clearance, 9½".



Locomobile Chassis. The "38" Type R-7. The "48" Type M-7

Fig. 29. Example of a 6-cylinder heavy car (Locomobile 48). Engine, 6-cylinder; bore, 4½"; stroke, 5½"; actual h. p.,90; crank-shaft main bearing, 5; wheelbase, 142"; tread, 56"; tire sizes, 37" x 5"; fuel capacity, 30 gal.; water capacity, 7¾ gal.; transmission, four speeds and reverse; clutch, multiple dry disk; rear axle, full floating.

INSTRUCTION No. 4

AXLES; DIFFERENTIALS; BEARINGS

FRONT AXLES

The front axle of a modern car carries about 80 per cent of the weight of the engine, and must at the same time withstand the shocks and jars that it receives through the steering wheels; it must therefore be strong and stiff. It also carries about 20 per cent to 40 per cent of the weight of the entire car.

Front axles are of two types: tubular and **solid** (Figs. **1** and 2). Formerly, axles were made of heavy steel tubes, but steel drop forgings with a cross-section of the form of the letter 1, are considered to give better results.

The center of the axle is usually bent down, so that it is the lowest point of the car except the wheels; this is done in order to protect the mechanism from being struck by high spots in the road. A rock or stump, standing up high enough to hit the fly wheel, will first strike the axle, which is strong enough to withstand a blow that could easily damage the engine.

The steering spindles are that part of the front axle on which the front wheels revolve and are made of nickel steel, heat treated. The steering spindles are sometimes fitted with either roller or ball bearings. The **steering knuckle** is that part which fits into the yoke of the axle. The **steering arm** of the device connects with the steering knuckle thrust arm, and the movement of the steering wheel guides the direction of the wheels. See page 910 for **types of front axle steering knuckles** (the **Elliott** and **Lemoine**).

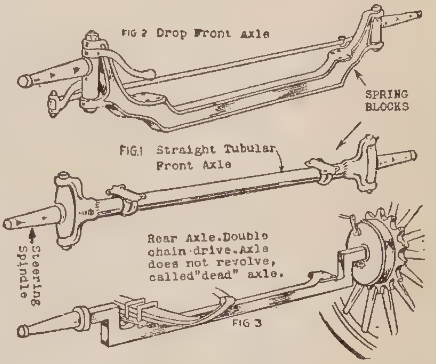


FIG 2 Drop Front Axle

FIG.1 Straight Tubular Front Axle

Rear Axle. Double chain drive. Axle does not revolve, called "dead" axle.

FIG 3

REAR AXLES

There are two types of rear axles: "dead axle" and "live axle." (Load is 60 to 80 per cent of car weight.)

Dead axles are stationary, with the wheels running free on the end of the axle, and are usually made as shown in Fig. 3. The wheels are usually revolved by chain and sprocket.

Live rear axles is the name given to axles that revolve with the wheels, and are known as "plain" live axle, "semi-floating" axle, "three-quarter floating" axle, "full-floating" axle.

The axle shafts on a live axle are in two sections (see **G**, **Fig. 7**, page 16). The inner end connects with the differential gears; the outer ends connect to the wheels. It is necessary to support the axle parts in a strong **housing** (**H**) and to brace it in order that the parts of the axle do not sag or get out of line.

Types of Live Rear Axles

There are **two types**: the "plain live rear axle" and the "floating live rear axle."

The plain live rear axle is the type where the **inner ends of the axle shafts support the differential.** See **Fig. 3A.** Note that the bearings are on the axle shafts; see also the Ford rear axle, page 1097. If the axle shafts are withdrawn the differential **would drop out of place.**

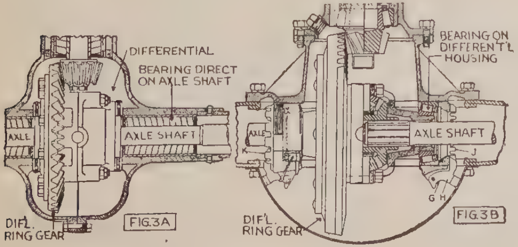


Fig. 3A. Plain live type of rear axle.
Fig. 3B. Floating type of rear axle.

To remove axle shafts the complete rear axle assembly must be removed from the car and the "divided housing" separated, as in Fig. 39, page 1096. See also pages 862, 863.

The floating rear axle is the type where **the differential supports the inner ends of the axle shafts.** See Fig. 3B. Note bearing is on outer ends of differential housing. If axle shafts are withdrawn differential **would not drop** out of place.

Types of Floating Rear Axles

There are **three types**, the "full-floating," "semi-floating," and the "three-quarter floating." The floating type is used more than the plain live type. See also page 863.

The type of floating axle is determined by: (1) whether or not the wheel bearing is on the outer end of the axle shaft or on the axle housing; (2) the location of the bearing or bearings; (3) the method of connecting the axle shaft with the wheel.

Full-floating type (Fig. 4). Two bearings in each rear wheel are mounted on the axle housing, placed on each side of the center of the wheel. Thus the wheels run on the housing and the housing supports the weight, not the axle shafts.

All of the bending stress due to weight or static force and to skidding force is carried by the housing.

The outer ends of **the axle shafts are not supported by the wheels** which do not depend upon the axle shafts for alignment. The wheel could run independently of the axle shaft in its bearings on the housing if necessary. Thus the axle shafts turn freely within the housing and bear only the torque (twisting effect) or stress of turning the wheels. The axle shafts are said to "float" within the housing.

The wheel can be driven by a jaw clutch or flange, but the true full-floating axle is driven by a jaw clutch (**D**, Figs. 4 and **4A**) which fits into notches in the driving flange (**F**). Note (**D**) is an integral part of the axle shaft.

Note: On some types of full-floating axles (see Fig. 35, page 877), the axle shaft is keyed (sometimes squared, or splined on others) to the flange and to remove the axle shaft the flange bolts are removed. This is termed a **"seven-eighths floating type."**

To remove axle shafts (Fig. 4), it is **not** necessary to remove wheels. Remove hub caps (not shown) and withdraw shafts (see also page 864). Technically speaking, the axle is not a true full-floating type if the shaft is keyed to the wheel.

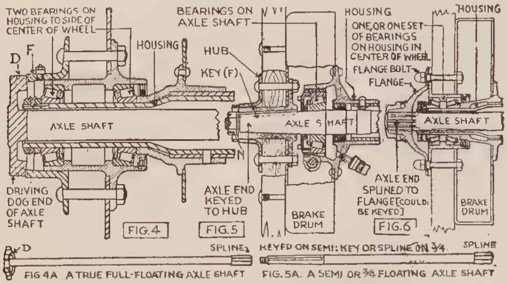

TWO BEARINGS ON HOUSING TO SIDE OF CENTER OF WHEEL
D
F
HOUSING
AXLE SHAFT
DRIVING DOG END OF AXLE SHAFT
BEARINGS ON AXLE SHAFT
HUB
KEY (F)
AXLE SHAFT
N
AXLE END KEYED TO HUB
BRAKE DRUM
HOUSING
ONE, OR ONE SET OF BEARINGS ON HOUSING IN CENTER OF WHEEL
FLANGE BOLT
FLANGE
HOUSING
AXLE SHAFT
AXLE END SPLINED TO FLANGE [COULD BE KEYED]
BRAKE DRUM
D
SPLINE
KEYED ON SEMI: KEY OR SPLINE ON 3/4.
SPLINE

FIG. 4 FIG. 5 FIG. 6

FIG 4A A TRUE FULL-FLOATING AXLE SHAFT FIG. 5A. A SEMI OR 3/4 FLOATING AXLE SHAFT

Semi-floating type (also called a "fixed-hub" type) is shown in Fig. 5. Outer ends of axle shafts are fixed, or keyed to the hubs of wheels, usually with keys (**F**) and nut (**N**).

The **bearings** (one on each outer end) are mounted directly on the axle shafts; thus the axle shafts support the weight, and carry the bending stress, torque, and the skidding and turning force.

To **remove axle shafts** (Fig. 5): The axle shafts on most semi-floating axles can be withdrawn from the axle housing without removing the entire rear axle, but it is necessary first to remove the wheels by loosening nuts (**N**) and draw the wheel off with a wheel puller; see pages 863, 864, 883 for further instructions.

For removing differential on different types of rear axles, see pages 863, 879.

The **three-quarter floating type,** also called the "flanged-hub" or "flanged-shaft" type, is shown in Fig. 6. The rear axle housing extends into the hubs of wheels as in the full-floating type. The outer ends of axle shafts fit into the hub flange and are splined as in Fig. 6 (could be keyed), and the flange is bolted to the wheel hub. Only one bearing is used on each wheel hub, usually placed directly under the center of the wheel and mounted on the axle housing (the two bearings in Fig. 6 are considered as one set of bearings).

The outer end of **axle shafts are supported by the wheels** which depend upon the axle shafts for alignment.

In the flanged-shaft axle, especially where only one bearing is used under the center of the wheel, the stresses (strains) are quite similar to those in the semi-floating type. The skidding force and that of turning corners is on the axle shafts.

To remove axle shafts (Fig. 6) it is not necessary to remove the wheel, but to remove the flange bolts and pull out the flange and axle shafts. See also pages 863, 868, and Fig. 27, page 921.

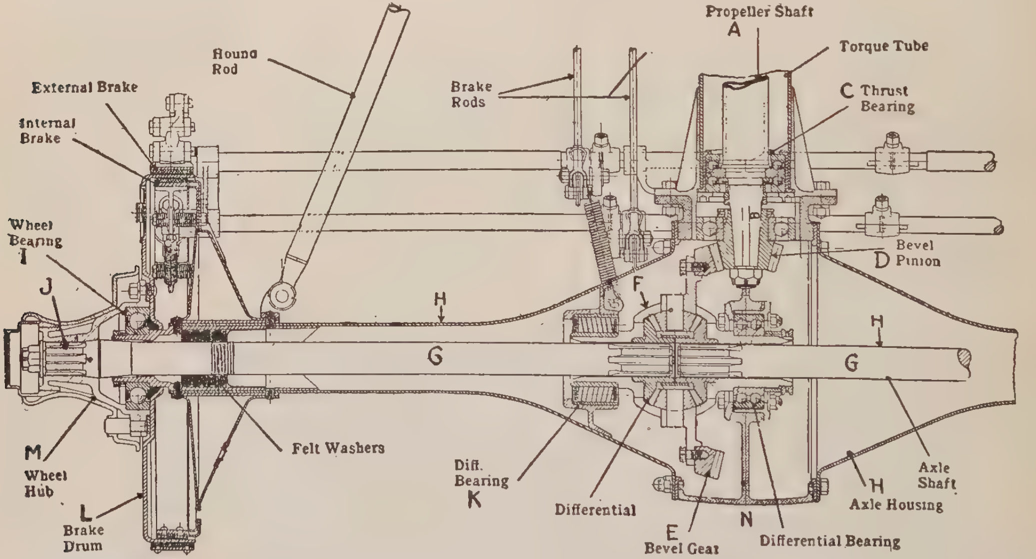


Fig. 7. Illustration of a three-quarter floating type of rear axle (Marmon as an example), complete with bevel driven gear (E). The driving axle shaft (G), does not support any dead weight. The road wheels run on ball bearings (I) carried on the outer sleeve or casing of the axle. The details are as follows: (**A**) propeller-shaft connection; (**B**) driving-pinion shaft; (**C**) ball-thrust bearings; (**D**) bevel-driving pinion; (**E**) large bevel; (**F**) differential gear; (**G**) half of driving axle; (**H**) tubular outer casing or sleeves (**I**) ball bearing for wheels; (**J**) driving ends of axle (squared or keyed); (**K**) roller bearings in differential case; (**L**) drum of internal and external brake; (**M**) hub of detachable wire wheel; (**N**) casing enclosing bevel gear and differential.

Note. The power is transmitted from the driving bevel (D) to large gear (E) this being bolted to the case of the differential (F), thence by the inside pinions to each half of the driving axle. It is usual to "anchor" the outer casing enclosing the differential gear to the chassis by means of torque tube or hound rods bolted to the upper and lower points of the gearcase which counteract the tendency for the whole casing to twist round from the reaction of the driving effort. On some cars the rear springs are made to serve as torque rods. The **thrust,** which is heavy between gears (D) and (E) is taken up by ball bearing (C).

TYPES OF REAR-AXLE DRIVE GEARING

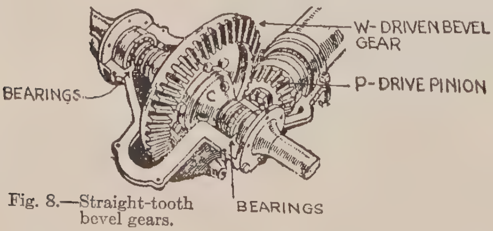


Fig. 8.—Straight-tooth bevel gears.

The power of the engine is transmitted at right angles to the rear axle and road wheels by means of bevel gears (P and W, Fig. 8), or by a worm and worm gear (Fig. 10). **Bevel gears are used on passenger cars** and the teeth are either **straight cut** (Fig. 8), or **spiral, or helical** (Fig. 9). The **ratio** of the diameter of these gears ranges from 3½ to 1, to 5 to 1, and the ratio determines the **high gear or direct drive** of the car.

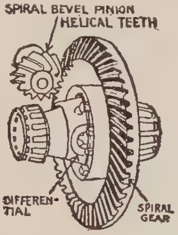


Fig. 9. Spiral or helical bevel gears.

The "spiral" or "helical tooth bevel gear" (Fig. 9), is a popular type of gear tooth used to a considerable extent. This type, if accurately made, is very silent.

In a straight-tooth bevel gear (Fig. 8), any given tooth goes in and out of mesh at one time along its entire length. In the helical bevel the meshing starts at one end of the given tooth and gradually moves towards the other end. Therefore, two helical teeth are in mesh at all times.

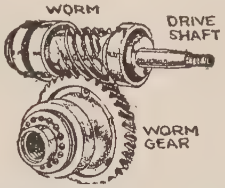


Fig. 10. The worm type of gear. The worm can be overhead or underneath the worm gear.

The "worm and worm gear" is used quite extensively on electric and commercial cars or trucks, where a large reduction of gearing is necessary. It is replacing the double-chain drive. It is made with the worm overhead, or underneath. The worm drive is very quiet and efficient.

The "single-chain drive" is now obsolete. It will not therefore be dealt with.

THE DIFFERENTIAL

Purpose of the differential: It is necessary to fit an automobile with **differential or compensation gears,** in order that the rear wheels may revolve at different speeds when the car turns a corner, while at the same time both are being driven by the engine. This gear is automatic, and operates according to the resistance of the road against the wheels.

Principle: There is more resistance to the turning of the inside wheel than the outside wheel when the car is turning; consequently the outside wheel may revolve faster. It is necessary for the outside wheel to revolve faster, because it has a longer distance to travel than the inside wheel. The same applies to a wagon, but the wagon wheels run free on the axle, therefore a compensating device is not necessary.

In illustration of this, see Fig. 12, and note that if the car is turning to the right, the wheel **A** must revolve faster than wheel **B.** Also refer to Fig. 11, and note that the axle shaft **A,** being attached to the wheel, must revolve faster than axle shaft **B,** when turning to the right and vice versa if turning to the left. Therefore, to compensate for this difference in speed of the two wheels and axle shafts, bevel gears (E) on the ends of the axle shafts (Fig. 11), mesh with the small bevel gears (D), called "compensating" or "differential gears," which are free in bearings on the housing or differential case attached to driven-ring gear **R.**

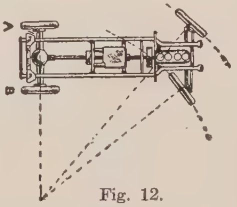


Fig. 12.

As long as the car travels straight ahead and the resistance of both rear wheels is the same, these gears (D) do not turn, but when the car turns, then greater resistance is offered to the inside wheel; therefore the compensating gears (D) with their spindles (DI), turn in their bearings, permitting the outside wheel to revolve faster than the inside wheel. In fact, the inside wheel could be stationary or revolve backwards if necessary.

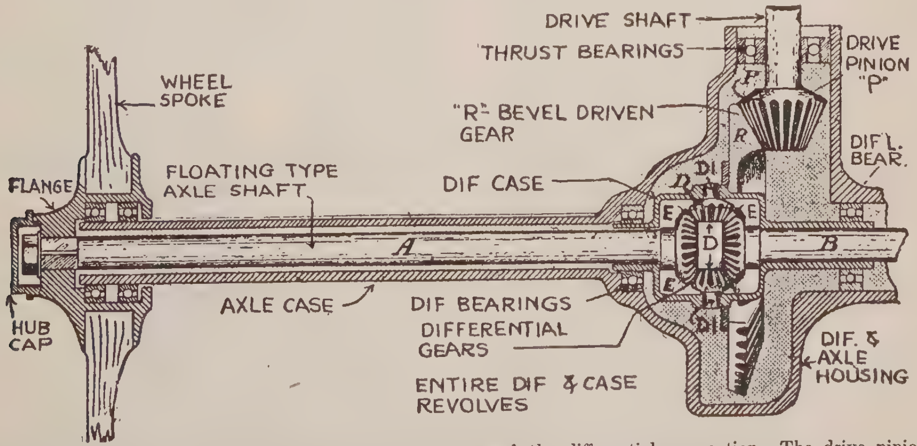


Fig. 11. Illustration explaining the rear-axle drive system and the differential-gear action. The drive pinion (P) on the end of the drive shaft drives the large bevel gear (R) which is connected to the differential case. Note that the entire differential case revolves on bearing. The power applied to the axle shafts (A and B) is then carried through the small bevel gears (D), which have spindles (DI) running free on bearings in the differential case. When the resistance is equal on both rear wheels and split-axle shafts (A and B), the gears (D) drive the bevel gears (E) on the end of the axle shafts, thus causing each axle shaft to revolve at the same speed. If resistance is greater on one axle shaft than on the other, the small bevel gears (D), with their spindles (DI), turn free in their bearings, thus permitting axle shafts (A and B) to turn at different speeds.

A study of Figs. 11, 12, 13, and 14 will make this principle clear. Note that the drive of the rear axle is through the drive pinion **P**, to gear **R**, thence through the differential case attached to it, then through the compensating gears **D**, to the bevel gears **E**, attached to the ends of the rear-axle shafts. You will observe that either axle shaft (**A** or **B**) could be held stationary, yet the other shaft could revolve.

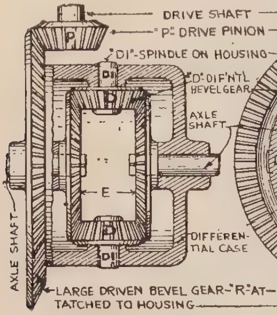


Fig. 13

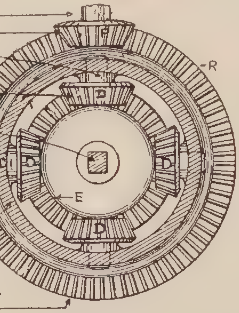


Fig. 14

Example of Differential Action

In order further to understand the action of the differential, refer to Fig. 11. Let us assume that the gear ratio of the rear axle is 4 to 1, which would mean that the ratio of bevel-driven gear (**R**) to drive pinion (**P**) would be 4 to 1. Consider that the engine is running at the rate of 1,000 r.p.m.

Consider gears (D) stationary, that is, we will assume, for the sake of explanation, that the spindles (**DI**) cannot turn on their bearings. Since the engine is running at 1,000 r.p.m., and the gear ratio is 4 to 1, the bevel-driven gear (**R**) would revolve 1,000÷4=250 r.p.m. Since the gear (**R**) is directly attached to the differential case, the latter will also revolve at the rate of 250 r.p.m. As we have considered the differential gears (**D**) as being stationary with respect to the differential case, they merely act as a direct connection between the differential case and the axle-shaft gears (**E**); consequently gears (**E**) will also revolve at 250 r.p.m., causing axle shafts (**A**) and (**B**) with their wheels to revolve at 250 r.p.m. This is exactly what happens when the car is traveling straight ahead, since there would be no effort exerted to cause gears (**D**) to revolve; consequently we can consider them stationary as assumed above.

Now consider gears (D) free to revolve, that is, we will permit the spindles to turn in their bearings. Now let us hold the axle shaft (**B**) stationary, and see what happens. The gear (**E**) attached to (**B**) will also remain stationary. The gear (**R**) and the differential case will still revolve at 250 r.p.m., thus causing the spindles (**DI**) to pass around the stationary gear (**E**) attached to (**B**) at the rate of 250 r.p.m. This would cause the gears (**D**) to revolve rapidly within the differential case as they rolled around the stationary gear (**E**) attached to (**B**). Now let us consider what happens to the gear (**E**) attached to the axle shaft (**A**). The motion of the differential case would tend to revolve (**A**) at 250 r.p.m. as explained above, but the rapid rotation of the gears (**D**) would also impart a further rotative effort to the gear (**E**) attached to (**A**), with the result that (**A**) would revolve faster than 250 r.p.m. This is exactly what would happen if the car was abruptly turned to the right, as (**B**) would then remain stationary.

The relative speed of (A) to (B) can easily be determined, because the sum of the speeds of (**A**) and (**B**) will always equal twice the speed of the driven bevel gear (**R**). Let us assume that (**R**) revolves at 250 r.p.m. as stated: then the sum of the speeds of (**A**) and (**B**) would be twice 250=500. If (**B**) is permitted to revolve at 250 r.p.m., then (**A**) will also revolve at 250 r.p.m., since their sum is 500. If (**B**) is only permitted to revolve at 100 r.p.m., then (**A**) will revolve at 400 r.p.m., since 100+400=500, or, in other words, 500−100=400. If (**B**) is permitted to revolve at 200 r.p.m., then (**A**) will revolve at 500−200=300 r.p.m.

Thus is seen the effect of the differential when the car is making a sharp or gradual turn. When making a gradual turn, (**B**) will revolve at nearly the same speed as (**A**), while, when making a sharp turn, there will be a great difference between the speeds of (**B**) and (**A**).

Q. 1: If the car was driven through mud, snow, sand, or on a greasy street, and the wheel attached to the axle shaft (**B**) (Fig. 11) should strike an obstruction that would cause that wheel to stop, describe what would happen.

Ans: Gear (**E**) attached to axle shaft (**B**) would also stop, thus causing the wheel attached to axle shaft (**A**) to spin, since it has slight traction on the slippery road.

Q. 2: Suppose you were starting from a standstill on a slippery road and one wheel should start to spin, and the car failed to move, what would be the reason and remedy?

Ans.: The wheel which is spinning would have no traction, that is it could not grip the road; thus it would spin and the other wheel, even though it had traction, would remain stationary. The remedy would be to put on skid chains, if available, or to tie a piece of rope around the tire, or to throw dry dirt or twigs under the wheel which spins, in order to give it traction or grip.

Q. 3: When the wheel spins, for example, the one attached to axle shaft (**B**) (Fig. 11), what action is taking place in the differential?

Ans.: The drive pinion (**P**) would be driving the driven bevel gear (**R**) thus causing the differential case to revolve with it. The axle shaft (**A**) with its gear (**E**) would remain stationary; the differential gears (**D**) would revolve rapidly around the stationary gear (**E**) attached to axle shaft (**A**). The motion of the differential case would tend to rotate gear (**E**) attached to (**B**) at the same speed as that at which the differential case is rotating, and the speed of (**B**) will be further increased by the fact that the gears (**D**) are revolving rapidly, as formerly explained.

When a double-chain drive is employed, the differential is placed on the jack shaft. The jack shaft is in two parts similar to a live axle.

Spur-gear differential: Most of the differential gears are of the bevel-tooth type. The spur-gear type (Fig. 15) is seldom used. Note that the illustration is that of a differential with a sprocket which was formerly used on a single-chain driven car.

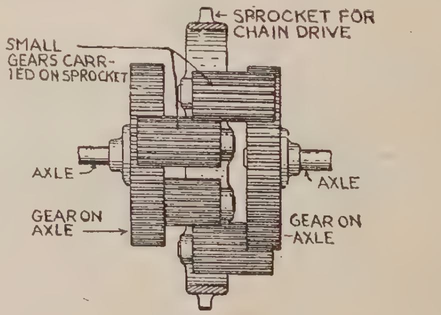


Fig. 15

BEARINGS

Every part of the car that moves with a rotary, sliding, or other motion is supported in bearings, which together with proper lubrication reduce wear and friction.

There are three different types of bearings in general use: the **plain, roller and ball bearings.**

Bearings are called upon to do two kinds of work: to take a **radial** load or a **thrust** load or a **combination** of both.

A radial load is a load or pressure perpendicular to the shaft supporting the load. For instance, the wheel bearings of an automobile, when running on a perfectly level road, are subject to radial loads.

Thrust load is a load or pressure parallel to or in direction of the shaft. When the automobile strikes a curve, a thrust load is imposed on the bearings in the wheels—that is, to the side, or endwise.

Fig. 16

Fig. 17

Fig 18

Fig. 16. Pure radial load.

Fig. 17. Combined radial and thrust load.

Fig. 18. An awkward way of resisting a combined end-thrust and radial load.

We might illustrate the relation between thrust and radial loads in this way: A man could be considered as being subjected to pure radial load when walking on an absolutely level surface (Fig. 16), but when this man walks along a hillside, without either ascending or descending the hill, as illustrated in Fig. 17, he is subjected to a combination of radial and thrust load; the thrust load having a tendency to push him down the hill.[1]

If a straight roller were called upon to take a thrust load as well as a radial load, it might be compared to the man in Fig. 18, he would need a crutch to prevent his toppling over. Therefore a ball-thrust bearing would be necessary at the end of the straight roller bearing (Fig. 22, below).

Plain bearings are usually on the main crank shaft, cam shaft, and connecting rods of an engine and take a radial load. Plain bearings can also be designed to take thrust loads.

Roller bearings are used in the wheels, rear axle, transmission, and other places and when straight, as in Fig. 19, they can only take a radial load. The roller itself runs over an inner race and inside of an outer race, case hardened.

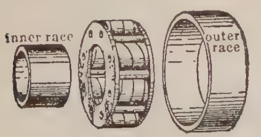


Fig. 19

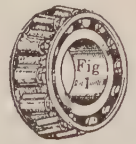


Fig. 20

When a roller is tapered, it runs over a cone-type hardened race (Fig. 20), and inside of an outer race, arranged as in Fig. 21. This type of roller bearing will take a radial and a thrust load without the use of a separate thrust bearing.

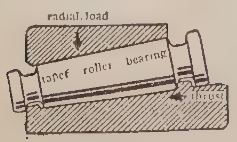


Fig. 21

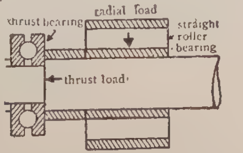


Fig. 22

The groove in the race and roller (Fig. 21) take the thrust load as well as the cone shape of race.

A straight roller bearing, to take a thrust load as well as a radial load, would require a separate thrust bearing (Fig. 22).

Ball bearings are also used on the wheels, rear axle, transmission and other places and are divided into three general classes; cup and cone, annular, and thrust.

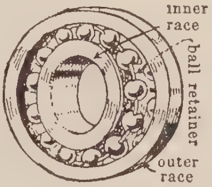


Fig. 23

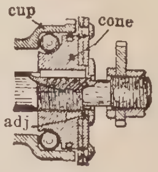


Fig. 24

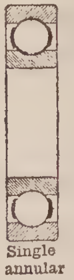


Fig. 25

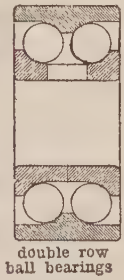


Fig. 26

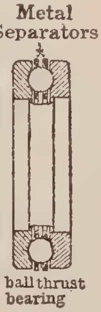


Fig. 27

The cup and cone bearing is shown in Fig. 24, and is used on many cars in the front wheels. This type of bearing is used extensively on bicycles. It is designed for radial loads, but is capable of withstanding considerable thrust also. It is adjustable.

The annular ball bearing is a bearing with an inner and outer race, which is grooved and hardened. They are not adjustable. This type can be a "single row" of balls (Figs. 23 and 25) or "double row" (Fig. 26). The single row takes a radial load.

The races of the double row are so shaped that it will withstand considerable thrust as well as a radial load. It is used where space would not permit the use of a separate radial and thrust bearing. This bearing is used extensively for supporting the drive pinion and taking the drive-shaft thrust in the rear axles.

The ball thrust bearing is shown in Fig. 27. This bearing can be used only where the load or stress is strictly a thrust or end-to-end load. This type is often used in clutches and is extensively used on the propeller shaft driving the propellers of motor boats.

The two parts the balls touch are called races. The one or two balls at the lower side support the entire weight and must be strong enough to hold up without being crushed. In automobiles, the balls are large and run in size up to 1 in. di. hardened and polished.

Sometimes balls wear flat or crack; if so a click will be heard and they must be replaced with perfect balls at once.

If one or more of the balls break in the annular self-contained bearing, pick out the pieces and run in on it and immediately secure another complete, or have it repaired by the manufacturer or a concern specializing in this work. If a ball breaks in a cone-type bearing it can be replaced.

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[1] From *American Automobile Digest.*

INSTRUCTION No. 5

CLUTCHES: Principle and Construction

GENERAL EXPLANATION

Purpose of the Clutch

The word "clutch" as used in connection with automobiles, indicates a device attached to cars having change speed gears of the sliding type, which permits the engine to be connected with, or disconnected from, the transmission, so that the car may or may not move while the engine is running.

The clutch is connected and disconnected from fly wheel of the engine by a foot lever.

When disconnected from the flywheel of the engine there is then no connection between the engine and rear axle.

When the clutch is connected with the flywheel of the engine, the power of the engine is connected with a rear axle—if the gears of transmission are not in "neutral" position.

If gears are in neutral position, the power of the engine would end at the end of the secondary shaft of transmission.

While other types of transmissions require clutches, they are of special kinds, and will not be referred to in this instruction. (The Ford, for instance, uses a different principle.)

Because a steam engine has behind it the pressure of the boiler, it can be called on to supply much more than its regular horse power for short intervals. A gasoline engine has no reserve power to call on, and cannot deliver more than a fixed horse power.

When the gasoline engine is required to start the car, it must overcome the inertia of the car. This might be greater than the power of the engine could accomplish, and the engine might be stopped instead of the car being started.

If the clutch made an immediate connection between the engine and the drive, the power of the engine would have instantly to overcome the inertia of the standing car.

The power of the engine coming from the revolving of the fly wheel, and the explosion that might be occurring in one of the cylinders, it would probably be stopped instead of the car being started.

If, however, the clutch is made so that the engine takes hold gradually, the inertia of the car will be overcome, and it will move faster and faster as the clutch permits the engine to apply its power more and more.

This is done by making the clutch in such a way that when it is applied, it slips, instead of instantly making a connection between the engine and the drive.

When the clutch is "let in," it connects the crank shaft of the engine through the fly wheel with the transmission through the clutch shaft, and if the gears are in the "neutral" (gears out of mesh) position, the counter or secondary shaft in the gear case of transmission will revolve without moving the car.

If the clutch is "in" and the gears are meshed, the course of the power from the crank shaft of the engine (Fig. 1) will then be through clutch, through gears, through drive shaft, driving pinion, large bevel gear on differential, through differential gears to axle shafts and wheels.

Clutches have two chief parts: one part (usually the fly wheel) is attached to the crank shaft of the engine, the other part (cone or disk or plate) is attached to the clutch or main shaft of the transmission.

When the two parts are separated, that is to say when the "clutch is thrown out" by the clutch pedal, they are independent of each other and the engine can run without moving the car.

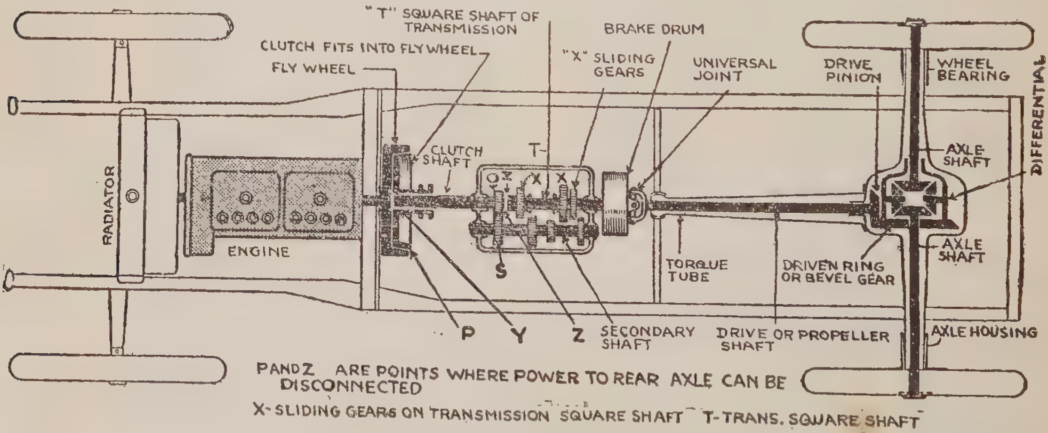

"T" SQUARE SHAFT OF TRANSMISSION
BRAKE DRUM
CLUTCH FITS INTO FLY WHEEL
FLY WHEEL
"X" SLIDING GEARS
UNIVERSAL JOINT
DRIVE PINION
WHEEL BEARING
DIFFERENTIAL
CLUTCH SHAFT
T
O
X
X
X
AXLE SHAFT
RADIATOR
ENGINE
S
TORQUE TUBE
DRIVEN RING OR BEVEL GEAR
AXLE SHAFT
P
Y
Z
SECONDARY SHAFT
DRIVE OR PROPELLER SHAFT
AXLE HOUSING
P AND Z ARE POINTS WHERE POWER TO REAR AXLE CAN BE DISCONNECTED
X-SLIDING GEARS ON TRANSMISSION SQUARE SHAFT T-TRANS. SQUARE SHAFT

Fig. 1. Illustration explains how the power is transmitted from engine to clutch, thence to secondary or counter shaft. Note drive parts are fly wheel, clutch, clutch shaft, drive gear (O), secondary shaft gear (S), and gears on secondary shaft. The driven gears are the sliding gears (X) on the square shaft (T).

Note. This power to the rear axle is disconnected at point (P) when the clutch is "out," at which time the clutch and clutch shaft turn free from the fly wheel, and at (Z) when the drive and driven gears are in "neutral" or not in mesh. (This end of the square shaft (T) runs free in the end of the clutch shaft, and is not actually separated at (Z), as shown above.)

Clutch Action

Note in Fig. 1 the power from the engine is transmitted to the clutch shaft only through the clutch when in the rim of the fly wheel (if disk or plate type, then by the disks or plates as explained under that type of clutch).

Observe that the clutch shaft does not connect with the engine, but runs free at the end (Y), at all times in the hub of the fly wheel. The cone part of the clutch is connected with the clutch shaft so that when the cone turns, the clutch shaft must also turn. But observe that the cone slides on the square part of the clutch shaft so that it can be pushed out by the pedal or in by the spring. See also, Figs. 2 and 3.

When the friction part of the cone is out of the fly wheel, power ends at the fly wheel.

When the clutch is in, then power ends at the end of the secondary or countershaft, if gears are in neutral, in which position they are seen in Fig. 1.

When the two parts are connected, that is, when the clutch is "let in" by releasing the clutch pedal, the clutch cone on the clutch shaft is forced into frictional contact with the inside face of the fly wheel by means of a clutch spring and held there. The two parts being thus connected force the clutch shaft, gears (**O** and **S**) and secondary shaft to revolve with the engine, but do not drive the car unless the gears on the secondary shaft and the square shaft (**T**) are in mesh, or unless connection is closed at **Z** (Fig. 1) by dogs or an internal gear connection, which would be high speed.

When the clutch is "let in," the part on the fly wheel does not grip the part on the cone clutch immediately, unless they are moving at the same speed.

If they are moving at different speeds, which is usually the case, or when the part on the transmission is stationary, the two parts slip. This slipping continues until the two parts revolve at the same speed, when they bind together firmly. When "thrown out," they must separate instantly.

A disk or any other type of clutch used with the gear type of transmission is placed in the same relative position, back of the fly wheel, between the fly wheel and gear case. Although the construction may vary, the reader will note that the clutch is necessary on all cars.

Clutch pedals: The left-foot pedal on all cars of standard design is the "clutch pedal" and on the right the "foot brake pedal."

Types of Clutches

There are four types of clutches in general use: **the cone, disk, plate,** and **expanding type.**

The disk clutch (formerly called the "multiple disk") is a clutch with more than three disks and can be a **lubricated disk clutch** or **dry disk clutch.** A **plate clutch** is one wherein one plate is clamped between two others.

The Cone Clutch

This type of clutch is built into the fly wheel, and the fly wheel forms one of its parts. The rim of the fly wheel is broad, and the inside of the rim is made slightly funnel-shaped, forming the surface against which the cone part of the clutch presses (Fig. 2). The surface of the cone that bears against the fly wheel rim is often covered with leather. Some manufacturers use fabric material, running in oil. This part can be replaced.

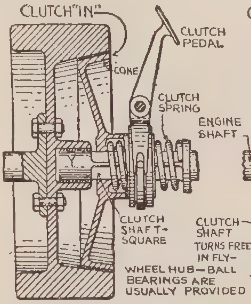

CLUTCH "IN"
CLUTCH PEDAL
CONE
CLUTCH SPRING
ENGINE SHAFT
CLUTCH SHAFT-SQUARE
CLUTCH SHAFT TURNS FREE IN FLY-WHEEL HUB—BALL BEARINGS ARE USUALLY PROVIDED

Fig. 2

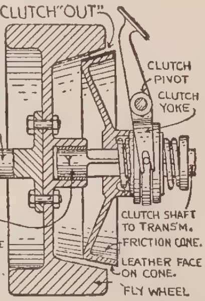


Fig. 3

The Disk Clutch

The disk clutch (formerly termed "multiple disk"), consists of a number of disks which are pressed together when the clutch is "in," the friction between them causing one to drive the other. This type of clutch is very compact, and is frequently built inside of a metal housing cast to the engine frame. See Fig 4, next page.

To illustrate the principle of the disk clutch place a silver dollar between two silver half-dollars, and squeeze them together between the thumb and forefinger of one hand. With the other hand, try to revolve the dollar, but not moving the halves. It requires only a slight squeeze to produce sufficient friction to make it impossible to move the dollar.

Multiple disk clutches are of two general types: those that operate in an oil bath and those that run dry; called **lubricated** and **dry** types.

The **lubricated** disk clutch **runs in oil**; its disks are usually alternate steel and bronze or all steel disks. The type that **runs dry** is usually composed of steel disks, one set of which is faced with a friction material of woven asbestos fabric.

Principle of the Lubricated Disk Type of Clutch

Parts: Fig. 5 shows the parts of the clutch separated from each other. The disks (**A**) are attached to the flange on the engine shaft; the smaller disks (**B**) are attached to the transmission shaft. The large disks (**A**) and small disks (**B**) are placed alternating.

The two flanges (**F** and **F1**) have pins extending from them, the disks (**A** and **B**) having holes so that they may be slipped on the pins or studs (**P, P1**).

The studs (**P1**) of the small disks (**B**) pass through the openings in the large disks. Thus the outer edges of the small disks come in contact with the inner edges of the large disks. All of the small disks (**B**) connect with flange **F1**, which has a square hole and slides on the clutch shaft by movement of the clutch pedal.

All the large disks (**A**) connect with the flange (**F**), which is connected to the engine shaft.

Assembled clutch: As will be seen from Fig. 4, which is the clutch assembled, the two flanges are connected only by the friction between the large and small disks, when the spring presses the parts together. The entire clutch is placed inside a casing, and runs in oil.

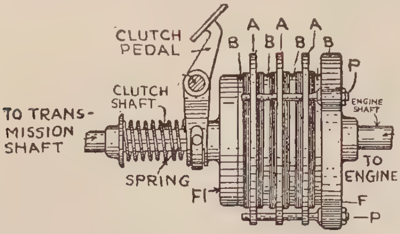


Fig. 4

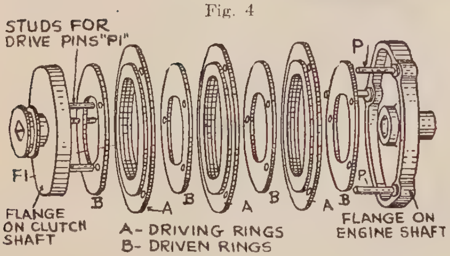


Fig. 5

When the clutch pedal is pressed forward, the clutch is "thrown out," the oil then flows between the disks and when the clutch is "in" and the spring presses the disks together, the oil is squeezed out from between them. While it is being squeezed out the clutch is slipping, and it begins to bind when the pressure has squeezed it out and the disks in consequence feel the effect of the friction. When the clutch is "thrown out," one set of disks may revolve independently of the other, for they are not connected in any way.

Hele-Shaw Lubricated Type of Disk Clutch

In the Hele-Shaw disk clutch (Fig. 6), a similar principle is adopted. The plates consist of a number of alternate bronze and steel disks much thinner. They are corrugated to increase the grip.

Half the plates are rotably connected by grooves with the driving member, and the alternate half with the driven member. When the clutch pedal is released, the clutch spring presses these disks together, and they all rotate as a solid mass. When the clutch pedal is depressed, the spring pressure is removed and the plates separated.

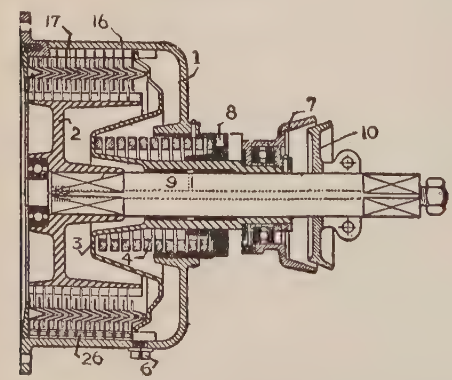


Fig. 6

Referring to the illustration (Fig. 6) the outer oil-tight case (1), to which the driving bronze plates (16) are keyed, is bolted to the fly wheel of the engine. The inner core (2) is keyed directly to the clutch shaft and to it are keyed driven steel plates (17).

The clutch is shown engaged as normally held by the spring (4) which actuates the ring (7) and the sliding presser (3). To facilitate quick disengagement, small springs (26) are fitted between the disks.

The case is oil-tight, provision being made for the replenishment of the oil through a plug (6) for the purpose.

Adjustments are made by means of an adjusting nut (8), and excessive spinning or dragging is prevented by a cone brake (10).

Principle of the Dry Disk Type of Clutch

Fig. 7 illustrates a dry disk type of clutch used on the Cadillac. The driving disks (**A**) are covered on both sides with a friction material, composed largely of asbestos, and are driven by six keys in the clutch ring (**H**) which is bolted to the engine fly wheel (**G**).

The driven disks (**B**) are not covered. These disks are carried on the clutch hub (**E**) and drive it through six keys on the hub. The clutch hub is keyed to the transmission shaft (**F**).

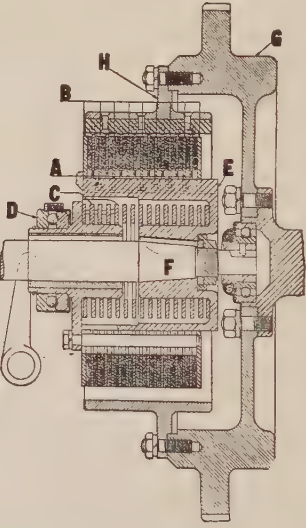


Fig. 7. The Cadillac disk clutch—dry type.

When the clutch is engaged by allowing the clutch pedal to come towards you, the spring (C) forces all of the disks together. The resulting friction between the disks (A) and (B) drives the clutch shaft (F) and the car, when the transmission control lever is in other than the neutral position.

There are no adjustments. The clutch pedal should be adjusted occasionally to compensate for wear on the facing of the clutch disks. There is one point (D) on the clutch for lubrication.

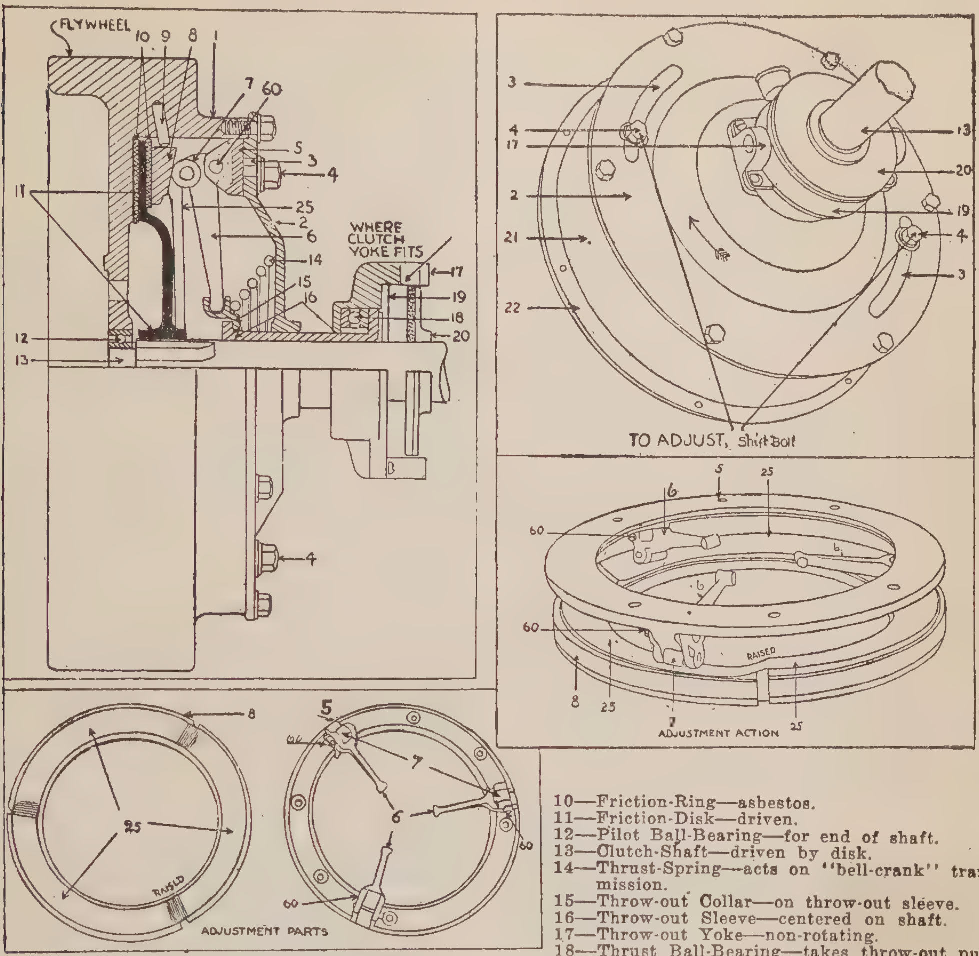
There are 17 steel plates, having 9 driven disks and 8 driving disks. The coil spring is held under 300 lbs. compression.

The Single-Plate Clutch

The S. A. E. term the disk clutch (formerly called the "multiple disk") a clutch with more than three disks.

The **single-plate clutch** is where one plate is clamped between two others. It is a popular type of clutch. It is a variation of the disk type, the latter comprising a large number of narrow disks, while the single-plate type usually consists of but three broad disks or plates, the ordinary type having two driving plates and one driven plate.

An example of a single-plate clutch is described in detail in the following matter. In this type, the clutch effect is created by wedging the plate. The type which will now be described is the Borg and Beck make, shown in Fig. 8, next page.



1—Clutch-Casing—cast with fly wheel.
2—Casing-Cover—carrying adjustment-ring.
3—Cover-Slot—for adjustment-bolt.
4—Adjustment-Bolt—for take-up action.
5—Adjustment-Ring—mounts thrust-levers.
6—Thrust-Lever (bell-crank)—mounts roller.
7—Thrust-Roller—acts against thrust-ring.
8—Thrust-Ring—acts against asbestos ring.
9—Driving-Pin—for thrust-ring.
10—Friction-Ring—asbestos.
11—Friction-Disk—driven.
12—Pilot Ball-Bearing—for end of shaft.
13—Clutch-Shaft—driven by disk.
14—Thrust-Spring—acts on "bell-crank" transmission.
15—Throw-out Collar—on throw-out sleeve.
16—Throw-out Sleeve—centered on shaft.
17—Throw-out Yoke—non-rotating.
18—Thrust Ball-Bearing—takes throw-out pull
19—Brake-Plate—rigid on throw-out yoke.
20—Brake-Collar—keyed on shaft.
21—Detachable-Casing—self-contained clutch.
22—Mounting-Flange—bolts against fly wheel.
23—Driving-Bolt—for thrust-ring (not shown).
24—Shaft, Brake and Universal Connection (not shown).
25—Adjustment-Incline—take-up seat for roller.
60—Bell-Crank Pivot—mounts thrust-lever.

Fig. 8

Borg & Beck Single-Plate Clutch

Principle: This type of clutch runs dry. The action is best understood when it is kept in mind that among the revolving parts, only the driven group: disk (11), shaft (13), and brake collar (20), can stand still when the fly wheel is running; all other parts being "anchored" to the fly wheel, must always revolve and drive with the latter.

When clutch is "in": The asbestos friction rings (10), though not positively attached to either the driving or the driven parts, will, in practice, "freeze" to the unpolished faces of the inner case of fly wheel and thrust-ring (8). They will thus always run bodily with the fly wheel.

When clutch is "out": The foot lever is applied which telescopes the coil spring (14) back, by action of the throw-out sleeve (16), which causes the roller (7) to withdraw a sufficient distance from the face of the thrust-ring (8), to permit the latter, with its companion friction-ring (10), to "back away" bodily, from friction-disk (11), thus releasing the disk from the friction-grip, and permitting it and other driven parts to come to a stop, while the fly wheel and parts anchored to it revolve.

Adjusting the Single-Plate Dry Clutch

Take-up action:[1] The roller-seat face of the thrust-ring (8) is formed on three, equal succeeding, take-up "inclines" (25); the ring being ¼-inch thicker, at the high end of each "incline" (25) than at the beginning, or low end. The three thrust-levers (6) are mounted upon, and equally spaced by, the adjustment ring (5); and this ring is adjustably mounted against the inner face of the cover (2), by means of the adjustment-bolts (4), of which there are two, through slots (3) in the cover.

When the bolts (4), are "slacked," and shifted in their cover-slots (3), they control and shift with them the ring (5), the latter carrying with it the levers and rollers (6 and 7), thus shifting all the rollers to new seats against the non-shifting thrust-ring; and, these seats being farther up the ring "inclines" (25). Where the inclines are thicker in cross-section, the ring is necessarily thrust so much farther toward the other friction parts, to compensate for any friction wear, and to maintain, at all times, a perfect friction grip.

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[1] See also Index under "Borg & Beck clutch," which is also discussed in the Repair Section of this book.

Therefore to **adjust the clutch,** the clutch is held entirely out. With the clutch thus held "out," it is only necessary to "slack" the adjustment-bolts (4), tap either of them "clockwise," in the slot (3) on the cover, a quarter or half-inch or any other distance required, thus shifting the ring (5), and carrying the levers and rollers to new seats, upon thicker sections of the thrust-ring. This compensates for the friction wear which made the adjustment necessary.

If too much oil gets into the clutch and **causes slipping:** It will be necessary in this case to unscrew the bolts (4) about three turns, have someone hold ~~out~~ clutch, and let the oil drain out. It is also desirable to squirt gasoline into the interior of the clutch to wash out the oil. If slipping continues, the trouble is due to oil working into the clutch housing and it must be separated from the main oil supply of the oil pan of the engine.

Removing clutch: First remove the transmission. Mark the clutch cover that bolts to the fly wheel with a punch and place a corresponding mark on the fly wheel, in order that it may be put back in the same position. The cover plate must not be turned.

Replacing clutch: There are two asbestos fabric rings; one lies against the face of the fly wheel (10), next to this comes the driven plate (11), then another friction washer (10). The cast thrust ring (8) comes next, but before installing, make sure that the driving pins (9) are in place in the inside of the fly-wheel rim. Drop the thrust ring (8) in position, so that the three slots fit over the pins (9). The adjustment ring (5), with its parts assembled to it, should not be installed. The adjusting ring (5) fastened to the cover plate by means of two cap screws and cover plate bolts to the fly wheel.

A clutch brake is provided, and this comes into action when the clutch pedal is pushed all the way down. The purpose is to stop the transmission gears from spinning when the clutch is disengaged. The throw-out collar (15) presses against the brake collar (20). The clutch brake is mounted on the transmission shaft and is faced with asbestos fabric.

If the clutch is worn, trouble will be experienced when shifting gears into first speed when car is standing. The clutch will appear to drag and will continue to drive the transmission gears when fully disengaged, so it will be difficult to mesh the gears. To remedy this remove the oil pan; have someone hold out the clutch, while the throw-out clutch and collar are examined to see if the collar (20) actually touches the brake or not. If it does not, the transmission should be removed, and if the brake-friction facing is in good condition, there is no need of installing a new one. See that the throw-out is not coming in contact with the brake flange and ascertain if it should be adjusted so that these two points form a contact.

Note. Always remember to drive with the foot off the clutch pedal. Make sure that the clutch pedal does not strike or press against the toe board. See also, Index under "Adjusting clutches."

UNIVERSAL JOINTS

A universal joint is a flexible connection between two shafts, which permits one to drive the other, although they may not be in line. Refer to Figs. 9, 10, and 11 and study the principle. Universal joints are usually placed forward and rear of the drive shaft. They are also termed "cardan joints."

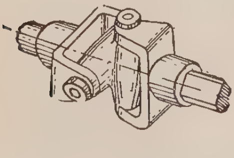


Fig. 9. Universal joint in a straight line.

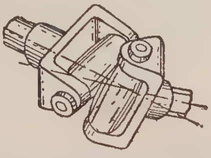


Fig. 10. Out of line.

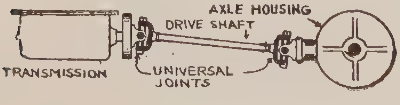


Fig. 11. Angular drive.

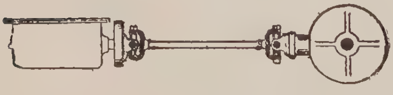


Fig. 12. Straight-line drive.

Universal joints are necessary on automobiles with shaft drive, for while one end of the driving shaft is attached to the transmission shaft, which is on the frame, the other end is connected to the axle, and is constantly moving up and down as the wheels follow the roughness of the road. If no universal joints were used, the shaft would jam in its bearings from the up and down movement of one end of it.

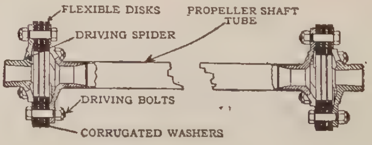


Fig. 13

Another type of universal joint is the flexible Thermoid-Hardy (Fig. 13). This joint is used only on "straight-line" drive. It consists of flexible discs secured to spiders on the ends of the shaft by means of bolts and corrugated washers. This assembly is bolted between a spider on the rear of the transmission and another on the front of the pinion shaft. The only attention these joints require is to see that all bolts are kept tight.

See Index for "Universal joints, adjusting," etc.

Angular and Straight-Line Drive

The angular drive is where the transmission is above the axle, as in Fig. 11.

The straight-line drive (Fig. 12) is where the drive shaft is in line when the car is carrying an average load, and is thrown out of line only to the extent that the chassis moves up and down on the springs. The variation is as great in one direction as another, but on the angular type, the shafts are never in alignment and the universals are required to act through a considerable angle.

INSTRUCTION No. 6

TRANSMISSION: Principle and Construction; Gear Shifts

GENERAL EXPLANATION

Purpose of a Transmission

When a bicyclist wants to race on a level track, he gears up his wheel with a larger sprocket, so that one revolution of the crank takes him farther. Yet if he takes his wheel, with this large sprocket on the pedal shaft, out on the road where there are hills, he must get off and walk or exert an extra lot of power. This clearly shows that if a bicyclist wants to speed while on the level, and yet take all hills, he must change the drive sprocket.

The same principle applies to the automobile. For this reason the automobile is provided not only with two changes of gears (instead of sprockets), but sometimes with three and even four changes of gears. These gears are contained in a gear-box usually placed back of the clutch.

The principle upon which all change-speed gears work is the fact that when two gear-wheels or spur-gears are meshed together the larger wheel turns more slowly than the smaller wheel.

As an example, a gear-wheel with 10 teeth, in mesh with a second wheel having 20, would revolve twice as fast as the latter, the explanation being that when the 10-tooth gears of the smaller wheel have moved round once they will have engaged with only 10 teeth of the larger wheel, and therefore will have turned the larger wheel through only half a revolution; that is, it will be necessary for the smaller wheel to revolve twice in order that the larger one may revolve once.

With this piece of elementary information, we will observe that in the gear-box (see below) there are two shafts—the upper one coming from the engine through the clutch, and the lower one continuing to the back axle.

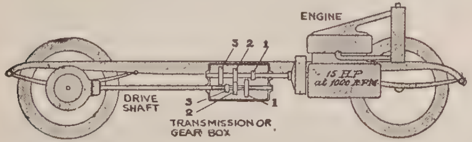


Fig. 1. This illustration is intended to simplify the explanation. In actual practice the arrangement is slightly different.

Each shaft is fitted with three different sized gear-wheels numbered in the illustration, 1, 2, and 3. Those on the upper shaft are fixed to the shaft itself, but those on the lower shaft are able to slide on a keyway, to right and left along the shaft. The shaft is not round like the upper one, but is squared, so that although the sleeve of the gear-wheels can slide backward and forward, they cannot revolve independently of the lower shaft.

In order now to vary the speed of the car, it is only necessary to slide the gear-wheels along the lower shaft until the correct two gears come into mesh to form the gearing required.

The illustration, for instance, shows the intermediate speed-gear in mesh, but were we to move the gears to the right so that wheels 1 and 1 come into mesh, we should put the car on its first speed, that is its lowest speed, so that, with the engine running normally, the car would be moving very slowly, the driving gear being much smaller than the driven gear.

When, however, the sleeve is moved to the left, so that gears 3 and 3 mesh, the effect is reversed. Now we have the driving gear much larger than that driven, and the result will be that when the engine runs normally the car will be traveling at a very high speed.

The sides of the teeth of the gears are usually made like the point of a chisel, so that when two gears are brought together they will mesh easily. (To "mesh" means that the teeth of two gear-wheels become engaged.)

Types of Transmissions

There are three types: the **sliding-gear, planetary,** and **friction-disk** type.

The **planetary** type used on the Ford (Fig. 8), is explained in the Ford Instruction. The **friction-disk** type (Fig. 9) is now seldom used.

There are two types of **sliding-gear** systems: the old-style **progressive** type (Fig. 2) and the modern **selective** gear type, pages 27 and 28.

The **progressive** type was discarded because it was necessary to pass one gear through another which made a clashing noise and was difficult at times to operate.

With the **selective** type it is not necessary for the sliding gear to pass through another gear. It is easier and quicker to operate and considerably less noisy. It is with this type that we shall deal.

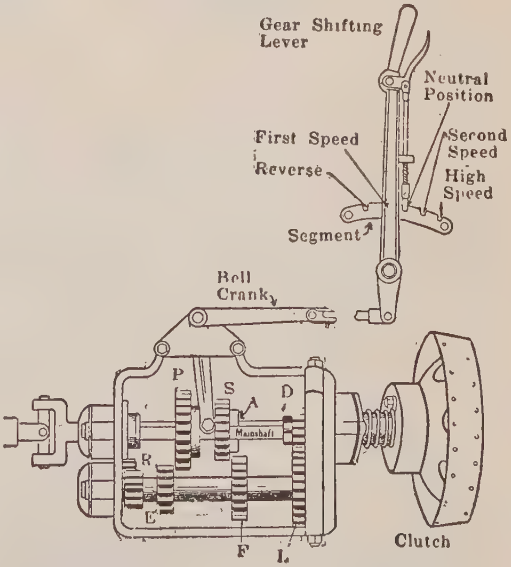


Fig. 2. A three-speed progressive type of transmission, showing the lever and gears in "neutral" position; an obsolete method. Note, in order for dog (A) to reach dog (D), which would be high gear or direct drive, it would be necessary for the sliding gear (S) to pass through gear (F); or to reach reverse, by gear (P) being meshed with (R), it would be necessary for gear (P) to pass through gear (E).

Location of the Transmission

The location of the transmission on the modern type of car is where the transmission and clutch are connected to the engine in one unit, termed a "unit power plant" (Fig. 3).

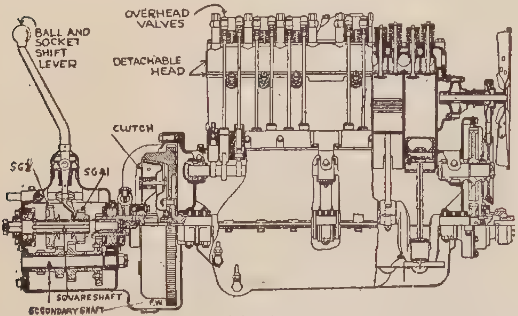
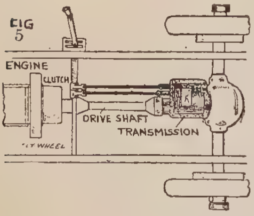
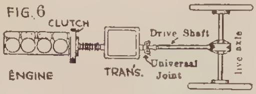
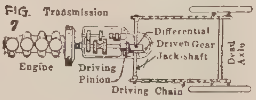


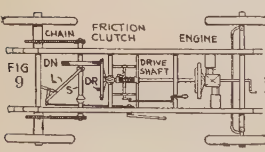
Fig. 3

On some of the earlier type of cars the transmission was placed adjoining the rear axle housing (Fig. 5).









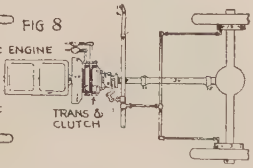


Fig. 6 shows the transmission separated from the engine. This method is used on the Locomobile.

Fig. 7 shows the location of the transmission when used with a double-chain drive and a dead rear axle.

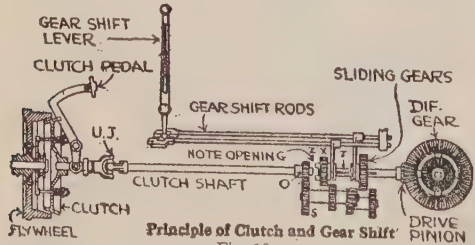
Fig. 8 is the Ford planetary transmission location, explained under Ford Instructions.

Fig. 9 is a friction-disk type of transmission, used on cars of the early period. The drive disk (DR) connected to the drive shaft transmits the power through the driven disk (DN) to the jack shaft, thence by sprockets and chain to the dead rear axle.

The change of speeds is obtained by sliding the driven disk (DN) on the keyed shaft (S) by the lever (L). By this means several ratios of speeds could be obtained. The disadvantage, however, was due to slipping. This type is now seldom used.

The Selective-Gear Type of Transmission

This type is preferable, because of the absence of noise from the gears and because of the ease of operation. The gear-change ratio, or gear desired, is "selected" by movement of the gear-shift lever, and the shift can be made without one gear passing through another.



Principle of Clutch and Gear Shift
Fig. 10

The relation of the gears to the clutch is shown in Fig. 10. The principle of the selective type of transmission is shown on pages 27 and 28.

Referring again to Fig. 10, note that the power is transmitted from the fly wheel to the clutch, thence from the clutch shaft to gear (O and S), through the sliding gear for first or second speed. For high speed, small dog-clutches on the sliding gear (X), on the square shaft (T), mesh with dogs on gear (O), which makes the drive direct to the rear axle. See also Fig. 12.

Relation of Parts

How the change of gears is obtained. Note, in Fig. 12, the square shaft (130) is independent of the clutch shaft (134). Also note, in Fig. 11, that the gear (128) and the driven gear on the countershaft, as well as the countershaft itself (129), always turn together. Thus power from the engine would end at shaft (129), providing sliding gears (SG-1 and SG-2) were in the position shown, which is "neutral" position.

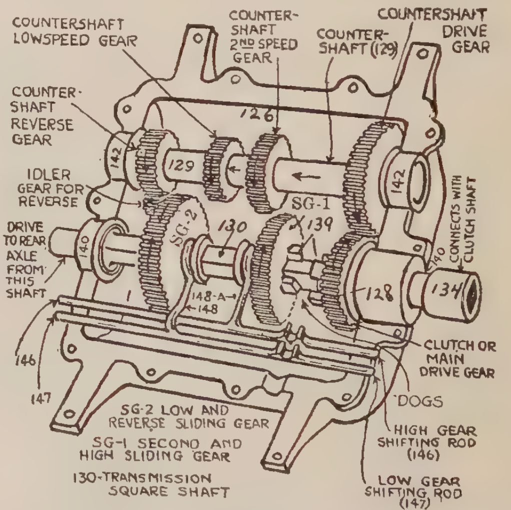

COUNTERSHAFT LOWSPEED GEAR
COUNTER-SHAFT 2ND SPEED GEAR
COUNTER-SHAFT (129)
COUNTERSHAFT DRIVE GEAR
COUNTER-SHAFT REVERSE GEAR
IDLER GEAR FOR REVERSE
DRIVE TO REAR AXLE FROM THIS SHAFT
126
142
129
SG-2
130
SG-1
139
142
140
128
134
140
CONNECTS WITH CLUTCH SHAFT
148-A
148
146
147
CLUTCH OR MAIN DRIVE GEAR
DOGS
SG-2 LOW AND REVERSE SLIDING GEAR
SG-1 SECOND AND HIGH SLIDING GEAR
130-TRANSMISSION SQUARE SHAFT
HIGH GEAR SHIFTING ROD (146)
LOW GEAR SHIFTING ROD (147)

Fig. 11.

Neutral position means the sliding gear is not in mesh with the gear that drives it. Therefore, with the position illustrated in Fig. 11, we could not drive the rear axle, even though the engine was running and the clutch "in."

First or low speed would be obtained by shifting gear (SG-2) in mesh with countershaft low-speed gear. **Second speed,** would be obtained by shifting sliding gear (SG-1) in mesh with countershaft second-speed gear. **Third or high speed,** would be obtained by shifting (SG-1) forward so that dogs (139) would grip; then the drive would be direct to the rear axle, but the countershaft and its gears would also turn, but not being in mesh with the

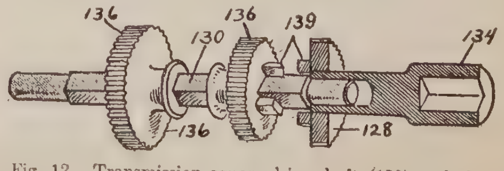


Fig. 12. Transmission square drive shaft (130) and sliding gears (136).

driven gears it would make no difference. **Reverse** would be obtained by shifting (SG-2) back until it meshes with the idler gear, which would reverse the direction of drive shaft (130).

Remember—gears cannot be shifted until the lever is brought to "neutral" position.

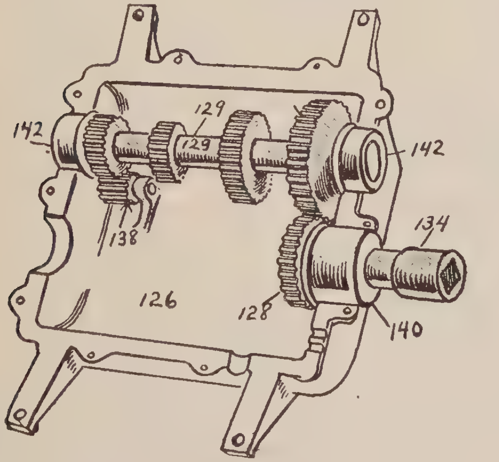


Fig. 13. The lower half of transmission with countershaft (129) and its gears which are permanently attached thereto. Idler gear (138), clutch or main drive gear (128), and clutch shaft (134) are also illustrated.

A Modern Selective-Gear Type of Transmission

The transmission in Figs. 11, 12 and 13 gives a clear explanation of the relation of one part to another.

The modern transmission now uses internal gears instead of "dogs." For instance, see Fig. 18, page 28. Note that instead of "dogs" (139, Fig. 12), the gear (8, Fig. 18) has internal teeth which mesh with a smaller gear on the side of gear (9).

The transmission (Fig. 18) is connected to the engine. It is therefore termed a "unit power plant." There are three speeds forward and one reverse.

Operation of the Gear-Shift Lever

There are two types of gear shift levers: the "**gate**" principle and the "**ball-and-socket**" type. The latter is used more than any other type.

The gate type: The gate type is shown in Figs. 14 and 15. A simplified explanation as to how the shift lever operates in relation to the shift bars (146 and 147) and shifting or sliding gears (SG-1 and SG-2) will be made clear by referring to Figs. 11 and 14.

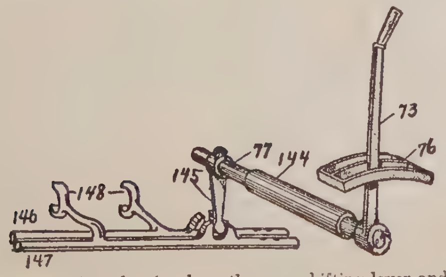


Fig. 14. View showing how the gear-shifting lever and the selector connect with the shifting bars. The lever is now in "neutral" position, but if pushed to the inside gate or selector, it would shift the inside bar (146); if pushed to the outside gate position it would shift the outside bars (147). Note, that the lever moves sidewise as well as forward and backward.

The movement of the gear-shift lever for different speeds varies on different cars. For instance, in

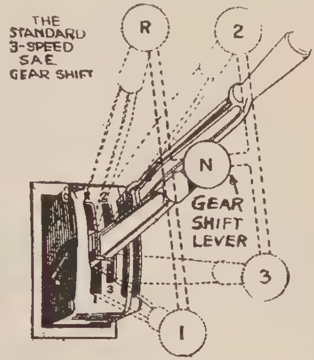


Fig. 15

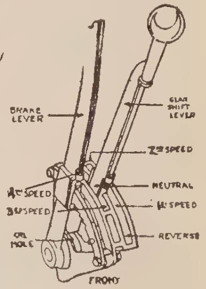


Fig. 16

Fig. 15. A three-speed forward and reverse gate type gear shift.

Fig. 16. A four-speed forward and reverse gate type gear shift.

Fig. 15, to obtain **first or low speed,** the gear-shift lever, which is now neutral (**N**), is moved sidewise to the left and then back. To obtain **second speed,** it is moved sidewise to the right and then forward; for **third, or high speed,** to the right and back; for **reverse,** to the left and forward.

The four-speed gate type of gear-shift (Fig. 16) corresponds with that shown in Fig. 20, page 29.

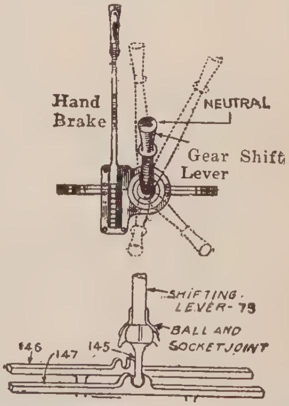


Fig. 17. Ball-and-socket type of gear-shift lever, with three speeds forward and reverse. The gear-shift lever (73) is now upright in the center of the socket and is in "neutral" position.

The ball-and-socket type of gear shift shows almost identically the same principle as the gate type, except the movement of lever (73), (Fig. 17), is in a "ball and socket" instead of a "gate." Note that arm (145) serves the same purpose as arm (145) (Fig. 14). This is the type in general use.

S. A. E. Standard Gear-Shift Movements[1]

The gear shifts as recommended by the Society of Automotive Engineers are illustrated on page 29.

The transmission, giving three forward speeds and one reverse speed (or gear changes) is in general use. On some few large cars, and also on most types of trucks, the four-speed transmission is used. Fig. 19, page 29, illustrates the gear shift in general use. The selector can be of the "gate" or "ball-and-socket" type, usually the latter.

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[1] See Index for "S. A. E. standard four-speed truck gear shift."

Clutch shaft (19) is permanently connected with the main drive or clutch gear (9) or the transmission. The other end (CE) works free in a ball bearing in the fly wheel, but does not connect with the fly wheel.

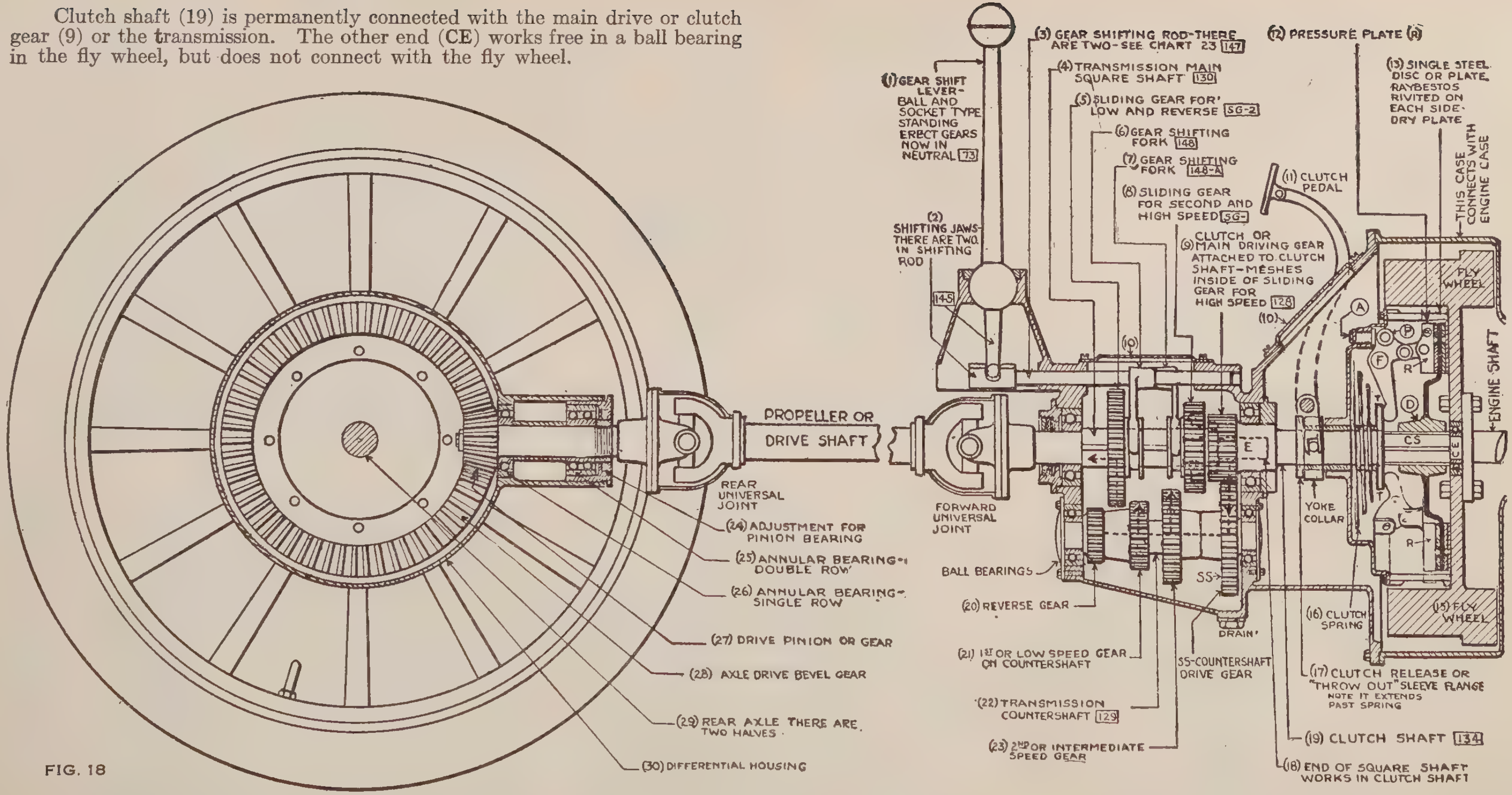

(1) GEAR SHIFT LEVER- BALL AND SOCKET TYPE STANDING ERECT GEARS NOW IN NEUTRAL 73
(2) SHIFTING JAWS- THERE ARE TWO IN SHIFTING ROD
145
(3) GEAR SHIFTING ROD-THERE ARE TWO-SEE CHART 23 147
(4) TRANSMISSION MAIN SQUARE SHAFT 130
(5) SLIDING GEAR FOR LOW AND REVERSE SG-2
(6) GEAR SHIFTING FORK 148
(7) GEAR SHIFTING FORK 148-A
(8) SLIDING GEAR FOR SECOND AND HIGH SPEED SG-
(9) CLUTCH OR MAIN DRIVING GEAR ATTACHED TO CLUTCH SHAFT-MESHES INSIDE OF SLIDING GEAR FOR HIGH SPEED 128
(10)
(11) CLUTCH PEDAL
(12) PRESSURE PLATE (R)
(13) SINGLE STEEL DISC OR PLATE RAYBESTOS RIVITED ON EACH SIDE-DRY PLATE
THIS CASE CONNECTS WITH ENGINE CASE
FLY WHEEL
ENGINE SHAFT
A
P
F
R
D
CS
CE
E
T
YOKE COLLAR
(15) FLY WHEEL
(16) CLUTCH SPRING
(17) CLUTCH RELEASE OR "THROW OUT" SLEEVE FLANGE NOTE IT EXTENDS PAST SPRING
(18) END OF SQUARE SHAFT WORKS IN CLUTCH SHAFT
(19) CLUTCH SHAFT 134
DRAIN
SS
SS-COUNTERSHAFT DRIVE GEAR
(20) REVERSE GEAR
(21) 1ST OR LOW SPEED GEAR ON COUNTERSHAFT
(22) TRANSMISSION COUNTERSHAFT 129
(23) 2ND OR INTERMEDIATE SPEED GEAR
BALL BEARINGS
FORWARD UNIVERSAL JOINT
PROPELLER OR DRIVE SHAFT
REAR UNIVERSAL JOINT
(24) ADJUSTMENT FOR PINION BEARING
(25) ANNULAR BEARING-DOUBLE ROW
(26) ANNULAR BEARING-SINGLE ROW
(27) DRIVE PINION OR GEAR
(28) AXLE DRIVE BEVEL GEAR
(29) REAR AXLE THERE ARE TWO HALVES
(30) DIFFERENTIAL HOUSING

FIG. 18

When the clutch is "in," a spring (16) presses against flange (T) of a sleeve, causing the three fingers working on pivots (F) to apply pressure through pressure plate (R) (a ring); this in turn applies pressure against the single plate. The single plate (13) is fitted with Raybestos riveted on each side. This friction material clutches the fly wheel. The drive is then through driven plate (13) to plate hub (D), then a square section of the clutch shaft (CS) to the main drive gear (9). Note (CS) part of clutch shaft is squared and clutch plate hub (D) slides thereon.

When the clutch is "out," the pedal (11) is pressed; this causes the yoke collar to press against flange (17) of the sleeve. This action causes flange (T) on the other end of the sleeve to relieve the pressure against fingers (F). This releases the pressure against the single plate (13).

The adjustment of fingers (F) or pressure against the plate is at (A). This type of clutch runs without oil.

Note. Figures in the squares at the end of the wording of Fig. 18 compare with reference figures on transmission on page 26 (Fig. 11).

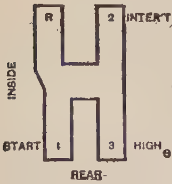


Fig. 19

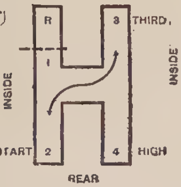


Fig. 20

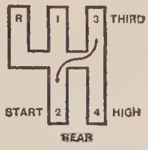


Fig. 21

Fig. 19. Three-speed movement; (R) is reverse; (2) intermediate or second speed; (1) low or first speed; (3) third or high speed. Note that reverse and second speed are forward movements.

Fig. 20. Four-speed movement. This corresponds with Fig. 16 (page 27). Note the reverse is a further movement in the same slot with first-speed movement.

Fig. 21. Four-speed; same as Fig. 20, except that the reverse (R) is in a separate slot, to the side of the first speed (1).

Example of Gear Shifts

The gear-shift principle (Fig. 22) is the "ball-and-socket" type and standard S. A. E. movement, as shown in Fig. 19. The transmission is of the "selective-gear" type, three speeds forward and one reverse. (Studebaker model "EJ" is used as an example.) Note that the gear-shift lever (1) is now upright and in neutral (N) position. If shifted according to the movements, first, second, third and R, the various transmission-gear ratios will be selected as shown in Fig. 22 below.

Remarks Relative to Changing Gears

To start the engine: See that the gear-shift lever is in neutral position. The clutch is then in, but the car will not move. Turn on the ignition switch and crank the engine.

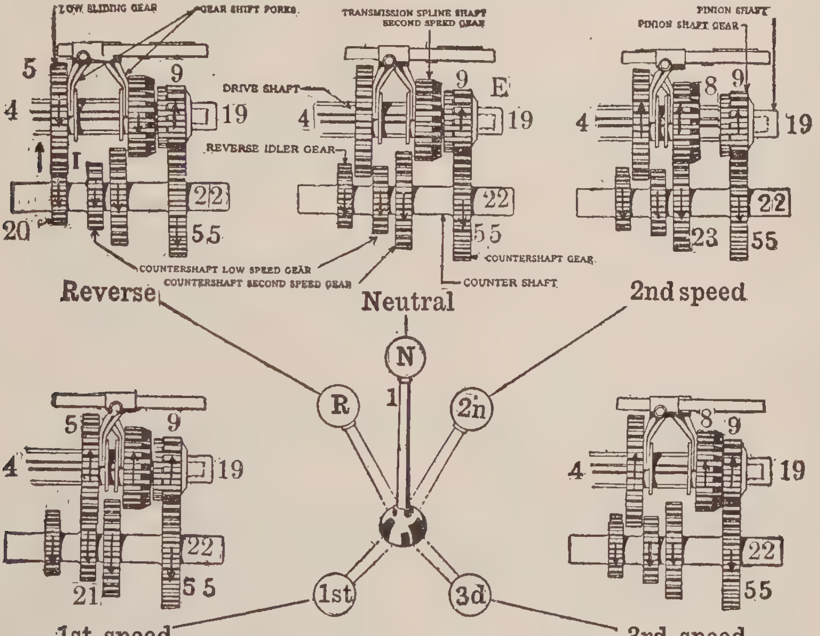


Fig. 22. **First speed:** The drive is from (19) to (9), to (55), to (21), to (5), to the transmission square shaft (4), to the rear axle. (Arrows on the gears indicate the direction in which the gears turn.)

Second speed: (19) to (9), to (55), to (23), to (8), through square shaft (4), to the rear axle.

Third speed, or high gear on direct drive: (19) to (9), to (8), through the transmission square shaft (4), to the rear axle. Note: Gear (8) fits over teeth at the side of gear (9); thus the drive is direct through shaft (4). The shaft (22) and its gears revolve, but no power is transmitted through them.

Reverse: (19) to (9), to (55), to (20), to the free-running idler gear (I) (directly back of an in-mesh with gear 20), to (5) to the transmission square shaft (4), to the rear axle. This idler gear, interposed between (20) and (5), gives a reverse motion to shaft (4)

To start the car: Speed up the engine slightly. Throw out the clutch by pressing the left foot pedal. Shift the gear-shift lever to first speed. Let in the clutch. Speed up the engine to give momentum to the car, and if on a level road, you can then throw out the clutch, quickly shift to third speed, and then let the clutch in. If on a hill, go to second speed instead of third, and then shift to third speed after the car is well under way.

To stop the car: Throw out the clutch, apply the foot brake, and slow the engine down. After the car stops, shift gears to neutral, then let clutch in. In order then to stop the engine, turn off the ignition switch.

Changing gears from a higher to a lower speed, when the car is running, is seldom done, as the speed of the engine is controlled instead, unless in a congested district it is necessary to run very slow, or if taking a hill and the engine pounds. This indicates that the hill is too steep for the power of the engine, and a change to a lower gear should be made at once by throwing out the clutch and shifting the gear lever.

Never shift to a lower gear when running at a fast speed, as there is danger of stripping the teeth from the gears.

Never shift to reverse gear unless the car is at a dead standstill.

Note. The shift gears by shifting ought to be made without a particle of noise if the clutch is thrown out when shifting. If there is noise, then it is usually due to the clutch not being fully thrown out or dragging or spinning, or to the transmission shaft, or to the fact that the transmission shaft is out of line owing to worn bearings.

INSTRUCTION No. 7

THE GASOLINE ENGINE: Principle and Construction

GENERAL EXPLANATION

There are three motive powers for automobiles: (1) The **gasoline engine,** also called an **internal combustion type of engine** because the fuel combusts, or, in other words, the burning of the fuel takes place inside the engine cylinder, between cylinder head and piston, or, in the combustion chamber. This type of engine could use either gasoline, kerosene, or alcohol, but in this treatise we will deal with gasoline as a fuel. (2) The **steam engine is an external combustion type,** the combustion taking place under the boiler, separate from the engine. (3) The **electric motor** derives its power from an electric storage battery.

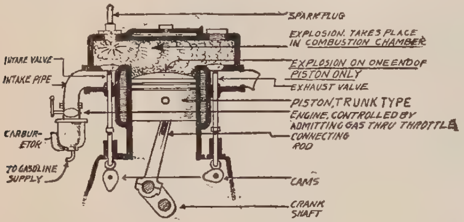

SPARKPLUG
EXPLOSION. TAKES PLACE IN COMBUSTION CHAMBER
INTAKE VALVE
INTAKE PIPE
EXPLOSION ON ONE END OF PISTON ONLY
EXHAUST VALVE
PISTON, TRUNK TYPE
ENGINE, CONTROLLED BY ADMITTING GAS THRU THROTTLE
CARBURETOR
CONNECTING ROD
TO GASOLINE SUPPLY
CAMS
CRANK SHAFT

Fig. 1. The gasoline engine: an internal combustion type.

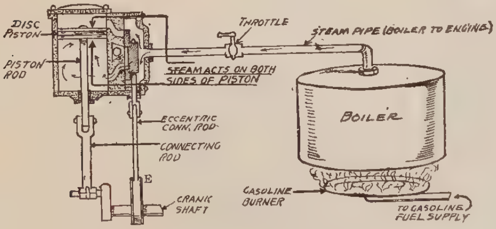


Fig. 2. Steam engine: an external combustion type.

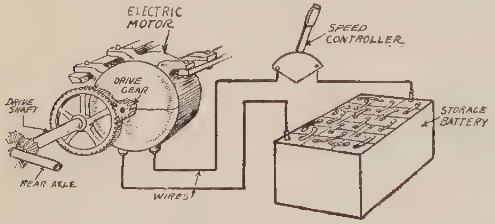


Fig. 3. The electric motor and its source of electric supply: the storage battery.

We shall deal with the gasoline type of automobile. The gasoline engine furnishes the motive power to drive the automobile.

Note. The word motor is often used to designate the engine but if one wishes to be technical and correct it should always be referred to as engine. The word "motor," however (owing to the popular practice), is used in many instances in the book.

Engines for small cars are sometimes made with but one, or perhaps two cylinders (now obsolete). A few motor cars formerly had engines of three cylinders. The majority have four, six and eight. Five-cylinder engines hardly exist. Seven-cylinder engines exist in a special form for flying machine, as the Gnome revolving cylinder type. The twelve-cylinder engine is also coming into prominence; motor boats indulge in engines with as many as twelve to twenty-four cylinders. But whether the engine has one or twenty-four cylinders, the explanation of how it works, or the principle, always remains the same.

All gasoline engines work on practically the same principle. It must be a four-cycle or a two-cycle type (the four-cycle type is dealt with in this instruction). The valve arrangement may be different, but we describe the various types of valves farther on in this instruction. The ignition may be different, but we shall discuss all forms of ignition. We mention this so that when you see an engine with a different ignition or a different valve arrangement, remember the principle is just the same on all engines (except the two-cycle type, which have no valves. The principle of combustion and ignition is similar, however).

When a compressed mixture or charge of gasoline vapor and air is set on fire, it burns with great rapidity and produces intense heat, which **causes the gases to expand and thus** develops the pressure against the head of the piston, which operates the crankshaft of the engine. This combustion is so rapid that it is usually spoken of as an "explosion"; this word is often used, although the word "combustion" is more correct. The intensity of the pressure decreases as the piston travels downward on power stroke, due to the expansion of the gases having more space in which to expand.

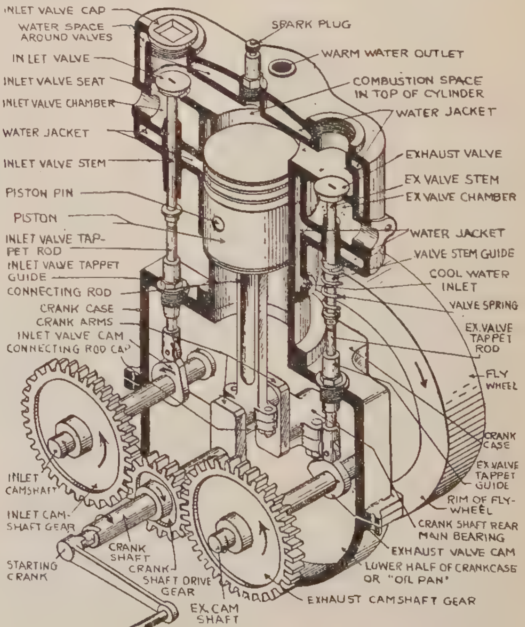


Fig. 4. Parts of a gasoline engine. Cylinder is a "T-head" type with inlet valves on one side and exhaust valves on the other. The inlet valves do not necessarily have to be on the right side. Some cars, for instance, the Locomobile six-cylinder T-head engine, have the inlet valves on the left and the exhaust on the right; whereas the Pierce-Arrow T-head six-cylinder engine is the reverse.

The difference is that an explosion is instantaneous, while the combustion of gasoline vapor and air, although very rapid, is not instantaneous. The combustion takes place within the cylinder of the engine.

One end of the cylinder is **closed,** and the other is **open,** the closed end being called the **cylinder head.** Within the cylinder is a **piston,** sliding back and forth.

The space between the piston and the cylinder head is called the **combustion chamber.**

The back-and-forth motion of the piston in the cylinder is called **reciprocating motion.** In order that it may turn the wheels, this reciprocating motion must be changed to the motion of a wheel revolving on its axle, which is called **rotary motion.** The reciprocating motion of the piston is changed to the rotary motion of the wheels by means of a crank shaft.

The piston is connected to the crank shaft by a connecting rod, so that it moves in and out as the crank shaft revolves. One complete turn of the crank shaft, by which the piston is moved from one end of the cylinder to the other, and back again, is called a "revolution." One-half of a revolution of the crank shaft moves the piston from one end of the cylinder to the other, and this is called a "stroke."

It must be remembered that there are two strokes of the piston to every revolution of the crank shaft: one down-stroke and one up-stroke.

A steam engine is called "double-acting," because the pressure of the steam acts on both sides of the piston.

A gasoline engine is called "single acting," because the pressure acts on only one side of the piston: on the top or side nearest to the cylinder head.

The combustion that causes the pressure or expansion that operates the engine takes place between the cylinder head and the piston, in the combustion chamber. The combustion should be timed to occur so that the greatest pressure is exerted when the piston is nearest the cylinder head. The pressure causes the piston to slide the length of the cylinder, from the head toward the open end.

In a steam engine, the pressure of the steam forces the piston to slide first one way and then the other.

In a gasoline automobile engine the pressure from the combustion acts on only one side of the piston, forcing it to slide only one way. After being forced downward, the piston must be brought upward again, and this is done by a fly wheel attached to the crank shaft. With the downward motion of the piston, the fly wheel starts revolving. When once started, the fly wheel continues to revolve until friction or some other resistance stops it, but before this can happen the pressure from another combustion is again exerted, keeping it going.

The fly wheel being attached to the crank shaft, they revolve together, and because the piston is connected to the crank shaft by the connecting rod it moves with them. The piston, moved downward by the pressure, starts the crank shaft and fly wheel, and then the fly wheel in continuing to revolve moves the crank shaft and piston. Since a gasoline engine does not operate with continuous pressure during its action, the piston first moves the crank shaft and fly wheel, and then the fly wheel and crank shaft move the piston.

Note. Larger fly wheels are used on single-cylinder engines than on multiple-cylinder engines, because there are not as many firing impulses to two revolutions of the crank shaft on a single-cylinder engine. The fly wheel is usually fitted securely to the tapered end of the crank shaft and flange. It must be secure, otherwise a knock would occur.

The fact that the crank shaft of a gasoline engine must first be turned by hand or by an electric motor or mechanical device, in order to start the engine, is due to the fact that a charge of gas must first be drawn into the cylinder by the suction stroke, and then compressed. After the gas is once ignited, then the force of the power stroke, and momentum of the fly wheel will carry the crank shaft and piston through the other three strokes until the power stroke occurs again.

Before there can be a combustion of mixture in the cylinder, the mixture must be drawn into the cylinder, through the inlet valve.

When in the cylinder, the mixture must be prepared, so that it ignites, burns and expands with the greatest possible rapidity and heat.

After the mixture has been burned, the useless gases must be removed, or exhausted from the cylinder, to make room for a fresh charge of the mixture.

These successive events must occur in their proper order, for if any one of them fails, or it is not performed properly, the succeeding event cannot occur, and the engine will stop running. **These events are called a cycle.**

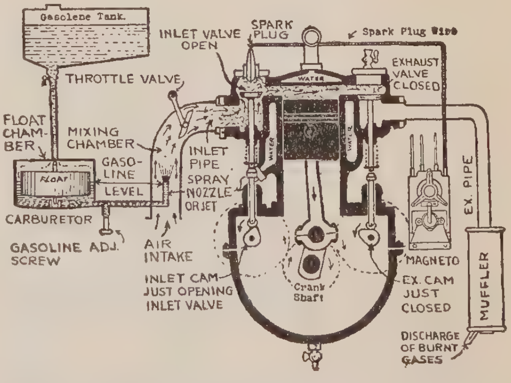


Fig. 5. In this view we are looking at the end of the engine. The illustration is exaggerated in order to simplify the explanation. Imagine the end cylinder cut in half. The object is to illustrate how the gasoline from the tank flows to the carburetor and fills the float chamber until the float needle cuts off the flow. The gas mixed with air, is then drawn into the cylinder by the suction of the piston on the **suction stroke.** During this suction the intake valve must be opened by a cam (the nose-shaped affair at the bottom of the valve lifter) to permit gas to enter the cylinder.

After the cylinder is filled with gas, which is the purpose of the suction stroke, the intake and exhaust valves are closed and the piston, on its up stroke (**compression stroke**), compresses the gas. At the highest point of compression, the gas is ignited by the spark at the points of the spark plug and the piston is forced down with considerable force; this is called the **explosion stroke.** As the piston travels up again the burnt gas is expelled through the exhaust valve which should open at this time and permit the burnt gas to pass out through the exhaust pipe and muffler. This fourth and last stroke, which completes the operation is called the **exhaust stroke.**

The Four-Cycle Principle

There are two distinct cycle principles; generally spoken of as **"four-stroke cycle"** and **"two-stroke** cycle" principles. The two-cycle engine is generally a small marine type of engine and will be dealt with farther on.

The four-cycle engine is the type used for automobile work. Therefore we still deal with this type throughout the automobile instruction.

The cycle is thus composed of: (1) the drawing into the cylinder of the mixture (Fig. 6) below; (2) the compression of the mixture (Fig. 7); (3) the burning or ignition of the mixture and the forcing downward of the piston by the pressure produced by the burning of the mixture (Fig. 8); (4) the removal of the burned and useless gases left after the combustion (Fig. 9).

The cycle is performed during two revolutions of the crank shaft, or, what is the same thing, four strokes of the piston.

The first event occurs while the piston makes a **downward stroke,** during which the cylinder is sucked full of the mixture, just as a similar stroke of a pump or syringe sucks in a liquid. This is called the **inlet stroke or suction stroke.**

The next stroke of the piston is an **upward stroke,** during which the mixture sucked into the cylinder is prepared by being compressed, and at the end or top of this stroke it is set on fire, or ignited. This is called the **compression stroke.**

When the compressed gas is ignited, the pressure from the combustion forces the piston to make a downward stroke. This is called the **power stroke.**

The next upward movement of the piston pushes the burned and useless gases out of the cylinder. This is called the **exhaust stroke.**

These four strokes occur in each cylinder during two revolutions of the crank shaft and are repeated over and over again in each cylinder as long as the engine continues to run.

On a six, eight, and twelve-cylinder engine, in order that the four events occur in each cylinder during the four strokes they "lap" one into the other. Thus we have two cylinders on power for certain periods of time.

In principle the gasoline engine is like a gun. In a gun the shot is fired by exploding powder behind it. In a gasoline engine we explode gasoline behind the piston in exactly the same way.

There are some differences, of course. The charge goes out of the gun, and that is the end of it. But in a gasoline engine, after the explosion drives the piston before it, in order to get any work out of the machine, this piston must come back and a new charge must be exploded behind it. The burned gases and heat must be disposed of, and all of these things must be done over and over again very quickly, at exactly the right time.

Explanation of the Four Strokes

Valves are arranged to open and close at the proper time to admit fresh gas and to let out the burned gas, and the positions of the piston, valves, and cams for each function are shown in Figs. 6 to 9. Note the direction in which the cams (1 and 2, Fig. 6) are turned by the cam gears, which are driven by the crank-shaft gear.

Cams on a gasoline engine are for the same purpose as an eccentric (E), (Fig. 2, page 30), on a steam engine—to open and close the valves.

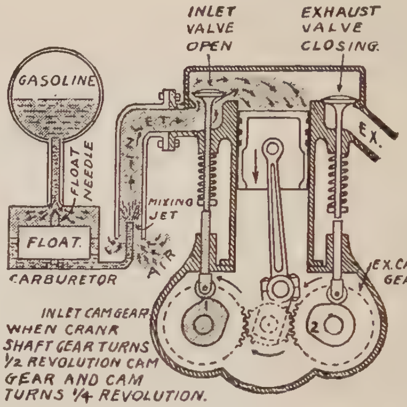


Fig. 6. Showing the suction stroke—down. The charge of gas is being taken into cylinder from the carburetor by the suction of the piston through the open inlet valve.

Note that the inlet valve is opened by inlet cam. Note direction of travel of cam. This stroke is also called "admission" or "inlet" stroke.

Note. The figures on the cams correspond to the figures on the cams in Fig. 10, which are intended to show the movement in degrees at each stroke of the piston.

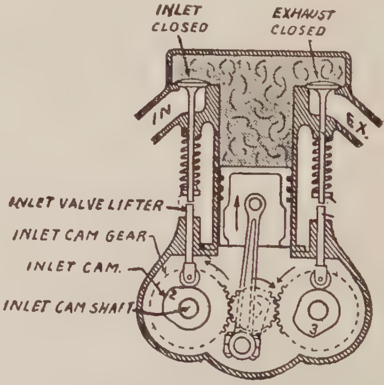


Fig. 7. Compression stroke—up. Both valves are closed because the nose of the cam is not raising either of the valves. Gas is being compressed as the piston travels up. Note the direction of travel of the cam.

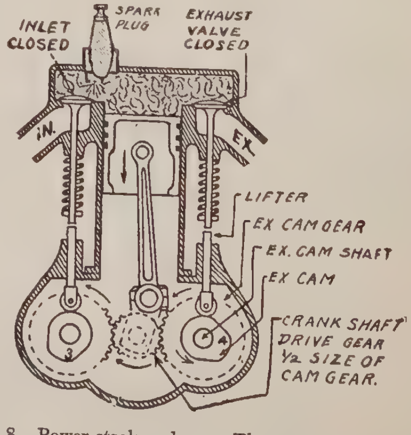


Fig. 8. Power stroke—down. The spark is now occurring, therefore the compressed gas is combusting and expansion force is being exerted against the piston head, thus forcing it down with great pressure. In actual practice, the spark occurs before combustion takes place. Both valves are closed. This stroke is also called the "explosion" or "working" stroke.

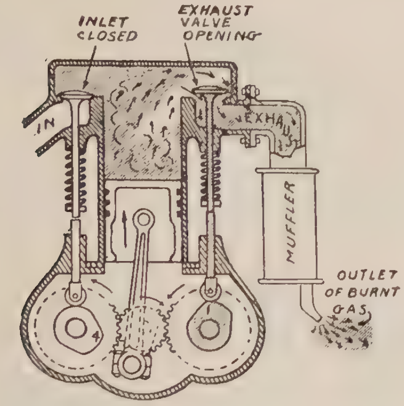


Fig. 9. Exhaust stroke—up. The exhaust-valve cam is now raising the exhaust valve which is open, thus permitting the burned gas to be forced out of the exhaust pipe through the muffler.

When the piston reaches the top of the exhaust stroke the piston will have completed the four strokes, or two crank-shaft revolutions, and the cam-shaft one revolution.

The next stroke is the suction stroke again. These four strokes are repeated over and over again as long as the engine runs.

The above explanation of the four strokes is based on a T-head type of engine, supposed to be cut in half.

The "L" head uses but one cam shaft. The view is from the front of the engine. Thus there is but one inlet and one exhaust cam for each cylinder, just the same as a T- or "round"-head cylinder or any type of four-cycle engine. The principle is identically the same.

Note. A "dual-valve" engine has four valves per cylinder. This is explained farther on.

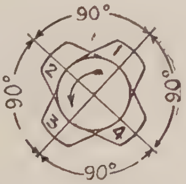


Fig. 10. Illustrates the movement of the cam. Note that the cam moves 90 degrees, or one-fourth revolution each time the crank moves 180 degrees, or one-half revolution.

When the crank shaft makes two revolutions, or 720 degrees to complete the four-cycle revolution, then the cam shaft and cam would be making one revolution, or 360 degrees, because the driven cam gears are twice the size of the driving crank-shaft gear.

The figures 1, 2, 3, 4 on the cams correspond to the cams in Figs. 6 to 9, and are intended to represent the movement in degrees at each stroke of the piston.

Control of Speed of Engine

After the engine is started with the starting crank (self-starters will be explained farther on), the speed of the engine is controlled by opening and closing the butterfly throttle valve of the carburetor which, when opened, admits gas to the cylinder. The more gas admitted, the stronger the compression, therefore the greater the explosive force, and hence more speed. Closing this valve reduces the speed. The gas, of course, is admitted through the inlet valve during the suction stroke.

The opening and closing of the throttle is regulated by hand (Fig. 11), by means of the throttle lever on the steering wheel, or by a foot pedal connected with the same throttle lever, and called an "accelerator."

The carburetor is connected to the inlet manifold by the inlet pipe, and the gasoline flows to the carburetor from the supply tank through a small brass or copper pipe, called the **fuel pipe.**

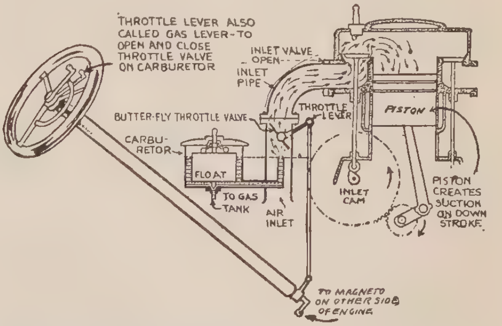

THROTTLE LEVER ALSO CALLED GAS LEVER-TO OPEN AND CLOSE THROTTLE VALVE ON CARBURETOR
INLET VALVE OPEN
INLET PIPE
BUTTER-FLY THROTTLE VALVE
THROTTLE LEVER
PISTON
CARBURETOR
FLOAT
TO GAS TANK
AIR INLET
INLET CAM
PISTON CREATES SUCTION ON DOWN STROKE
TO MAGNETO ON OTHER SIDE OF ENGINE

Fig. 11. Illustrating the principle of opening and closing the throttle valve in the carburetor by the throttle lever on the steering wheel.

Pure gasoline vapor will not burn, but must be mixed with air before it can be used to develop pressure. The mixing of gasoline vapor and air in the proper proportions is called "carburetion." To give the best results, the mixture of gasoline vapor and air must always be in correct proportion. (This is explained in the carburetor instruction.)

There is a passage through the carburetor into which the air is drawn as the piston makes the suction stroke. The liquid flows to the carburetor and is brought into contact with the current of air. The gasoline turns to vapor, and is absorbed by the air, the mixture being sucked into the cylinder on the suction stroke.

The quantity of mixture that is drawn into the cylinder during one suction stroke is called the **charge.**

If the speed of the engine is governed by the amount of gas drawn into the cylinder through the butterfly throttle valve of the carburetor and the inlet valve on the engine, it is clear that if high speed or more power is desired, it is necessary that all of the mixture possible be drawn into the cylinder through the inlet valve, and that the inlet valve must open at the exact time and open wide enough to permit a full charge being drawn in.

As the inlet valve is mechanically operated, the cam must be adjusted (by having the inlet cam gear properly meshed with the crank-shaft gear) so that it will open the valve promptly as soon as the sucking action of the piston commences, which it is just beginning to do in Fig. 6. Note that the cam is just starting to raise the inlet valve.

If the inlet valve does not open soon enough, the piston will have made part of its stroke before the charge begins to enter; if it opens too soon, part of the burned gases from the previous power stroke will be pushed into the carburetor. If it closes too soon, the cylinder will not get a full charge; if it closes too late, part of the mixture will be pushed out of the cylinder on the compression stroke.

The setting of the cam gear (which controls the position of the cams) with the crank-shaft drive gear, is termed **valve timing** and is treated more fully under the instruction on that subject.

If all the openings into the cylinder, such as the exhaust valve, the spark plug, piston rings, relief cock, etc., are not tight, air or gas will be sucked into the cylinder through them at the same time that the charge enters through the inlet valve, and this would destroy the proportions of the mixture.

As the piston travels up on compression stroke, the gas is tightly compressed until it occupies only the space between the inside of the cylinder and the head of the piston, and it is the force or expansion from this compressed gas, when ignited, at the highest point of compression, that the power of a gasoline engine depends upon.

If the valves are not closed tight, or if there are any leaks by which this gas can escape, it is clear that the gas will not be compressed as much as if there were no leaks. The result is a weaker power stroke.

When an engine is running with the throttle wide open, as, for instance, on a steep hill, the compression is greater, because more gas is drawn into the cylinders.

If the engine is running on a level, with the throttle partially open, then the compression is less.

Thus it is clear that if the space between the cylinder and piston head is, say, one inch, the more gas that is compressed in this space, the greater the pressure.

The greatest power is obtained from a given volume of compressed gas when it is ignited at its highest point of compression, which is at the top of the compression stroke and just at the moment when the piston is over center in the direction of rotation.

It is the expansion force of the ignited gases, caused by the heat when combustion takes place, that produces the pressure against the head of the piston. It is, therefore, clear that as the piston travels down on the power stroke, this expansion force becomes less and less, because it has more space in which to expand. Hence the importance of having the spark occur at the correct time and also of having the valves open and close at the proper time.

Toward the end of the power stroke, and usually before the piston reaches the bottom of its power stroke, the **exhaust valve is set to open.** There is still pressure in the cylinder, and when the **exhaust valve is open,** this pressure will cause the gases to begin to escape.

As the exhaust stroke is an **upward stroke** of the piston, the piston will push out through the exhaust valve all of the burned gases that do not escape by their own pressure.

If all the burned gases are not pushed out of the cylinder, it will prevent a full charge of fresh gas from being drawn in, which will cause a weak mixture and a weak explosion.

The exhaust valve closes as the piston reaches its upmost point, or a little after, the inlet valve opening as the exhaust valve closes.

Back pressure, caused by the muffler or obstructions in the exhaust pipe, will prevent the burned gases from escaping as freely as they otherwise would, and all may not be pushed out by the time that the exhaust valve closes.

The exhaust valve and its seat are exposed to the full heat and flame of the burning mixture, and are more liable to warp or pit than the inlet valve. It must be watched, and if there does not seem to be perfect compression when the engine is cranked, the probability is that it needs grinding to seat it properly. The exhaust valve thus requires more grinding than the inlet valve.

A proper mixture will be entirely burned before the exhaust valve opens. An **improper mixture** that burns slowly may still be burning when the exhaust valve opens, and will heat the exhaust pipe and muffler so that the pipe may become red hot. Such a mixture wastes fuel, and may result in a fire. It may be corrected by making a correct adjustment of the carburetor and spark, which will be explained later on.

Ignition: When the throttle is being opened and the engine begins to speed up, it is necessary also to "advance" the time of ignition; in other words, to cause the spark to occur earlier than if engine is running slow.

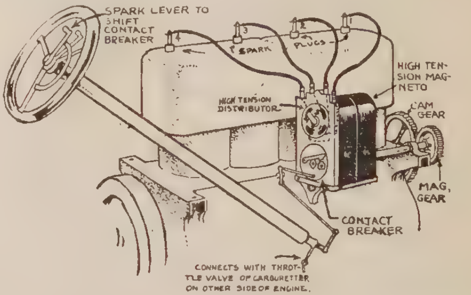

SPARK LEVER TO SHIFT CONTACT BREAKER
4
3
2
1
SPARK
PLUGS
HIGH TENSION MAGNETO
HIGH TENSION DISTRIBUTOR
CAM GEAR
MAG. GEAR
CONTACT BREAKER
CONNECTS WITH THROTTLE VALVE OF CARBURETTER ON OTHER SIDE OF ENGINE.

Fig. 12

A spark lever is usually placed on the steering wheel along side of the throttle lever, which is connected by a rod and bell crank to the contact-breaker box on the magneto, or, if a coil and timer is used, to the commutator or interrupter.

When the spark lever is moved, it also moves the contact-breaker box on magneto, or commutator, which causes the spark to occur "late" or "early," according to the movement of this lever.

The proper time for the ignition of the mixture is at the top of the **compression stroke**—when the gas is compressed to the highest point.

Up to this point we have supposed that the spark occurs exactly at the moment when the piston reaches the top of the compression stroke. Now, this would be, in fact, the correct time, were it not for the fact that the gas takes quite an appreciable time to combust and expand after being ignited, an interval, let us say of a fraction of a second. Thus before the gas has had time to burst into a full combustion and expansion, the piston, on account of its great speed (suppose it is traveling at 1,500 revolutions per minute), will have traveled part of the way down the cylinder before being affected by it. This means part of every power stroke wasted.

The advance of spark: The remedy for this is to make the spark occur earlier; that is, to make it occur just before the piston has completed, or reached the top of the compression stroke, so that the full burst of explosion and the piston arrive simultaneously at the top of the stroke, or just as the piston is slightly over the top of "dead center." This is called "advancing the spark."

The retard of spark: Suppose the engine is now running at only half the speed, say 700 revolutions per minute. During the exploding or igniting period, which we assumed to be a fraction of a second, and which remains the same, the piston, with its speed now reduced, has not time to travel so far, and the spark therefore need not be so much advanced.

Again, when the engine runs dead slow, say at 100 revolutions per minute, which is slow for an automobile engine, the spark requires hardly any advance at all. So that we see, at once, that the **faster** the engine runs the more the spark must be **advanced,** and that the **slower** the engine runs the less it need be advanced, or, to express it in a more usual way, the more the spark must be **retarded.**

To "advance" or "retard" the spark, means that the spark is made to occur earlier or later relative to the position of the piston. It does not mean that the spark is made to occur more frequently or less frequently. (This subject is treated more fully under "Ignition Timing.")

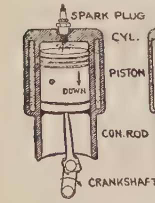


Fig. 13

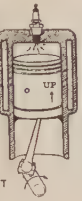


Fig. 14

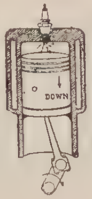


Fig. 15

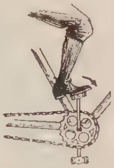


Fig. 16

Fig. 13. Here the explosion is occurring at just the right time, at the moment when the piston starts downward, securing the full length of the power stroke.

Fig. 14. Here the explosion is occurring too early, causing the piston to push backward on the crank shaft, applying power in the wrong direction. While a single-cylinder engine would "kick back" and stop, in a four-cylinder engine the remaining three cylinders would have this resistance to overcome.

Fig. 15. Here the spark is occurring too late, wasting the top or best part of the power stroke.

Fig. 16. The piston is like the pedal of the bicycle. It should receive the push when it first starts downward. (Illustration through courtesy of K. W. Ignition Co.)

The point to bear in mind is that the spark must be made to occur so that the greatest expansion takes place just the moment the piston is over the top of dead center. In order to give the gas sufficient time to ignite, so that complete combustion will occur at this point, the spark is "advanced" or "retarded," according to the speed of the engine, as explained above.

Another factor to be considered is the electrical apparatus producing the spark. For instance, an ignition system using a vibrator coil would require more advance than a closed-circuit type of interrupter, because the action of the vibrator-coil system is slower. This condition is termed "electrical lag."

If the spark is advanced too much, all of the mixture will have been burned before the piston reaches its upmost point, so that it will be necessary for the fly wheel to force the piston upward against the pressure until it gets to its upmost point. This strains the engine, and causes a sound that is called an **"ignition knock"**; a hard, metallic sound.

The knocking is not always detected easily by the novice, who will probably confuse it with other sounds on the car, but when once it has made itself evident, the **spark should instantly be retarded** until the knocking ceases. The strains set up in an engine which is allowed to knock may seriously damage connecting rods and cranks.

It will be seen from the foregoing that in addition to controlling the speed of the engine through the gas throttle lever, it may also be controlled by advancing or retarding the spark, the speed of the car changing accordingly.

An engine should not be slowed by retarding the spark. If it has appeared to the reader in the last few paragraphs that it is possible to slow an engine by retarding the spark, let him at once understand that this is the last method by which it ought ever to be done. It is not only unscientific, but is also wasteful of fuel and produces extra heat, and causes rapid pitting of the exhaust valves, the gases passing through them in an incandescent form.

The correct method of slowing down or increasing the engine speed is to shut or open the throttle valve, which is situated between the carburetor and the inlet valve, by which the amount of fuel supplied to the engine may be regulated. Then as the engine varies its speed, slower or faster, the spark should be retarded or advanced accordingly.

The rule, therefore, is to let the engine speed follow the throttle and to make the spark follow the engine speed; or, to put it in another way, in order to drive economically, the throttle valve must be kept closed as much as possible and the spark advanced as far as possible, short of knocking or of a tendency to knock.

Such subjects as ignition, carburetion, cooling, fuel systems, lubrication, etc., will be taken up farther on under their respective headings. We are still dealing with engine construction, and must, for the present, adhere to this branch of the subject.

INSTRUCTION No. 8

ENGINE PARTS: Assembly; Types

ASSEMBLY OF PARTS

The stationary parts are: crank case, upper and lower half, bearings, cylinders, exhaust and inlet ports, valve caps, compression or relief cocks, water-cooling pipes, carburetion and part of the ignition systems, exhaust and inlet manifolds.

The moving parts are: crank shaft, connecting rods, pistons, piston rings, piston pin or wrist pins, cams, cam shaft, timing gears, crank-shaft gear, valves, valve plungers or tappets or lifters, fly wheel.

In order to enable the reader thoroughly to grasp the meaning and purpose of the parts, we will build up a four-cylinder T-head type of engine as shown below. The illustrations are not drawn to scale, nor are they technically correct, but will serve the purpose of explaining the location of the parts of an engine.

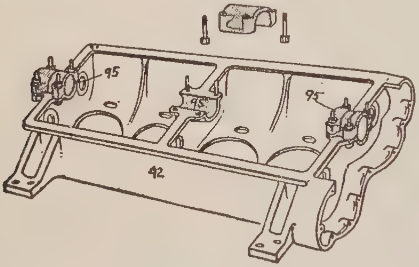


Fig. 1. Main bearings. Upper half of crank case upside down.

Crank case: A reference to Fig. 1 will show an aluminum crank case, upper-half part, which we lay on the floor, upside down, so that we can see the bearings (95).

Note. The S. A. E. designates the lower part of the crank case as the "oil pan" when containing no bearings. If it contains bearings, it is termed the lower crank case. The S. A. E. further designates crank cases as of the "split type" and the "barrel type." In the barrel type the crank shaft is removed from one end of the crank case, the bearing caps being removed through hand-hole plates. The type shown here, and most used, is the "split type" with the bearings in the upper half.

The main bearings are made in halves and are usually made of bronze or white metal and are termed "bushings," instead of bearings, when removable or renewable. The bushings are fitted into bearing caps and the upper part of the bearing.

Shims (thin paper or metal strips) are placed between the two halves of the bearing, so that when wear occurs, a "shim" can be taken out and the lost motion taken up. See Index, under "Shims."

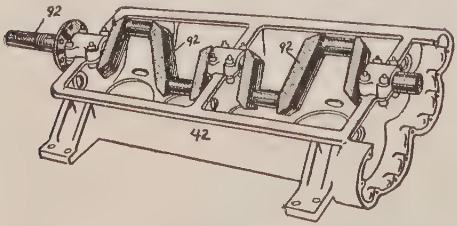


Fig. 2. Crank shaft. Upper half of crank case upside down.

The crank shaft (92) (Fig. 2) will now be fitted in the bearings. The bearing caps are placed over the bearing surface of the crank shaft, and the bearing cap nuts are tightened.

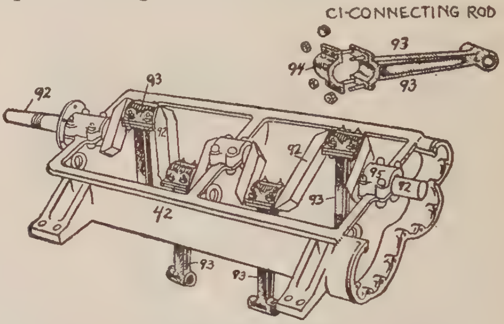


Fig. 3. Connecting rods fitted to crank shaft.

The connecting rods (93) (Fig. 3) are now fitted to the crank shaft. The lower half of the large end of the connecting rod, called the connecting-rod cap (94), is removed, so that it can be fitted to the crank shaft. Shims are inserted, so that it works free on the crank shaft. Then the nuts are drawn good and tight, so that there will be no lost motion. If there was lost motion a knock or pound, which would cause wear, would result.

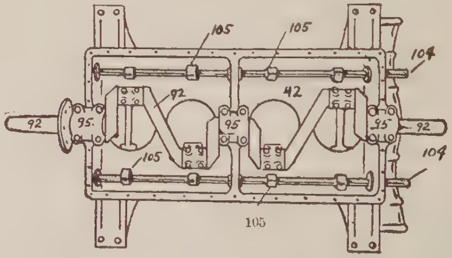


Fig. 4. Cam shafts.

The cam shaft (104) (Fig. 4) with the four cams (105, nose-shaped) is now fitted to its bearings. In this engine there are two cam shafts: one with four cams for raising the four inlet valves, and the other, with its four cams (105), to raise the four exhaust valves.

The cams are placed with their noses equi-distant, so that when they revolve they will raise the valves, by pushing them up with their nose, at a given time. The timing gears which operate the cam shafts will be explained farther on.

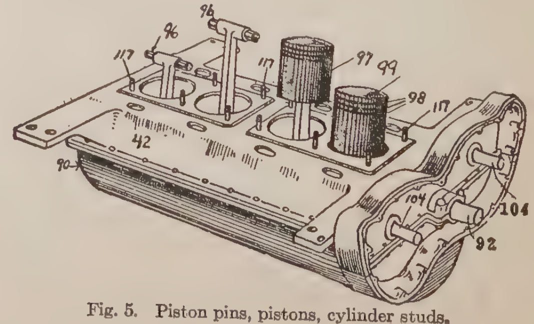


Fig. 5. Piston pins, pistons, cylinder studs.

The crank case is now turned right side up, after having fitted to it the lower half of the crank case (90). This lower half holds the oil, which the crank shaft splashes in and is called the oil pan (lubrication systems explained farther on).

The piston or wrist pin (96) (Fig. 5) in the small end of the connecting rod is shown here. This holds the piston to the end of the connecting rod (details of each part will be explained farther on).

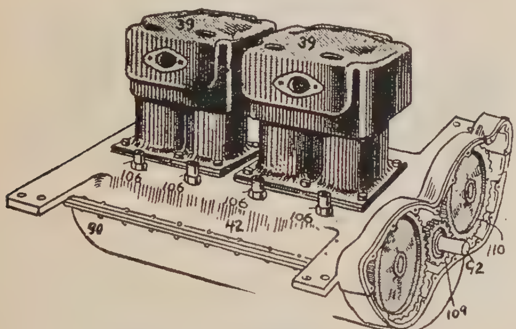


Fig. 6. Cylinders, valve-plunger guides, timing gears.

After the four pistons are fitted to the connecting rods, the cylinders (39) (Fig. 6) are fitted down over the pistons, care being taken not to break the piston rings.

The cylinders (39) are held to the crank case by nuts fastening to **studs** (117) (Fig. 5).

The valve-lifter guides (106) (Fig. 6) are fitted in holes in each side of the crank case so that they will come in line with the exhaust valves on one side of the cylinders, and with the inlet valves on the other side.

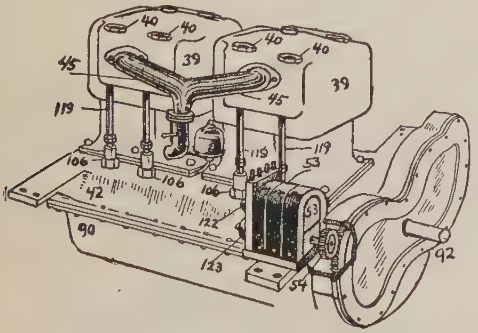


Fig. 7. Inlet valves, inlet manifold, carburetor, magneto.

Valve lifters, or tappets, are now fitted through these valve-lifter guides which raise the valves through the action of the cams.

The gear for driving the timing gears, called the **crank-shaft timing gear** (109) (Fig. 6), is keyed or threaded to the end of the crank shaft (92); this gear drives the two timing gears (110 and 111).

The cam-shaft timing gears are keyed to the cam shaft (104) (Fig. 4); one gear and shaft to operate the inlet valves (119) (Fig. 7), and the other gear and shaft to operate the exhaust valves (120) (Fig. 8). The gear-case cover is placed over the gears.

The inlet valves (119) are placed in their seat by passing them through the inlet valve-cap holes (40) (Fig. 7).

The exhaust valves are placed in position, on the opposite side of the cylinders, in the same manner.

The inlet manifold (45) is now bolted to the inlet-valve side of the cylinders, and the carburetor is connected to it.

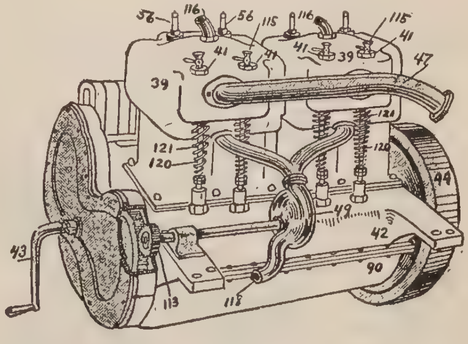


Fig. 8. Exhaust valves, manifold, fly wheel, pump, etc.

The exhaust manifold (47) (Fig. 8) is bolted to the exhaust side of the cylinders, and is connected with the muffler at the rear of the car, by the exhaust pipe (47).

The exhaust-valve caps (41) and the inlet-valve caps on the opposite side are now screwed in place—tightly.

The priming cups, also known as "compression" or "relief cocks" (115), are screwed into the exhaust-valve caps.

The spark plugs (56) are screwed into the inlet-valve caps or in the center of each cylinder, but usually over the inlet valves.

The fly wheel (44) and **starting crank** (43) are fitted to opposite ends of the crank shaft. By referring to Fig. 3 (92), the reader will note that the end of the crank shaft tapers, and a flange is also turned on this crank shaft. The fly wheel fits to this taper and bolts to the flange, as there must positively be no lost motion.

The magneto (53) (Fig. 7) (a high-tension magneto is used for ignition in this example), is bolted in place on a brass base provided for it, on the side of the engine. An extra gear (which will be explained farther on) is operated by the cam shaft and drives the magneto, which generates electricity. The electricity is distributed to the four spark plugs (56) at certain periodical times by the distributor on the magneto (122) (Fig. 7).

Wires are now connected through a switch to the magneto. This switch is to control the ignition circuit.

The circulating pump (49) is connected to the water jacket of the cylinders. The gear (113), driven by the cam gear, drives the pump, and keeps the water in constant circulation, which keeps the cylinders from getting too hot (not over 170 to 180 degrees Fahr.). We now connect rubber hose to metal pipes on the radiator and also to our pump (49), and belt up our fan, which is run from the same shaft. The radiator is filled with water by unscrewing the radiator cap.

The gasoline fuel pipe from the gasoline or fuel tank is now connected with the carburetor.

TYPES OF ENGINES

As previously mentioned, there are several types of engines, all of which work on the four-cycle principle. In order that the reader may more clearly understand, we will give an outline illustration of some of the different types of engines in general use.

The type of engine used more than any other for automobile work is the four and six, and the eight and twelve "V"-cylinder type of engine.

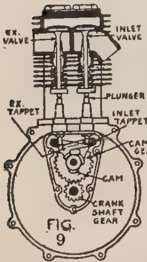


FIG. 9

SINGLE CYL. VERTICAL

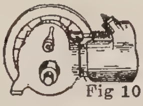


Fig 10

SINGLE CYL. HORIZONTAL

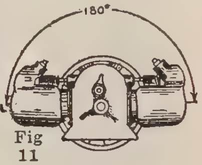


Fig 11

2 CYL. OPPOSED-HORIZONTAL

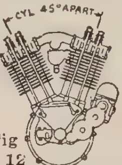
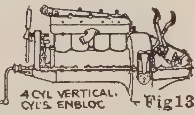


Fig 12

2 CYL "V" TYPE



4 CYL VERTICAL. CYL'S. ENBLOC

Fig 13

Fig. 9. A single-cylinder vertical type of engine, with air-cooled cylinder. Valves are both on the side and mechanically operated. There are two flywheels with a crank pin between them. The flywheels run inside of the aluminum crank case. This type of engine is used on motorcycles, cycle cars, and railroad light cars.

Fig. 10. A single-cylinder horizontal type of engine, with water-cooled cylinder. Formerly used on light-weight automobiles. Seldom used; valves mechanically operated.

Fig. 11. A double-cylinder opposed type of engine, with water-cooled cylinders and mechanically operated valves. Note that the cylinders are 180° apart. Cylinders are of the "L"-type. The crank shaft is also of the 180° type.

Fig. 12. A twin-cylinder "V"-type of engine, with cylinders placed 45° apart. Cylinders are air-cooled. Valves are mechanically operated from overhead. The cylinder is of the "round" type. This type of engine is used on motorcycles and cycle cars.

Fig. 13. A four-cylinder, vertical type of engine, with transmission and clutch in one housing joined to the engine—called a "unit power plant." This engine is suspended in a frame at three points; it would therefore be called a "three-point suspension" type of power plant. Valves are all on one side of the "L"-type cylinders.

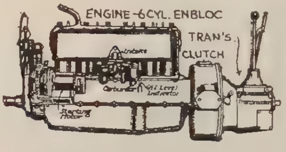


Fig. 14

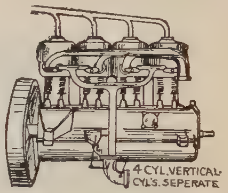


Fig. 15

Fig. 14. A six-cylinder "unit power plant." Transmission and clutch case join the engine. Cylinders are cast together, or "in block."

Fig. 15. A four-cylinder engine with cylinders cast separate. All valves are on one side; hence "L"-type cylinders.

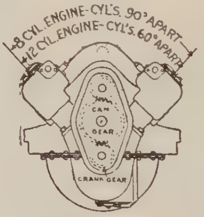

8 CYL. ENGINE-CYL'S. 90° APART
12 CYL. ENGINE-CYL'S. 60° APART
CAM
GEAR
CRANK GEAR

Fig. 16. Eight-cylinder "V"-type engine, with cylinders placed at an angle of 90° apart. One cam gear operates the valves on both sides of the "L"-shaped cylinders. There are four cylinders on each side, usually "in block." The crank shaft is a four-cylinder type (180°) between crank throws, with two connecting rods to each crank pin.

THE AUTOMOBILE, TRUCK, AND TRACTOR ENGINE[1]

The Automobile Engine

The 4, 6, 8, and 12-cylinder engine is used for automobile work. The "four" and "six" are used most.

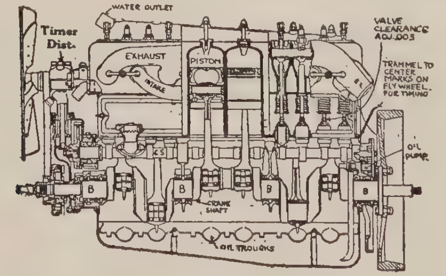


Fig. 17

Valves are placed on the side or overhead. **Ignition** is usually coil and battery, using an interrupter and distributor. A **generator** supplies current for charging the battery, also for lights and ignition. A **battery** supplies current for lights, ignition, and starting the motor. **Speed** of automobile engines varies from 150 to 2,000 r. p. m. On some few engines the speed is as high as 3,000 r.p.m. The engine shown in Fig. 17 is a 6-cylinder engine with a 3⅞″ bore by a 5″ stroke, with valves on the side. **Control of speed** is by a hand-throttle lever and foot accelerator. A governor is never used.

The Truck Engine

Usually a 4-cylinder engine is used on trucks, for reasons stated in the instruction on "Trucks." **Valves** are usually on the side. **Ignition** is usually a high-tension magneto. On the Buda truck engine (Figs. 18, 19), the Eisemann magneto with automatic advance is used. The speed of the engine is comparatively slow (950 to 1,000 r.p.m.). Speed is governed by McCann or Pierce governor on this

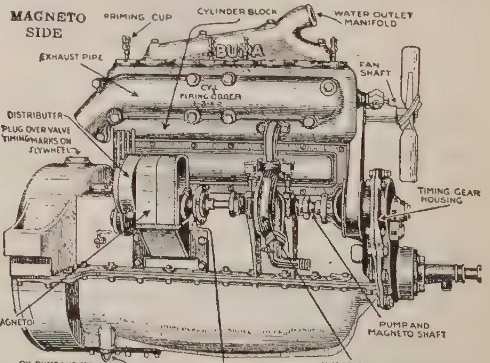


Fig. 18. Magneto side.

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[1] The truck and tractor engine is further explained under the "Truck and Tractor" Instruction.

engine (see Index under "Governors"). The **stroke of the piston** is usually long, and in this instance, the bore is 4½" by 6" stroke or 32.4 H.P. (S.A.E.), or 52 actual H. P. **Truck speed** is from 9 to 17 m.p.h. **Starting** is usually by hand-crank in connection with an "impulse starter" (see Index). **Control of speed** is by hand throttle and accelerator.

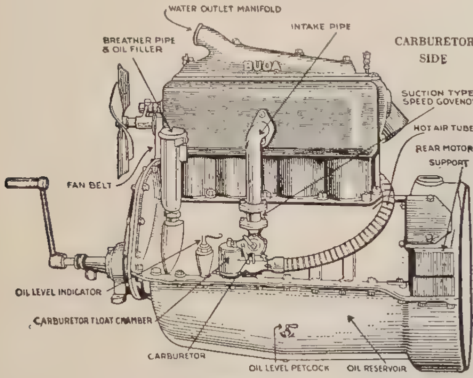

Fig. 19. Carburetor side.

Airplane Engine

Many airplane engines are 8 or 12-cylinder, "V"-type, and in most instances use the overhead type of valves. The "V"-type cylinders give a maximum of power at a minimum weight. **Ignition** is by means of a high-tension magneto or coil-and-battery ignition. The **speed of the engine** at flying speed is 1,400 to 1,700 r. p. m.

The Tractor Engine

Usually a 4-cylinder engine is used on tractors, for reasons stated in the instruction on "Tractors." **Valves** are overhead or on the side, and some use the overhead "dual" valve system. The **stroke** is usually long, the average being 6" stroke by 4½" bore. The speed of the engine is controlled by a **governor** (Fig. 20), which is a centrifugal ball-type, operating through levers to the carburetor throttle (T). The governor is used to maintain a uniform speed and to prevent the engine from "racing" if the load is suddenly released, or from "stalling," if the load is suddenly applied. **Speed of the engine** is usually 950 r. p. m., which is usually maintained for long periods of time while working. The **speed of a tractor** is very slow, the average being about 2½ or 3 miles per hour on high speed.

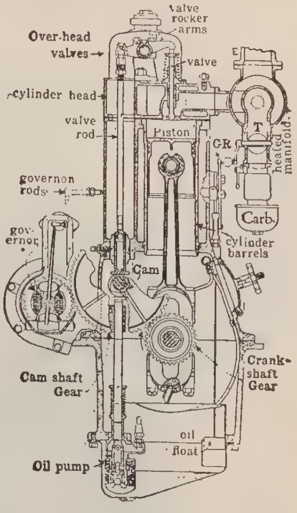

Fig. 20

Ignition is usually provided by means of a high-tension magneto, in connection with an "impulse-starter," which is used to facilitate starting when cranking the engine.

Carburetion is secured by means of gasoline to start with and kerosene to run on after the engine is heated up. The heating of fuel around the intake manifold from exhaust gases is very important when using kerosene.

Cylinder sleeves, or barrels, are used on many tractor engines. They consist of removable sleeves or barrels (Fig. 20) placed in cylinder blocks, which, in case of wear or accident, can easily be replaced with new ones. See also, Index, under "Cylinder sleeves."

The reader can now compare the relative difference between the four engines and thus note, that while the construction may vary, the same underlying principles apply to each.

TWO EXAMPLES OF AUTOMOBILE ENGINES

An example of an engine with valves-on-the-side operated by one cam shaft on the side is the Overland "4," as shown in Fig. 21.

An example of an engine with valves-in-the-head operated by one cam shaft on the side is to be seen in Fig. 22, showing a cross-sectional front view of the Nash model 681, 1919, six-cylinder engine.

The clutch and transmission (not shown) are mounted with the engine as a single-unit power plant.

Specifications of the Nash engine (Fig. 22) are as follows:

Engine: 6-cylinder, in-block, high-speed, valve-in-head type, operated by push rods on the side.

Cylinder bore, 3¼", stroke, 5".

Main bearings are die-cast babbitt, brass backed; three in number; diameter and length: front, 2¼" x 2¾"; center, 2¼" x 2¾"; rear, 2¼" x 2¼".

Crank shaft, forging steel, double-heat treated, 2¼" diameter.

Lubrication, gear pump, driven by spiral gears from cam shaft. Circulating splash system and force feed to main bearings, oil fed to oil pans, in which the lower ends of the connecting rods dip. On later models of this engine a "force"-lubrication system is used.

Valve adjustment: The clearance for valve adjustment is made between the valve stem and its point of contact with the rocker arm. The clearance is adjusted to .015". Loosen the push-rod lock nut and move the ball-adjusting nut either up or down until the correct clearance is obtained.

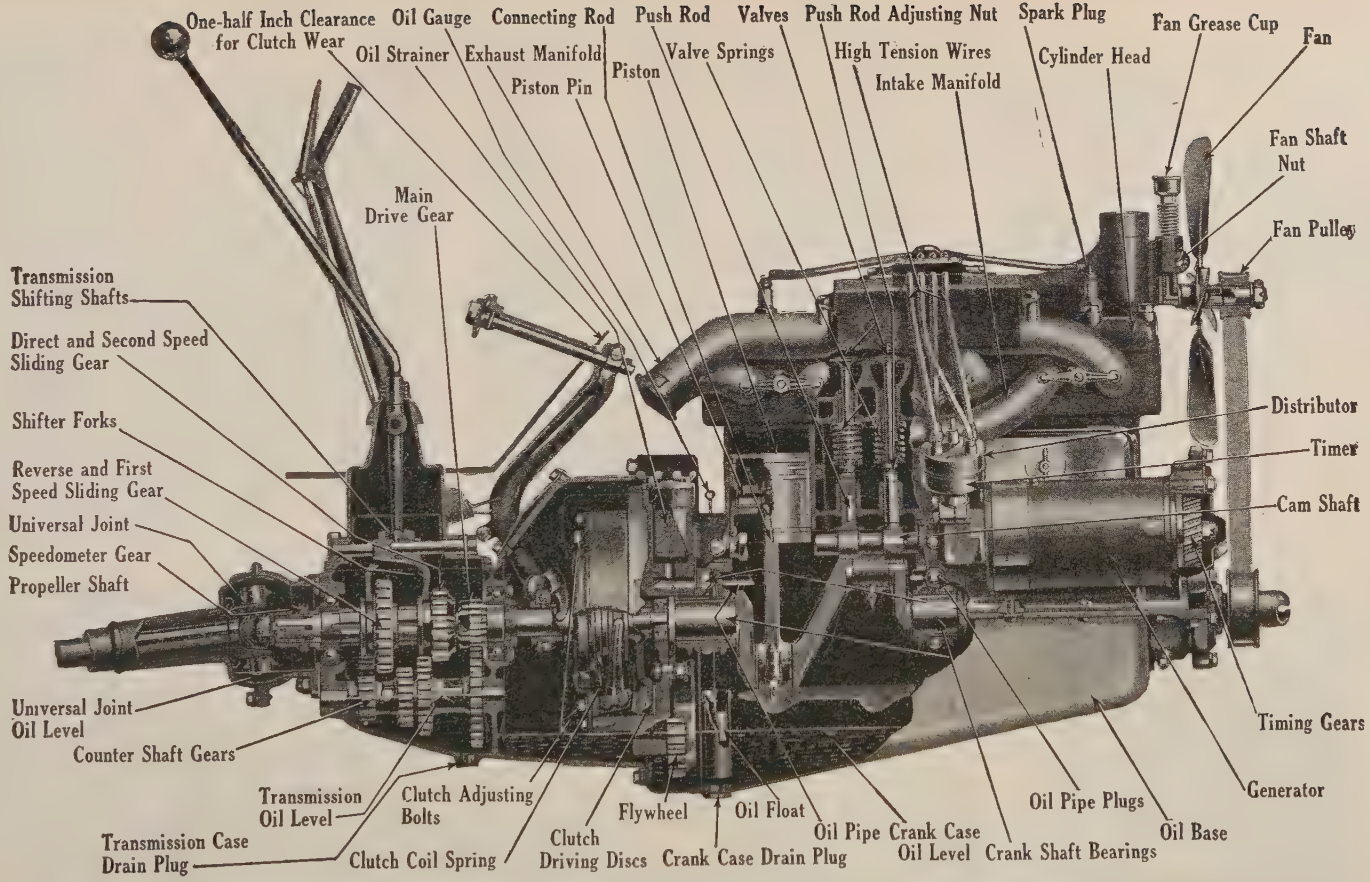

Fig. 21. Example of an Engine with Valves on the Side Operated by One Cam Shaft on the Side. Cross-section of engine, clutch, transmission and universal joint, or the unit power plant of the "Overland 4" L-type mono-block engine, with valves on the side.

Specifications

Engine: 4 cyl. 3 3/8″ bore x 4″ stroke; S. A. E. h.p. 18, actual 27; three bearings; lubrication, splash, and centrifugal force; oil thrown from periphery of fly wheel which feeds under this pressure to crank shaft bearings; monobloc (meaning all four cylinders cast in one block); L-type cylinders with separate head; helical timing gears; unit power plant.

Valves on the side: size 1 9/16″ di. head; 3/8″ di. stem; 1 3/8″ di. in clear; 45° seat; 7/32″ lift; cast-iron head welded to steel stem. Rings: 3, and are 3 3/8″ di. x 3/16″ wide.

Valve timing (measurements on flywheel): Inlet opens 31/32″ past upper d.c.; inlet closes 2 53/64″ past lower d.c.; exhaust opens 3 41/64″ before bottom and closes 13/16″ past top d.c. This is the distance laid out on the periphery of the flywheel.

Valve timing by degrees: Inlet opens 12° past upper d.c.; inlet closes 35° past lower d.c.; exhaust opens 45° before bottom d.c.; exhaust closes 10° past top d.c. (measurements on flywheel).

Valve timing by piston travel: This measurement means the distance the piston travels from its highest or lowest position. Inlet opens 1/16″ past upper d.c.; inlet closes 9/32″ past lower d.c.; exhaust opens 29/64″ before bottom d.c.; exhaust closes 1/64″ past top d.c.

Cooling: Thermo-syphon. Capacity of radiator 3 3/4 gal.

Carburetor: Tillotson 3/4″ special. See discussion of "Carburetion."

Electric system: see Index on "Overland 4" electric system.

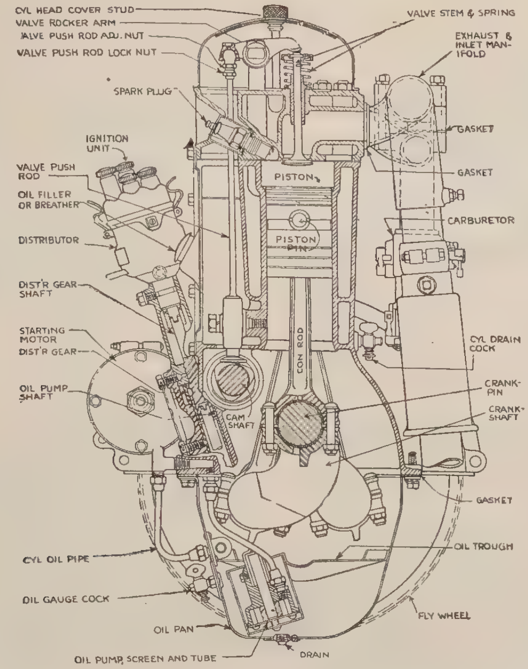

Fig. 22. Sectional end-view of the Nash automobile engine with valves-in-the-head. Specifications are given on page 39.

ENGINE PARTS

Crank Case

The difference, or variation in construction of the various parts of an engine will now be taken up.

The adjustments and repairs of the various parts are treated farther on in the "Repair Section" of the book.

The cylinder is attached at its open end to the crank case, which forms a box around the crank shaft.

The crank case is of irregular shape, so that while there is plenty of room for the cranks and connecting rods to operate, there is little waste space. It contains the crank-shaft bearings, and forms the bed-plate, or foundation, for the engine.

It is often made in two parts: an upper part bolted to the cylinder and containing the crank-shaft bearings, and a lower part enclosing the crank shaft, and which is called the "oil pan."

As the lower crank-shaft case is intended to contain lubricating oil, it is tight so that there may be no leakage. Usually the lower part of the crank case can be removed for adjustment of bearings.

The crank case is usually made of aluminum alloy, or, if in two pieces, the upper may be made of iron, and the lower of aluminum and sometimes of cast iron.

The crank case is used to support the cylinders and the various parts of the mechanism, such as the pump, magneto, etc.

The S. A. E. designates two types of crank cases: the "split type," where the lower part is separate and contains no bearings. The lower part is then called the "oil pan." The "barrel type" is when the lower part is permanently attached and has a hand-hole plate for reaching the bearings, and the crank shaft is removed from the end of the crank case with the removal of the crank-case head.

The arms for supporting the crank case on the chassis are sometimes made short to bolt to a sub-frame, while other manufacturers make longer arms to extend and bolt to the main frame.

A "three-point suspension" is where the power plant is suspended in the frame at three points of contact. **"Four-point suspension"** is where the power plant is suspended at four points.

A "unit power plant" is where the engine clutch and transmission are in one unit, as in Fig. 21.

Engine Bearings

The engine crank-shaft bearings are known as "main bearings." Most of the manufacturers make four-cylinder engines with three main bearings for the crank shaft. Some are made with five bearings, but these are usually very large engines. On six-cylinder crank shafts there are as many as seven main bearings, the majority of smaller engines using three.

The Marmon "34" uses four main bearings; Pierce-Arrow uses seven bearings on the six-cylinder passenger-car engine and three on the four-cylinder truck engine; Hudson model "O" uses four; Packard "six" has seven and Packard "twelve" ("twin-six") three; and Locomobile "five." If the six cylinders are cast "single," which is unusual, usually five bearings, two ends and three inside, are used. If the cylinders are cast in "pairs," there are usually five bearings, two ends and three inside. If the cylinders are cast "in-block," small six-cylinder engines use three bearings and large engines, four or five. If ball bearings are used, there are usually two bearings.

Crank-shaft main bearings are usually in two parts: the upper and lower halves (Fig. 24). Both parts constitute the bearing.

The upper half is supported by the upper part of the crank case, and the lower half in a bearing cap.

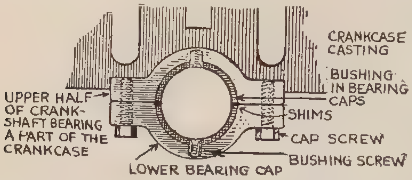

Fig. 24. Construction of a crank-shaft main bearing.

The bearing cap is fastened to the upper half of the bearing with cap screws.

On some engines, babbitt metal is cast into the bearing halves, and then dressed down, scraped and run-in.

On others, the upper half is cast and the lower half is in the form of a bushing which can be renewed when worn, by screwing a new bushing in place in the lower bearing cap.

Most of the wear is on the lower half of the bearing, because it supports the weight of the crank shaft and receives the thrust of the power impulses. Therefore it can be taken up by removing the lower bearing cap and the "shims," which are usually placed between the two halves, or by dressing the sides of the lower cap down to a proper fit, thus drawing the cap tighter around the shaft. After a long period of time and after the lower half has been taken up two or three times, the upper half will have to be cast again. On some engines the upper and lower half can be fitted with bushings, which are detachable and are held in place with a countersunk screw. Thus new bushings can be replaced and run-in.

A bearing bushing is that part of a plain bearing that the shaft comes in contact with. They are usually made of babbitt, phosphor bronze, or white metal. The phosphor bronze is very hard and lasts a long time, but is somewhat liable to "seize," if run without oil.

A white metal bushing consists of a layer of white metal, run (when in a molten state) into a channel in the bearing. It then hardens and is scraped and polished. White metal has the virtue of not seizing or doing much damage if ill treated, but if it is run for a long time a knock will result. There are many different alloys used for bushings, some being faced with brass. Bushings can be purchased ready for application. **If a bushing is burned or cut** from lack of oil, it can be scraped and "spotted up" to a fit, if the cut is not too deep, or a new bushing may be put in place and burned and run-in. These subjects will be treated farther on under the subject of "Repairs."

All ordinary wear in engine bearings can be taken up by removing shims and drawing to a tighter fit, termed "taking-up-on-the-bearings." The rear main bearing is usually the bearing which wears first, because it supports the weight of the fly wheel.

Connecting-Rod Bearings

Probably the **first bearings to require renewal** are those of the connecting rod.

The big end of the **connecting rod** is attached to the crank pin, and a bushing of bronze or white metal or other metal (with a melting point lower than that of cast iron) in the form of a shell, surrounding the crank pin, is secured in it.

The bushing is split lengthways into two halves, like the bearing of the crank shaft, one part being set in the connecting rod and the other being held in place by the **connecting rod cap.**

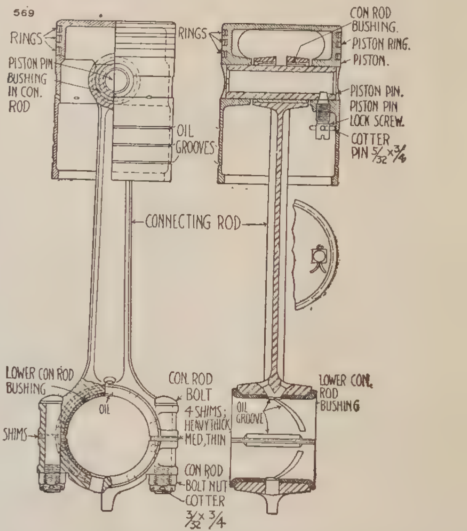

Fig. 25. A connecting rod showing piston-pin bushing and crank-pin bearing and cap. The bearing is in the small end of connecting rod for the piston pin. The piston pin is stationary.

The small or upper end of the connecting rod contains a solid bronze bushing (Fig. 25) that forms the **wrist or piston pin bearing.**

Because of the small space in the piston, it is not possible to have this bushing split and held in place by a cap. The bushing is therefore set in the connecting rod, and the piston pin pushed through it. The wear of the piston-pin bushing is slight, and if it should wear loose, a new bronze bushing is driven into the connecting rod.

The **piston pin** is passed through the piston, and secured so that it cannot move. It is usually case hardened. This type is termed a "stationary piston pin."

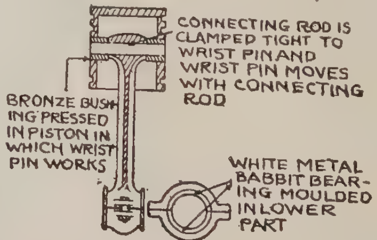
CONNECTING ROD IS CLAMPED TIGHT TO WRIST PIN AND WRIST PIN MOVES WITH CONNECTING ROD
BRONZE BUSHING PRESSED IN PISTON IN WHICH WRIST PIN WORKS
WHITE METAL BABBIT BEARING MOULDED IN LOWER PART

Fig. 26. Note that in this type (Ford) the piston pin moves with the upper end of the connecting rod, and the bearings are in the piston bosses.

On the Ford (Fig. 26), the piston pin moves with the motion of the connecting rod, the small end of the connecting rod being clamped to it. The piston pin moves in bronze bushings fitted in the piston. This type is termed an "oscillating-type piston pin."

Through the connecting rod the piston transmits the pressure of the explosions to the crank shaft and fly wheel. In order that it may withstand the heavy shocks of the explosions, the connecting rod must have great strength. It is made of drop-forged carbon steel, heat treated, and, in rare instances, is of bronze. A straight I-beam type is used almost universally.

Bronze is used extensively on large, slow-speed engines, but would be too heavy for automobile work, as the high-speed engine requires light-weight reciprocating parts. Each connecting rod should weigh the same.

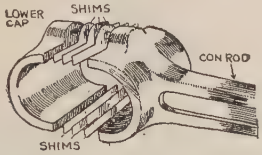

Fig. 27. Connecting-rod bearing end with cap removed to show shims.

Most connecting rods and main bearings are fitted with "shims" as in Fig. 27. When the bearing wears, a shim can be removed, thus drawing the lower cap tighter around the shaft. Shims are made of thin layers of metal .001″ to .005″ thick. The thinnest shim is usually placed at the bottom. Sometimes shims are made of paper.

Shims are used on the lower end of nearly all connecting rods, except in those engines using oil pressure in a hollow crank shaft which is cross-drilled to supply oil to the connecting-rod bearing. If shims were used with this type, they would allow oil to escape so rapidly that the oil gauge would show little or no pressure. The lower half of the connecting-rod bearing face is lapped off until an amount of metal representing the thickness of a shim has been removed.

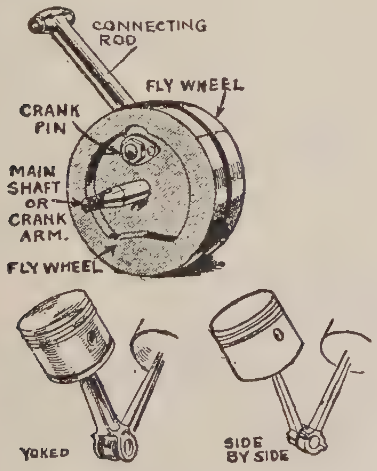

Fig. 28. Upper illustration shows a connecting rod, a crank pin, and a crank arm on a single-cylinder motorcycle or cycle-car engine. Note that a crank pin is between the two fly wheels which are placed in the crank case. The lower illustrations explain two methods of connecting two connecting rods to one crank pin on a "V"-type engine.

The connecting rod on a crank shaft of a "V"-type engine can be placed either "yoked" or "side by side," as shown in Fig. 28. When they are yoked, the cylinders would be "in line"; if side by side the cylinders would be "staggered," or slightly out of line.

The Piston

The piston of a gasoline engine is called a "trunk piston," to distinguish it from the "disk piston" of a steam engine.

A trunk piston is longer than its diameter, and is hollow, with one closed end. The closed end is toward the combustion space, and it is against the closed end that the force of the explosion acts.

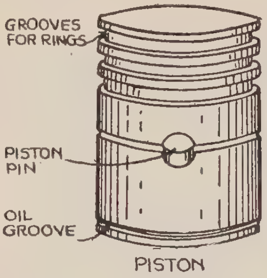

Fig. 29

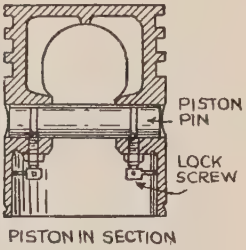

Fig. 30

Fig. 29. A trunk type of piston.

Fig. 30. Sectional view of piston. Note piston pin is stationary.

The piston pin passes through the piston, usually about the middle or a little nearer the top (depending on the stroke).

The open end of the piston permits the connecting rod to swing from side to side.

The piston does not fit the cylinder tightly, for a tight fit would cause friction and wear. This space is called **piston clearance** (see Index). The piston is usually slightly smaller at the top than at the bottom, because the heat is more intense at the top and expansion must be allowed for.

A piston is usually measured at the skirt, or below the piston pin. Pistons are made of cast iron, and when heated they expand. The usual clearance between the cast-iron piston and cylinder wall is about .001″ to each inch of piston diameter.

Meaning of "piston clearance": Let us take, as an example, a Continental Model N engine which is 3¾″ bore. In decimals, therefore, its bore would be 3.750 (three inches and seven hundred and fifty thousandths of an inch).

Suppose the clearance of the piston was .003 (three thousandths of an inch), which would mean the piston diameter should be .003 less than the bore, then 3.750 (the bore) minus .003 (the clearance) would equal 3.747 (three inches and seven hundred and forty-seven thousandths), which would represent the diameter of the piston for a clearance of .003 for this engine.

Pistons are usually marked on top and in decimals. The diameter is that of the skirt. The **bore of a cylinder** is usually stamped on the lower machined face of the cylinder block.

Aluminum alloy pistons are used to a certain extent instead of cast iron.

Advantage: They are about one-third lighter; thus the inertia of the reciprocating piston is reduced considerably, and consequently the side-pressure or thrust on the walls of the cylinders is lessened. The great heat conductivity of aluminum alloy lessens the carbon deposit on the piston head and the deposit is more easily removed. In case of extreme heat, if the piston should "seize," the cylinder is not damaged by aluminum because it is softer than the cylinder.

Disadvantage: Aluminum alloy pistons expand twice as much as cast iron, and therefore when the engine is cold the clearance between the piston and cylinder wall being twice as great as normally, raw gasoline is drawn into the cylinder which passes down to the crank case and thins the lubricating oil and washes off all of the lubrication on the cylinder walls. A "piston-slap" is also produced, due to the great clearance, until the pistons are heated up, at which time they expand and the piston-slap noise should cease.

On one model of the Franklin, the shallow, square groove of screw-thread form was turned at the bottom of the skirt of the piston just beneath the lower ring. This held oil and permitted a smaller clearance.

Pistons and connecting rods for high-speed work should be made very light. In some instances, where cast iron is used, the piston is made lighter by making the skirts thinner and the piston pin-boss lighter. On some high-speed engines the piston skirt is sometimes drilled with large holes for the sake of lightness.

Piston Rings

The pressure from the explosion is prevented from escaping between the piston and the cylinder wall by **piston rings.**

The piston rings fit in the groove around the upper end of the piston, and there may be from two to five of them, usually three. The rings fit the groove snugly, but not so tight that they may not move freely.

They are cut crossways, so that they may be sprung open. When closed, so that ends touch, the rings are a trifle smaller than the diameter of the cylinder.

When sprung open, they are larger than the diameter, or bore of the cylinder. They are so made that they always stand a little open.

The rings are slipped into the grooves by springing them open, and sliding them over the piston.

When a piston is to be placed in a cylinder, the rings are drawn together, so that they will slide in easily. The piston with its rings fits the cylinder snugly, and the elasticity of the rings keeps them pressed against the cylinder wall, making a fit that keeps the pressure from escaping.

Since none of the pressure of the explosion is able to escape, it is all exerted against the closed end of the piston, or **piston head.**

The rings must be placed on the piston so that the ends are not one over the other, for if they were in line the pressure might escape through them (see Fig. 31).

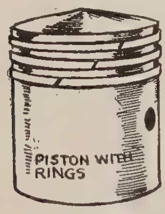

Fig. 31

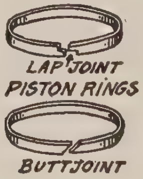

Fig. 32

Fig. 31. In order to prevent compression passing through the joints of rings they are placed as illustrated.

Fig. 32. Two standard types of piston-ring joints.

The rings are prevented from moving around the piston by **pins** placed between the ends (although this is not the case on all pistons). The only motion they have is the spring in and out.

The ends of the rings are beveled, or made with a joint (as in Fig. 32), so that the gas will not leak through the joint. Two of the usual types of piston rings are shown in Fig. 32. Piston rings are made of cast iron of a slightly softer grade than the cylinder.

There are many improved types of piston rings which the manufacturers claim will not leak; usually three rings are placed on a piston. Two rings are often used for high-speed work, whereas, for average automobile engines, three rings are generally used. This subject is fully treated in the "Repair Section" of this book.

Piston rings are measured according to the bore of the cylinder and the width of the ring groove.

The Crank Shaft

The crank-shaft-throw changes the reciprocating motion of the piston to the rotary motion necessary to turn the wheels. It rests in bearings that hold it in a fixed position, but permit it to revolve.

The crank pin must be rigidly attached to the crank shaft, and to secure this rigidity, it is usually made in one piece, solid as in Fig. 33, and is usually made of chrome nickel steel.

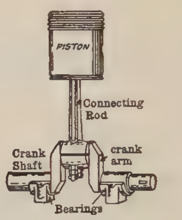

Fig. 33. A single-throw crank shaft. Crank is set at 360°.

The crank projects from the crank shaft, and when the shaft revolves, the crank makes circles around it. A crank is one of the most common mechanical devices. The crank pin is that part to which the connecting rod fits and is also called the "**throw**" of the crank. A windlass is turned with a crank; a bucket or chain pump is operated with a crank; the pedals of a bicycle form cranks.

In a bicycle, the crank arms are attached at their inner end to the crank shaft, and to their outer ends the pedals are attached. When riding a bicycle, the feet press on the pedals at the ends of the crank arms, and make the crank shaft revolve. The feet describe circles around the crank shaft. Each crank arm and pedal form a crank, and there is only one arm to a crank.

In a gasoline engine, two arms are necessary, for the reason that the cranks are not at the ends of the shaft. There are therefore **two arms** to each crank or "throw." (Fig. 33.)

The outer ends of the crank arms are connected by the **crank pin.** The crank pin corresponds to the pedal of a bicycle. A gasoline engine has as many cranks as it has cylinders.

Degrees as Used with a Crank Shaft

The position of a crank on a crank shaft in relation to other cranks on the same shaft is expressed in degrees of a circle.

A degree is designated with a small ° at the right of the figure. For instance, a crank shaft with throws of 360 degrees, would be designated as 360°. See Index, explaining the meaning of "degree."

If the cranks project from the same side of the shaft, as in Fig. 33, so that the crank pins are in line, it is called a 360-degree (360°) crank shaft.

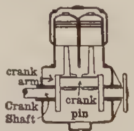

Fig. 34. A two-cylinder vertical engine with a 360-degree crank shaft; both connecting rods on one crank pin.

When the two crank pins on a crank shaft project in the same direction, as in Fig. 34, both connecting rods drive as one crank. This type of engine, however, is not used on account of its vibration. An engine with a crank shaft as shown in Fig. 36 would be more balanced. See Index under "Firing order" of cylinders.

If a crank shaft has two crank arms projecting in opposite directions, as in Figs. 35, 36, and 38, it is called a 180-degree (180°) crank shaft.

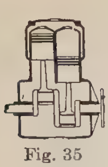

Fig. 35

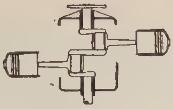

Fig. 36

Fig. 35. A two-throw crank shaft for a two-cylinder vertical engine; crank set 180 degrees.

Fig. 36. A two-cylinder opposed type of engine with crank shaft set 180 degrees. Cylinders are also 180 degrees apart.

The engine in Fig. 36 is **a two-cylinder opposed type of engine.** It was formerly used to a great extent on small cars, and is still used on trucks and tractors for heavy work. The cylinders are placed 180 degrees apart. The crank shaft is also 180 degrees.

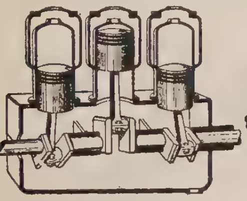

Fig. 37

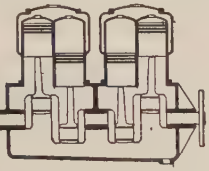

Fig. 38

Fig. 37. A three-cylinder ~~vertical~~ type of engine with cranks set at 120 degrees. Note No. 2 piston is up. No. 3 (right) would be 120 degrees or one-third of a revolution; No. 1 would be 120 degrees, or one-third revolution from No. 3, or two-thirds from No. 2.

Fig. 38. A four-cylinder vertical engine with crank shaft set 180 degrees. Note piston No. 1 and 4, and 2 and 3 are always in line.

The four-cylinder engine (Fig. 38) employs a 180-degree crank shaft. Note the "throws," or crank pins, of the crank shaft on cylinders 1 and 2 are 180 degrees apart and on 3 and 4 are 180 degrees apart. Therefore, pistons on cylinders 1 and 4 always move up or down together, and 2 and 3 move up or down together. In other words, these crank throws are in line.

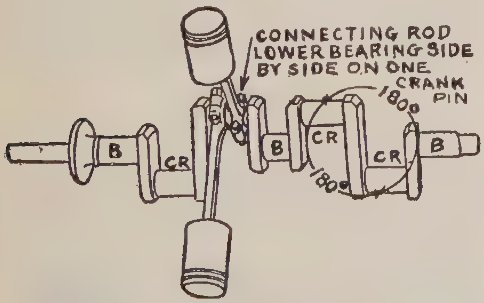

Fig. 39. A regular four-cylinder type, 180° crank shaft is used on the eight-cylinder "V" type of engine. Two connecting rods are placed on one crank pin, either side by side, or yoked (see Fig. 28).

The eight-cylinder "V"-type engine would in reality be nothing more than two four-cylinder engines with cylinders set "V" shape, the angle of the cylinders usually being 90 degrees, or one-half of the 180 degrees of the crank shaft. The same four-cylinder 180-degree crank shaft is employed. There are **two connecting rods to** each throw of the crank, which can be placed "side by side" (Fig. 39), or "yoked."

When connecting rods are placed side by side, as shown in Fig. 39, it is necessary to "stagger" the cylinders by setting them out of line with each other. If "yoked," the cylinders would be in line.

A three-cylinder engine must have a crank shaft with the three crank pins placed in three positions, or one-third of a revolution apart; this would be placing them 120 degrees apart (see Fig. 37).

A six-cylinder engine would have a crank shaft with six crank pins or crank "throws" placed in thirds, or 120 degrees apart. There would be three pairs in line (see Fig. 40).

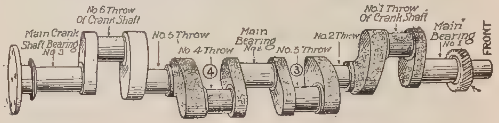

Fig. 40. A solid crank shaft, with three main bearings; six cylinder.

A twelve or twin-six-cylinder "V"-type engine would use the same type of six-cylinder crank shaft, but with two connecting rods to each crank pin. The cylinders would be placed 60 degrees apart, or one-half of the 120-degree crank shaft.

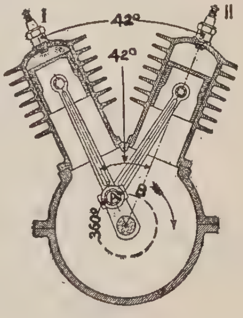

Fig. 41. A two-cylinder twin type of engine used on motorcycles and light cars. Note the 360-degree crank. Cylinders are at a 42° angle.

The twin-cylinder "V" type of engine used on a cycle car and motorcycle would use a 360-degree crank or one crank pin, with connecting rods "yoked." Cylinders on this type of engine are usually placed at an angle of from 42 to 45 degrees apart.

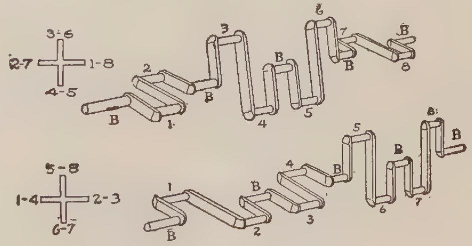

Fig. 42 (lower); Fig. 43 (upper).

Two methods of placing the crank throws on a "straight-eight" cylinder engine, where the eight cylinders are all in line are shown in Figs. 42 and 43. (B) are bearings and (1) to (8) are the crank pins.

The Duesenberg arrangement where two four-cylinder crank shafts are placed end to end, one of them being given a twist so that its "throws" are 90 degrees to the throws of the other is shown in Fig. 42. This crank shaft is made from a solid piece of steel. Counterweights not shown in the illustration are integral with the shaft. Fig. 43 shows another arrangement, which would give a different firing order. The advantage claimed in using the "straight eight" is a better balance than any other eight-cylinder engine of the "V" type.

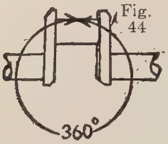

Fig. 44

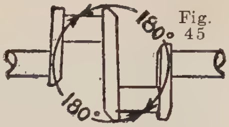

Fig. 45

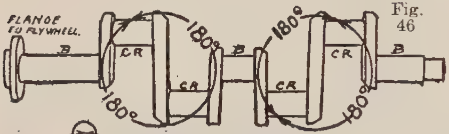

Fig. 46

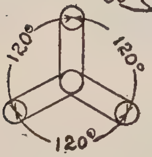

Fig. 47

Figs. 44–47. In the illustrations above, the idea is to explain the term "degree" used in connection with crank shafts. Any perfect circle is 360°. If the circle is divided into quarters, each quarter would be 90°; half of the circle 180°; a third 120°.

Fig. 44. Note one crank pin—hence 360° crank.

Fig. 45. From center of one crank pin to center of another is half a circle, or 180°.

Fig. 46. Here we have two pairs of crank pins as shown in Fig. 45. Each pair of crank pins is placed 180° to each other.

Fig. 47. End view of a three or six-cylinder crank shaft. Note that crank arms are one-third apart, or 120°.

Construction of Crank Shafts

There are two kinds of crank shafts, one known as the **"solid crank shaft"** and the other as the **"built-up crank shaft."**

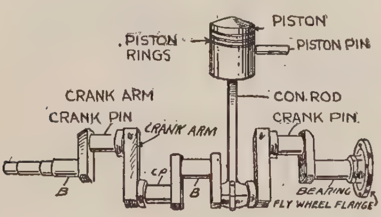

Fig. 48. A solid type of crank shaft—three-bearing type, four-cylinder.

The solid crank shaft is by far the most commonly used. It is made from one piece of steel, which is forged to shape and then turned up in a lathe, the workmanship in many cases being accurate to a ten-thousandth part of an inch.

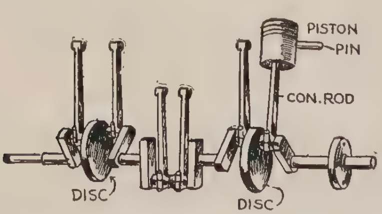

Fig. 49. A built-up type of crank shaft (seldom used). The above is a six-cylinder crank, with four bearings. Note that it is built-up to disks.

The built-up crank shaft (Fig. 49) has each of its parts made separately and then fixed strongly together, and quite often fitted with ball bearings. Ball bearings can be fitted only to a built-up type if there are more than two bearings.

An advantage of the built-up crank is that the crank-shaft bearings could be fitted with ball bearings, as shown in Fig. 50. However, built-up shafts of this kind are not usual, and in the case of powerful engines, only the strongest solid crank shafts are ever used.

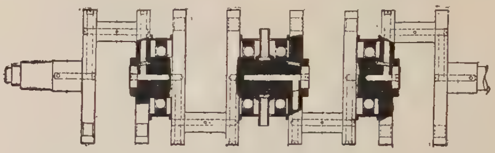

Fig. 50. A ball-bearing, built-up type of crank shaft with three bearings for a four-cylinder racing engine. With three or more bearings it is necessary to have a built-up crank shaft in order to mount the ball bearings. On the **Autocar truck** engine there are two ball bearings placed on the outer bearing ends of the crank shaft. Thus a solid ball-bearing crank shaft can be used. See Index under "Autocar truck engine"; and under "White ¾-ton truck."

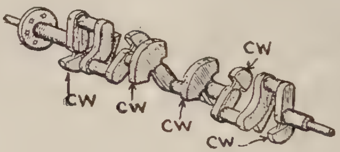

Fig. 51. Counterbalance weights applied to a six-cylinder crank shaft.

The counterbalanced crank shaft (Fig. 51), with counterweights (CW) electrically welded to the crank shaft and an integral part of the crank shaft, as illustrated, is becoming popular. It permits high speeds to be obtained without detrimental vibration, and relieves the tendency to "whipping" of the crank shaft and "slapping" of the pistons at high speeds.

Whipping of crank shaft is more pronounced where there are very long weak crank shafts with great distance between bearings. Vibration of an engine can also be due to forces being out of balance or unequal; for instance, engine loose on frame; uneven compression; weak explosion in one or more cylinders due to leaky rings or valves, or too much oil in that particular cylinder; defective spark or plug; sprung crank shaft; clutch out of balance; new full-size bearing and shims on one crank throw, and the old worn or lighter bearing with shims or liners removed on the other crank throw; different weight pistons; front wheels out of true, rim out of plane with spokes.

Cylinders

The cylinder of a gasoline engine is made of cast iron or twenty per cent semi-steel, and the water jackets are generally cast in one piece with it. The cylinder of a gasoline engine is cast with **water jackets** surrounding it and in one piece (Fig. 52).

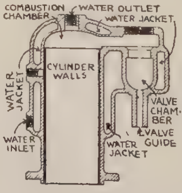

Fig. 52

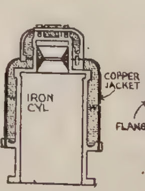

Fig. 53

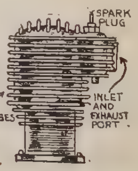

Fig. 54

Fig. 52. A single cylinder with water jacket cast around it.

Fig. 53. A single cylinder with a copper water jacket placed around it. An obsolete design.

Fig. 54. Air-cooled, flanged type cylinder.

On some of the early-model engines, such as the Pope Toledo and the 1914 Cadillac, the water jacket was formed by surrounding the upper part of the cylinder with sheet copper as in Fig. 53. This method is now obsolete.

The portion of the cylinder in which the piston moves should be a true circle, and as smooth as possible. In the better grade of cars the **cylinder walls** are ground to a smooth finish so that there may be as little friction as possible. Any roughness of the walls will cause wear, which comes in the form of cuts and scratches lengthways, and permit the pressure to escape around the piston.

Cylinder heads may be cast **solid** or with **detachable head** (see Fig. 62). The detachable head is very popular, especially where cylinders are cast "in-block." It permits easy access to the valves, and for removing carbon and removing pistons, and is also good manufacturing practice because it makes the grinding of cylinders easier. Where cylinders, on a **multiple-cylinder engine,** are cast singly or in pairs, the heads are usually solid and the entire cylinder is removed from the crank case when work is to be done inside.

Cylinders for **gasoline engines** are made in several **different shapes** and are usually made of cast iron. Some of the **airplane engines** have cylinders made of steel, and some of the engines used on trucks and tractors have **inner sleeves** which are removed and replaced with new sleeves when worn. The Marmon "34" passenger car automobile engine uses cylinder sleeves. See Index under "Cylinder sleeves." The type used most for automobile work is the **cast-iron cylinder** with a water jacket cast around it.

Cylinder Designs

The "T"-head type of cylinder is made so that the exhaust valves are on one side and the inlet valves are on the other side. Note the "T" shape in Fig. 55.

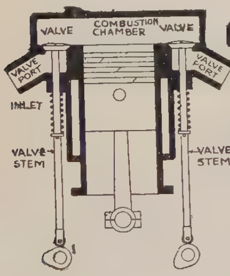

Fig. 55

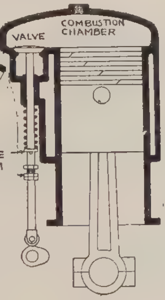

Fig. 56

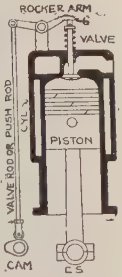

Fig. 57

The "L"-head type of cylinder is made so that the exhaust and inlet valves are all on one side of the cylinder. Note the "L" shape in Fig. 56 (if turned up-side-down).

The "I"-head type of cylinder is made so that the valves are placed in the top of the head of the cylinder (Fig. 57), and is termed the "valve-in-the-head" type.

The "F"-head type of cylinder is made so that one valve is in the head, usually the inlet, and the exhaust is on the side.

How Cylinders Are Cast

When an engine has **more than one cylinder,** the cylinders can be cast singly, in pairs, or in-block, and can be of either the "T," "L," round or "I"-head type. Sometimes multiple cylinder engines have all cylinders cast singly. They can be of the "T," "L," or "I"-head type.

Cylinders cast singly, as applied to a four-cylinder engine, are shown in Fig. 58.

The term **Cylinders cast** in-block means that the multiple cylinders are all cast in one piece. They can also be of the "T" or "L"-head construction.

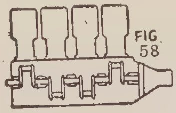

FIG. 58

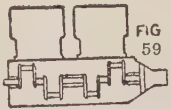

FIG 59

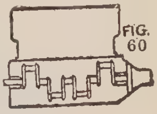

FIG. 60

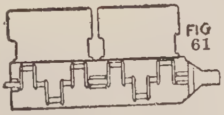

FIG 61

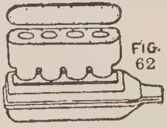

FIG. 62

Note in Fig. 60 that the cylinders are in-block and the **head is solid,** whereas in Fig. 62, the **head is detachable.** The term "mono-block" is also often used where all cylinders are cast in one block. **Cylinders cast in pairs** are shown in Fig. 59. The engine is a four-cylinder type. **Cylinders cast in triplets** are shown in Fig. 61. The engine is a six-cylinder. The cylinders could be cast in-block, or in pairs, triplets, or singly. The Locomobile six-cylinder engines have the cylinders cast in pairs and the majority of other six-cylinder engines have cylinders cast in-block.

Cylinders on the **six-cylinder engines** are usually of the "L"-type, except the Pierce-Arrow and Locomobile, which are "T"-type.

Cylinders on **eight-cylinder "V"-type engines** are usually cast "in-block" and are placed 90 degrees[1] apart, and on a twin-six-cylinder engine, 60 degrees[2] apart (see Fig. 63). On a **twin "V"-cycle car or motorcycle engine,** the cylinders are usually 42° to 45° apart.

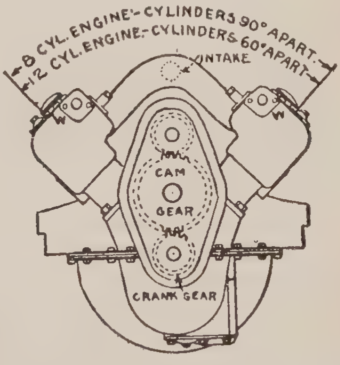
8 CYL. ENGINE-CYLINDERS 90° APART.
12 CYL. ENGINE-CYLINDERS 60° APART.
INTAKE
W
W
CAM
GEAR
CRANK GEAR

Fig. 63. A "V"-type eight-cylinder engine. A 180-degree four-cylinder type of crank shaft is used with two connecting rods on one crank pin.

Cylinders on a **two-cylinder engine with cylinders placed opposite** are shown in Fig. 64. Note that the cylinders are placed 180 degrees apart and are in a horizontal position. This is termed an "opposed-cylinder" engine.

The offset cylinder with an offset crank shaft or offset cylinders, or with Des Axe crank shaft setting, as you choose to say, is represented in Fig. 66. The line **A**, which passes through the center of the cylinder, is some distance to one side of the line **B**, which passes through the center of the crank shaft. Some of the advantages claimed for the offset crank shaft are less liability of a back-kick, reduced wear on the bearing surface of the cylinder walls, connecting rods, and crank shaft, less liability of the engine to be stalled when the car is running slowly on a high gear, and other construction facilities. The cylinder **set central** over the crank shaft, as in Fig. 65, is the type in general use. See page 61; "Effect of offset cylinders."

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[1] Lincoln and Wills-Saint Claire eight-cylinder "V"-type of engines have cylinders set 60° apart.

[2] On the Liberty, twelve-cylinder "V"-type of engine, the cylinders are set 45° instead of 60° apart.

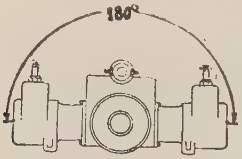


Fig. 64. Two-cylinder opposed type engines.

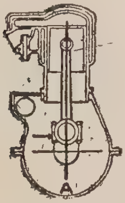


Fig. 65

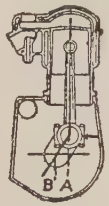


Fig. 66

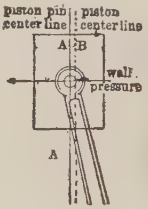


Fig. 67

An **offset piston** is shown in Fig. 67. Note that the piston center line is not in line with the wrist, or piston-pin center line. The reason for the offset of the piston is to compensate for the reaction of the side thrust of the piston during the power stroke. When the piston is part way down on its power stroke all of the power or pressure on the piston is transmitted to the connecting rod at an angle, which reacts against the piston wall in proportion to the angle at that moment, mounting to a maximum at 45 deg. The greater portion of this area is below the wrist pin, so by placing the largest area on the left side, the tendency is to tip the piston against the side-thrust pressure and thus give a better equalized pressure. The Buick engine has the piston slightly offset.

Meaning of Bore and Stroke

The stroke is the length or distance the piston travels up and down inside of cylinder. **The bore** of a cylinder is its inside diameter.

Square stroke. When the piston travel in a cylinder has the same length as the bore in diameter, it is called a square stroke and bore.

Long stroke. When the piston travel is much more than the bore diameter, then it is called a long stroke. For instance, an engine with a piston of 4″ diameter, with a stroke of 4″, is called "square-stroke" engine. The case of a cylinder whose bore is, say, 4″ and the stroke 5½″, would be called a "long stroke."

The valve chamber is that part surrounding the valve. The **valve port** is the opening for the intake or outlet of gas.

The combustion chamber is the inside upper portion of the cylinder, above piston, when the piston is at the top of its stroke.

Inlet and Exhaust Manifold

The **inlet manifold** is the part which connects to the inlet port openings in cylinders, from the carburetor. If there is only one connection to the cylinder, as on a single-cylinder engine, then it is called an **inlet pipe.**

When the valves are all placed on one side of the engine, as in the "L"-head type of cylinder, then the inlet and exhaust manifold are both on the same side of the cylinder.

When the inlet valves are on one side and the exhaust valves on the other side, as in a "T"-head cylinder, then the inlet manifold is generally on one side and the exhaust manifold on the other side.

The **exhaust pipe** leads from the exhaust manifold to the muffler. If the engine is an eight or twelve "V"-type, there are usually two exhaust pipes and two mufflers. In order that the exhaust manifold may be cooled as rapidly as possible, the exhaust manifold and pipe, connecting the exhaust valve chamber to the muffler, are exposed to the air.

The **connection from exhaust manifold to exhaust pipe** is usually made with a flange connection, with asbestos packing between.

The muffler and exhaust pipe should be made so that there is as little **back pressure** as possible. Back pressure is caused by anything that prevents the free escape of the gas. Therefore sharp bends should be avoided, otherwise the incoming fresh mixture becomes mixed with that part of the burned gas left from the previous charge, and the power of the engine is cut down accordingly.

The Muffler—also Called "Silencer"

Purpose: If the exhaust valve opened directly into the open air, the noise of the combusted gases escaping through the exhaust port during the exhaust stroke would sound like the firing of a gun.

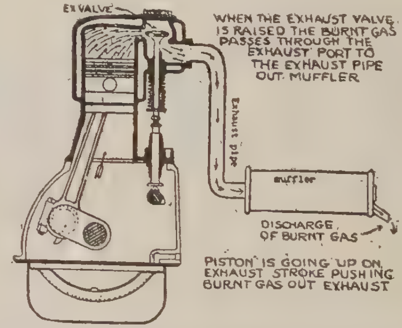

EX VALVE
WHEN THE EXHAUST VALVE IS RAISED THE BURNT GAS PASSES THROUGH THE EXHAUST PORT TO THE EXHAUST PIPE OUT MUFFLER
Exhaust pipe
muffler
DISCHARGE OF BURNT GAS
PISTON IS GOING UP ON EXHAUST STROKE PUSHING BURNT GAS OUT EXHAUST

Fig. 68. Illustrating how the exhaust gases pass from the cylinder, through the open exhaust valve, to the muffler.

This noise is due to the pressure in the cylinder being much higher than the pressure of the air, and a sudden change from one to the other produces a loud report. The more sudden the change and the greater the difference in the pressure, the sharper will be the noise. For instance, the noise would be greater if climbing a hill with an open throttle, than if running on a level with a partially closed throttle.

To silence the noise, a muffler is connected to the end of the exhaust pipe, which is connected to the exhaust manifold (Fig. 68). The exhaust manifold is connected to the exhaust valve ports.

Construction: The muffler is usually made of iron pipe, like a stove pipe, with cast-iron heads, as in Fig. 69. The exhaust gases (when the exhaust valves are opened) pass through the exhaust pipe into the chamber (C), as shown by the arrow marks; then through openings in rear of (C), passing into chamber (B), then through openings in front of (B), into (A), then through (A) to the open air.

If the muffler is not designed properly and is too small, or if it becomes clogged with soot, then the burned gases cannot be expelled as rapidly as they should be. The result is **back-pressure,** or a tendency for the gases to work back against the outcoming exhaust, and also a retention of heat, thus causing overheating of engine and a slight loss of power, due to the back-pressure.

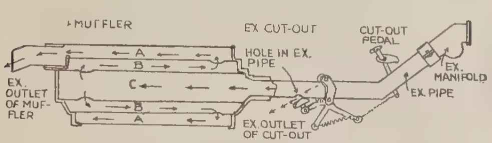


Fig. 69. Sectional view of a muffler also showing how a "cut-out" is placed on the exhaust pipe.

The Exhaust Cut-Out

The exhaust cut-out is a device which can be placed on the exhaust pipe, between the engine and muffler (Fig. 69). It is arranged so that it can be opened by a foot pedal, thus permitting the exhaust gases to pass into the open air instead of the muffler.

The cut-out is now seldom used, except on speed cars or for hill climbing, because of the noise, and also because of the fact that mufflers are now designed so that there is only a slight back-pressure. The cut-out was used extensively during the early days, because engines were minus power and mufflers were not properly designed.

Inlet Manifold Construction

In the simplified illustrations below are shown different constructions, in order to give the reader an idea of the different methods which are and have been used.

With the **inlet manifold,** the design should be such that there may be as little resistance as possible to the flow of the mixture. This manifold should be as straight as the position of the carburetor will permit. There should be no sharp angle-bends, the bends being as flat and easy as possible and the distance from carburetor to inlet ports as short as possible to prevent condensation.

When more than one cylinder is supplied from one carburetor, the distance from the carburetor to each valve should be the same. The inside of the inlet manifold must be smooth and clear so that there is no obstruction offered to the flow of gas.

In those illustrations marked "incorrect," the distance from the carburetor to the inlet valves is not equal, and consequently the valves nearest the carburetor will get more of the mixture than those farther away.

In the arrangement marked "good form," the distances are almost equal, and consequently the valves get equal quantities of mixture, and the engine will run more evenly than if the cylinders received different amounts.

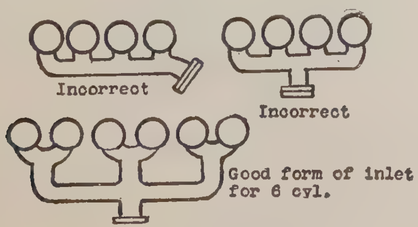


Fig. 70. Inlet manifolds.

Inlet manifolds are usually provided with **means for heating,** so that the gas mixture when passing through the manifold is vaporized. A hot-water jacketed manifold is shown in Fig. 71. The water connections are made with the circulating pump.

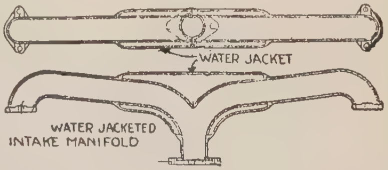


Fig. 71. Top and side view of a water-jacketed inlet manifold.

Most inlet manifolds are heated by a part of the exhaust gases passing through a jacket which surrounds part of the manifold.

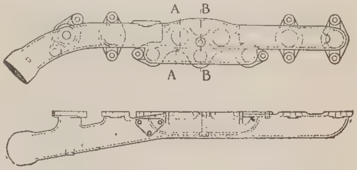


Fig. 72. Top and side view of an exhaust-heated intake manifold.

The "hot-spot" manifold is so arranged that the exhaust manifold surrounds part of the inlet manifold. Thus the exhaust gases pass over a portion of the inlet manifold which shortens the warming-up period with present-day fuel, and thus vaporizes the heavier particles of fuel more quickly. (See Fig. 72.)

This subject is also treated under the general subject, "Carburetion," in the discussion of "Heating the mixture."

Exhaust Manifold Construction

Sharp bends in the exhaust manifold or pipe cause back pressure, and should be avoided. Dirt in the pipe, or muffler, as well as soot in the muffler, has the same effect. In other words, the idea is to have the exhaust pipes offer the least resistance possible to the burned gases passing from the exhaust ports, otherwise part of the burned gases remain in the cylinder, mix with the fresh gases drawn in, and thus affect the mixture.

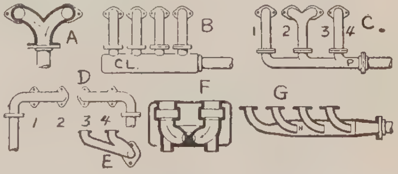


Fig. 73. Exhaust manifolds: A good method of exhaust outlet for a 2- or 4-cylinder vertical engine is shown in Fig. 73 at **A.**

B is a simple manifold in which an individual pipe from each cylinder exhausts directly into the large collector chamber **CL.** In this manifold the collector tube is made sufficiently large so that when the exhaust valve closes, the pressure in it is less than that in the cylinder at the valve, and thus there is no danger of back pressure.

C shows an arragement in which the pipes 2 and 3 for the middle chambers are formed in one, whereas they are separate for cylinders 1 and 4. This works satisfactorily in that cylinders 2 and 3 never fire consecutively, and the one pipe is capable of taking care of the exhaust of the two.

D is quite similar to the case shown in C, excepting that there are individual pipes for cylinders 1 and 2, and 3 and 4. This is bad construction, in that 4 fires immediately after 3, and 1 immediately after 2.

As the direction of the exhaust leaving the cylinders is the same, it is very easy to make a manifold in which the exhaust pipes, instead of having a tendency to obstruct one another, assist the other cylinders to exhaust.

In engines which have their inlet and exhaust valves opposite, frequently all four of the exhaust valves are connected through one manifold with a single orifice. F is one example of an arrangement where it is possible to make the two passages unite. This is suitable for engines with cylinders cast in pairs.

The defects of A and D can readily occur in this one; if makers were considering loss of power, they would not use this one, but they want only to save space.

For the best design, illustration G offers a reasonable solution. In this illustration there is an individual pipe from each cylinder to the large collector. At the end, each individual pipe projects into the collector tube and curves in the direction of the exit for this collector tube.

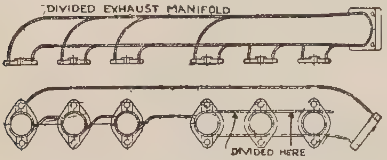


Fig. 74. Two views of a divided exhaust manifold.

The divided exhaust (Fig. 74) is used on several six-cylinder engines with cylinders cast in two blocks of three cylinders to a block. It is claimed for this design that it prevents overlapping and refilling of the cylinders with burned gases.

Valve Caps

Where valves are on the side and the head is cast integrally with the cylinders, **valve caps are screwed over the valves** in the cylinder. By removing these caps the valves can be lifted from their seat and ground. There are two valve caps to each cylinder; an **inlet-valve cap** and an **exhaust-valve cap.**

Compression or Relief Cocks, or Priming Cups

They consist of small **pet cocks** screwed into the exhaust valve caps. By opening them when the engine is running, it is possible to see if any of the cylinders are missing fire. A flame will shoot out if firing. They are also used for injecting gasoline when the engine is cold and hard to start. The S. A. E. now terms this a "priming cup."

Cams and Cam Shafts

A cam is a device that produces intermittent motion. When an object is in motion part of the time and at rest between motions, its action is said to be "intermittent." A cam may best be described as a wheel with a hump or nose on one side (Figs. 75 and 76); in other words, it is a piece of metal revolving with a shaft, part of its circumference being farther from the shaft than the rest. The part of the cam that projects is called the **nose.** Anything resting against the cam will be moved only when the nose comes around to it; otherwise it remains stationary.

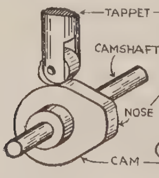


Fig. 75

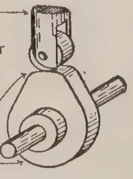


Fig. 76

Fig. 75. Showing the nose of cam.

Fig. 76. Nose of cam raising valve plunger or tappet, which raises valve.

For a four-cylinder engine, four cams on the inlet cam shaft are shown in Fig. 77. Four more cams on an exhaust cam shaft are provided on the opposite side of this engine, because it has "T"-head cylinders. The cams are divided in four positions on the cam shafts, and are made in one piece or integral with the cam shaft. If the cylinder is the "L"-type, then all cams would be on the one cam shaft (see Fig. 79).

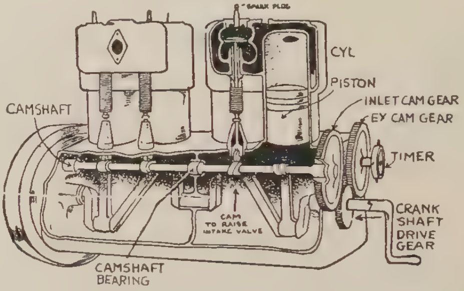


Fig. 77. Illustrating how the cam shaft on a four-cylinder engine is operated by timing gears; also how the nose of the cams raises the valves. There are two cam shafts placed opposite, therefore it is a "T"-head type.

For each cylinder there is one inlet cam and one exhaust cam. The **exhaust cam** usually has a **broader nose** because it must hold the valve open longer.

The **cam shaft,** also called the "secondary" or "half-time shaft," has a cog wheel or gear, called a "timing gear," on one end, which meshes with the **drive-shaft-gear** on the crank shaft. The cam shaft gear is also often driven by a **silent chain.**

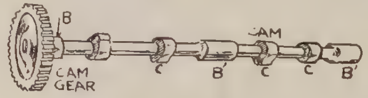


Fig. 78

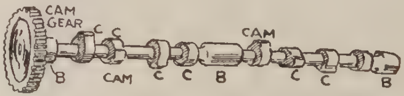


Fig. 79

Fig. 78. The cam shaft as used with a four-cylinder "T"-head type cylinder. There are two shafts, an intake cam shaft and an exhaust cam shaft—one on each side of the cylinder as shown in Fig. 80. There are four cams on each shaft. The noses of the cams are placed at different positions, so that the valves will be raised at a certain time. **C** are the cams. **B** are the bearings for the cam shaft.

Fig. 79. The cam shaft as used with a four-cylinder, "L"-head type of cylinder. There is but one cam shaft in this type because all of the inlet and all of the exhaust valves are on the "L"-side of the cylinder (see Fig. 81). There are eight cams on the cam shaft.

When the crank shaft revolves, the **drive gear on the crank shaft** drives the **timing gears,** which drive the cam shaft and thereby rotate the cams (see Figs. 80 and 81).

The **nose of the cam** raises a valve lifter or **tappet,** which plunges against the end of the valves and raises them from their seat. When the nose of the cam is under the roller or valve lifter, the valve is held open; the valve is closed after the nose passes, by the action of a strong spring.

The **valve stem,** being held in a **valve guide,** cannot move in any direction but up and down. Thus the steady **rotary** motion of the **cam** is changed to the **intermittent** motion of the **valve.**

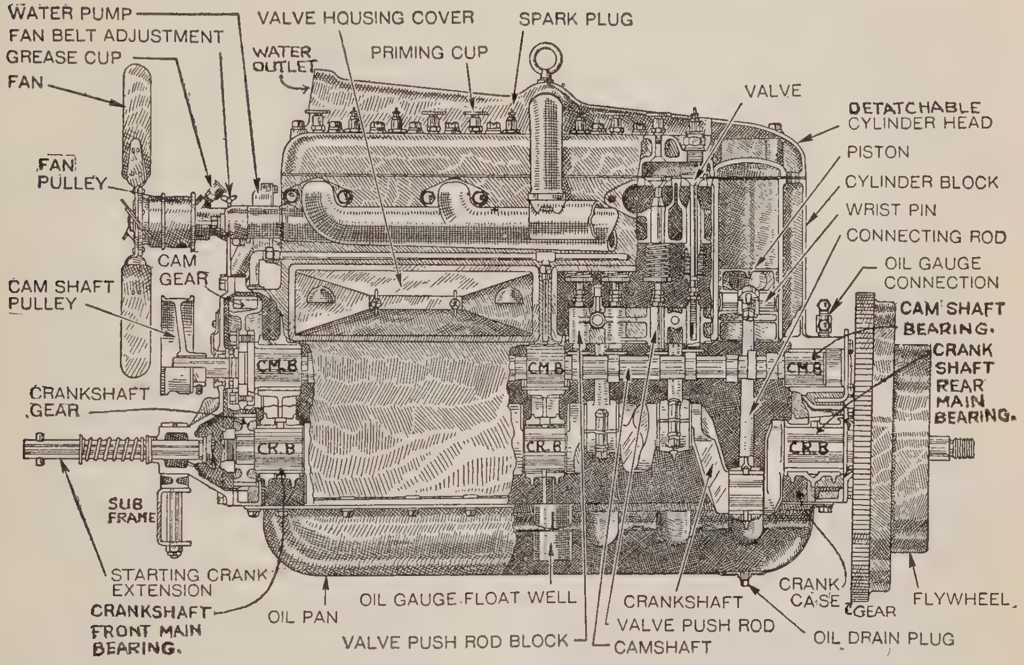


Fig. 83. Top view of the Mitchell model "F" six-cylinder engine. The illustration shows how the cam shaft is driven by gears. The crank-shaft gear drives the cam gear, which is attached to the cam shaft. The one cam shaft operates all valves (inlet and exhaust) from the one side of the engine.

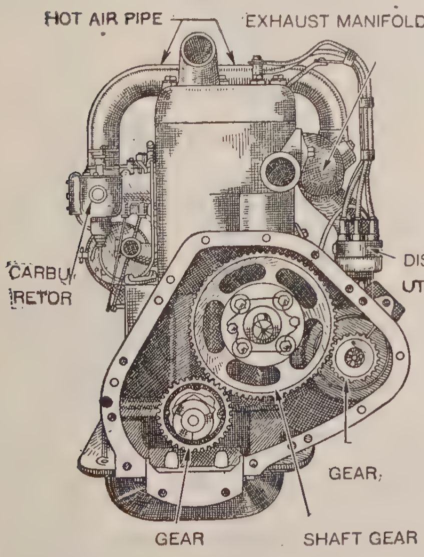


Fig. 83A

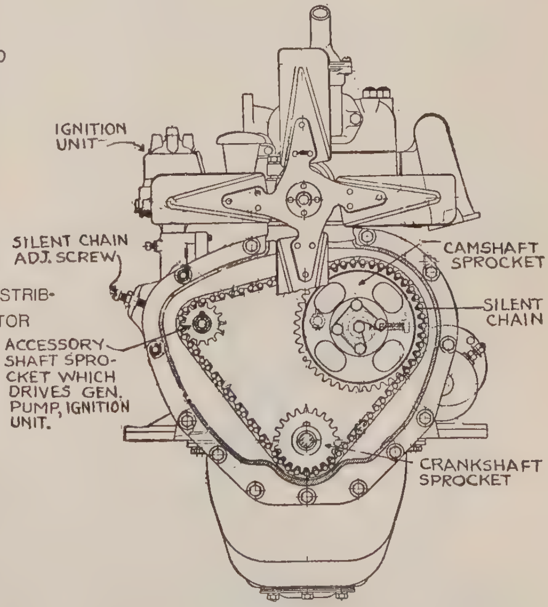


Fig. 84

Fig. 83A. End view of the Mitchell engine. Note that the crank-shaft gear (lower one) drives the cam-shaft gear (large one). The cam-shaft gear then drives the generator gear (on the right).

Fig. 84. Front view of the Studebaker model "EJ" six-cylinder engine. The cam shaft is driven by a silent chain.

As has been shown on four-cycle engines, each valve opens only once while the crank shaft makes two revolutions. Therefore the cam shaft should revolve only once while the crank shaft revolves twice.

The cams are an integral part of the cam shaft and one cam cannot be moved one way or the other unless all move together. There are **two types of cam shafts,** those operating from the **side** of the cylinder and those operating **overhead,** or above the cylinder.

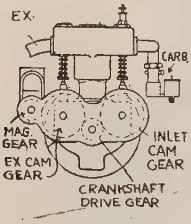


Fig. 80

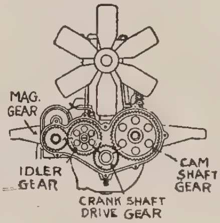


Fig. 81

Fig. 80. Showing method of driving the two cam shafts and magneto on a "T"-head engine. Note the two cam gears and shafts.

Fig. 81. Method of driving the one cam shaft. An idler gear is provided to drive the magneto gear. "L"-head type of cylinder engine. Note the one cam gear and shaft.

Gear-Driven Cam Shafts

The crank shaft drive gear and cam gears are called **timing gears.** If two gears running together (or in other words, in "mesh"), have the same number of teeth they will make the same number of revolutions.

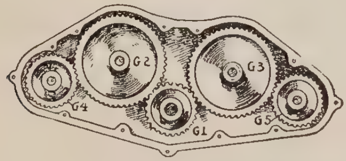


Fig. 82. End view of the cam gears and drive gear. The two cam gears (G2, G3) are called "half-time" gears, because they revolve just one-half the time, or revolutions, that the drive gear (G1) revolves. G1 is drive gear on crank shaft. G3 is cam gear for inlet cam shaft. G2 is cam gear for exhaust cam shaft. G4 and G5 are extra gears to drive the magneto and generator ("T"-head engine).

If the **driven gear** has twice as many teeth as the **drive gear,** it will revolve only once while the other revolves twice. This is called a "two-to-one" or "half-time" gear.

Because the cam shaft must revolve only once while the crank shaft revolves twice, the cam-shaft gear has twice as many teeth as the crank-shaft drive gear (see Fig. 82).

The **cam shaft revolves in the opposite direction to the crank shaft** when driven by gears without an idler and in the **same direction** when driven by a silent chain or an idler. The crank shaft and fly wheel of all gasoline engines revolve **clockwise,** or to the **right,** when facing the front of the engine. Thus gear (G1) (Fig. 82) would revolve clockwise.

The **wide-faced helical gear** is the popular type of gear for the timing gears because they make less noise than a straight-tooth spur gear. Special materials, such as fabroil, micarta, and other compressed materials, are used by many as material for making gears which are silent. Drop-forged gears are also used, so also is steel for the crankshaft gear and cast iron for the cam gear.

Silent-Chain-Driven Cam Shaft

The **silent chain** for driving the generator is quite popular, and it is also being used to a great extent for driving the cam shaft. The object is to obtain quieter running. This type of chain must not be confused with the ordinary roller type as used on chain-driven trucks. The silent chain is more positive in action, otherwise the timing would be thrown out of adjustment. The **teeth on a sprocket** used for a silent chain are very close together and are accurately made. The **silent chain,** as its name indicates, is silent, but requires taking-up occasionally. After a certain period new links, or a new chain, is required. See Index under "Silent chains, adjusting of."

ENGINE VALVES

Purpose of valves: There are two valves to each cylinder of all four-cycle gasoline engines: an **inlet** valve and an **exhaust** valve.

Note. The "dual-valve" engine has four valves to each cylinder; two inlet and two exhaust valves. This subject will be treated later.

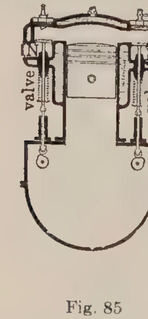


Fig. 85

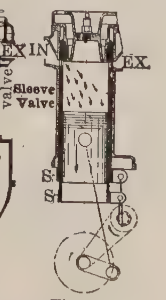


Fig. 86

Fig. 85. Poppet type of valve: so named because the valve pops up and down. Poppet valves are used on "L," "T," "I" or "F"-head type of cylinders, and are always mechanically operated.

Fig. 86. The sleeve type of valve. There are two sleeves (S),—with openings at upper end. When these openings are together, the fresh gas is admitted or the burned gas is discharged. Mechanically operated. "IN" means inlet, and "EX," exhaust.

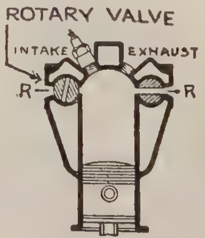


Fig. 87

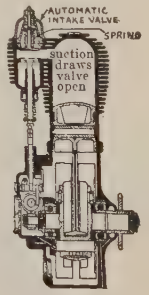


Fig. 88

Fig. 87. The rotary valve.

Fig. 88. Automatic inlet valve. Suction of piston draws the valve open against the tension of spring. Exhaust valve mechanically operated.

Types of valves: There are three types in general use: the "poppet," the "sleeve," and the "rotary," (see Figs. 85 to 88), the poppet type being used almost exclusively.

The inlet valve admits fresh gas to the cylinder. As fresh gas is going into the cylinder during only one stroke in every four, the inlet valve is opened during only one stroke in every four, in other words, during one stroke in every two revolutions of the crank shaft.

The exhaust valve permits the burned and useless gas to escape. It is opened and held open by a cam on the cam shaft. It is thus described as "mechanically" operated.

Mechanically operated valves are opened and held open by means of cams and closed by means of a strong spring. The **exhaust valve** is always mechanically operated.

Inlet valves are generally mechanically operated, but some of the old and motorcycle type of engines have the inlet valves of the "automatic" type.

The **automatically operated inlet valve** is held against its seat by a light spring (see Fig. 88). During the suction stroke, the sucking action of the piston, as it travels downward in the cylinder, draws the valve open. At the end of the suction stroke, when the suction ceases, the spring forces the valve disk back to its seat, and the gas is prevented from escaping through the valve.

It must be understood that the valves of a gasoline engine always open in such a direction that the pressure from power and compression strokes tends to keep them firmly on their seats.

Valve Operation and Location

The **"mechanically"** operated **"poppet"** type valve is the type in general use, therefore we shall confine our attention to this type.

Valves are operated, or opened, by the intermittent motion of a cam and are closed by a strong spring.

The **location of the valves** may be overhead or on the side, or a combination of both.

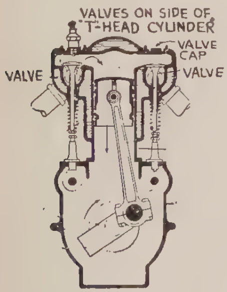


Fig. 89

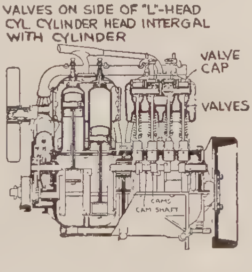

VALVES ON SIDE OF "L"-HEAD CYL CYLINDER HEAD INTERGAL WITH CYLINDER
VALVE CAP
VALVES
CAMS
CAM SHAFT

Fig. 90

Valves-on-the-side may be placed on opposite sides of the cylinder, as in the "T"-head cylinder type of engine (Fig. 89), or all on one side, as in the "L"-head cylinder type of engine (Fig. 90). Valves are operated by a cam shaft on the side.

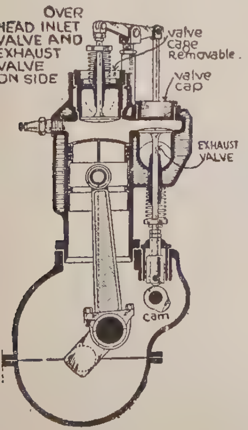


Fig. [illegible]

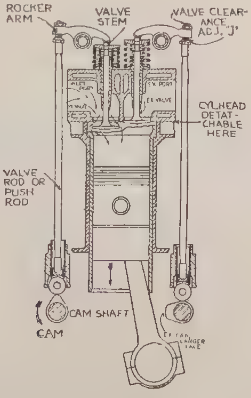


Fig. 92

Valves-in-the-head-and-side are illustrated in Fig. 91. In this instance, the overhead valve is always the inlet, and the valve on the side is the exhaust valve. Both valves in Fig. 91 are operated by one cam shaft on the side. The cylinder is of the "L"-type.

Valves-in-the-head (or both valves placed overhead) with a **detachable cylinder head** are shown in Fig. 92. The head is usually detachable from the valves. Thus valves are ground in the detachable cylinder head.

Note. Although Fig. 92 shows two cam shafts and valve rods on opposite sides of the cylinders, this is seldom found in actual practice. In most instances there is but one cam shaft, and the push rods are all on one side.

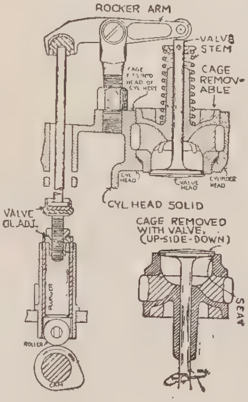


Fig. 93

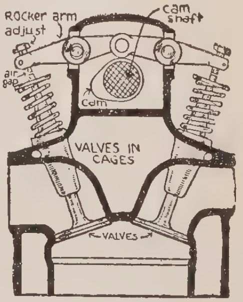


Fig. 94

Fig. 93. Illustration of solid cylinder head with removable cage, with valves ground in the cage.

Fig. 94. Overhead valves operated by an overhead cam shaft.

Valves-in-the-head (or both valves placed overhead in a solid cylinder head) are in cages which are removable and the valves are ground in the cage (Fig. 93). Valves are mechanically operated from the side by the cam shaft.

Valves-in-the-head operated by an overhead cam shaft are shown in Fig. 94. This principle is used on the Liberty Engine and on many other aviation engines.

The method of **driving the overhead cam shaft** is shown in Fig. 95. Note that the shaft (S) which drives the cam shaft is driven from the crankshaft gear. This principle is similar to that employed on the Stutz racing-car engine (Fig. 98).

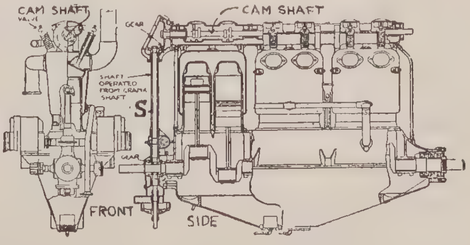


Fig. 95. Wisconsin six-cylinder aviation engine which has a valve action quite similar to that used on the Stutz racing cars. The cam shaft is carried overhead.

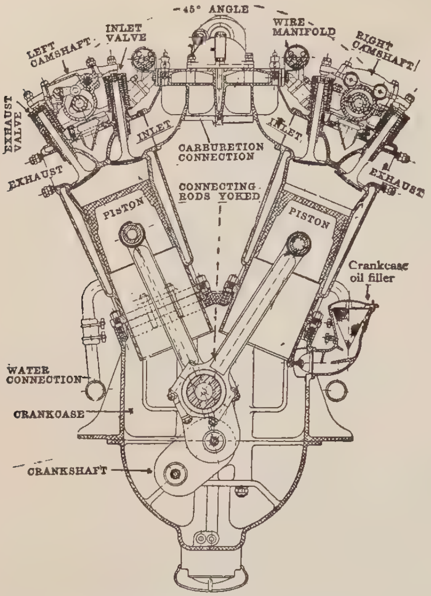


Fig. 96. A twelve-cylinder, or "twin-six" engine with valves-in-the-head operated by overhead cam shafts. This is the Liberty Airplane engine. The cam shaft is driven in a manner similar to that shown in Fig. 95.

The Dual Valve Engine

Dual valves are valves with two inlet and two exhaust valves to each cylinder. The Pierce-Arrow six-cylinder engine (Fig. 97) is an example of a dual-valve engine. The cylinders shown in the illustration are of the "T"-head type, with detachable head, cast in pairs, with a cam shaft on each side.

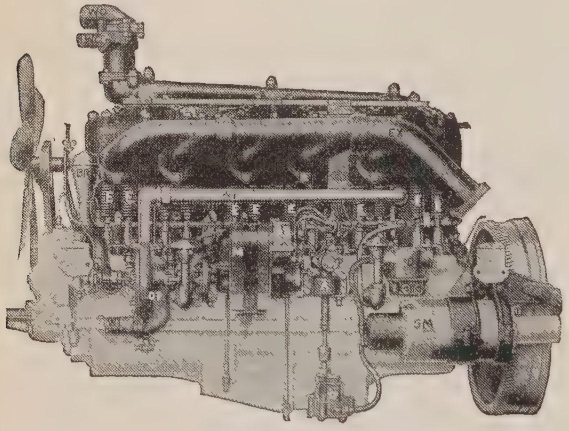


Fig. 97

Exhaust valves (**EE**) are on the left side of the engine and the inlet valves are on the right. This would be termed "valves-on-the-side." On the late model of Pierce-Arrow engines the cylinders are in-block.

Note. The left or right side of an engine or automobile is determined by being seated in the car, looking toward the front.

The Stutz engine (Fig. 98) is another example of dual valves, with both valves-in-the-head of the cylinder operated by an overhead cam shaft.

Advantage of dual valves: It is well known that greater power, especially at higher speeds, is obtained by using large valves. For instance, in standard practice, the rule is to have the valve diameter one-half that of the bore of the cylinder. For a 4½″ bore, a 2¼″ valve is used. In order, however, to get the maximum possible power, a 3″ valve with a ⅜″ lift would give greater power, but this would result in noisy valves, due to the heavy valve spring required to close them promptly, and also on account of the tendency of the exhaust-valve head to warp out of shape when heated.

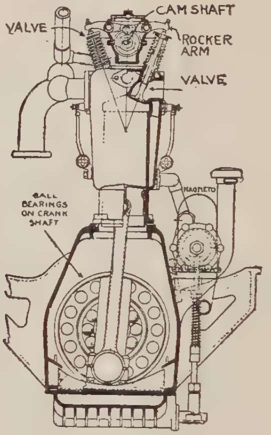


Fig. 98

Therefore, by using two smaller valves of about 2⅛″ diameter with a ⅜″ lift, the same opening area as the single 3″ valve is obtained. This gives the maximum power and a very quiet valve action through the use of light valve springs.

Valve Arrangement

On the "L"-head type of cylinders, all inlet and exhaust valves are on one side, but they do not run consecutively. Owing to the fact that the exhaust manifold must connect with all exhaust valves and the inlet manifold must connect with all inlet valves, the valves are usually arranged as in the illustrations above. The exhaust is on the outside, next to the water jacket on most all engines, because of the greater heat at the exhaust valve. Fig. 99 shows a four-cylinder engine; Fig. 99**A** illustrates a six-cylinder engine. ("X" are exhaust valves).

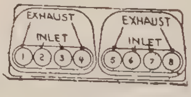


Fig. 99

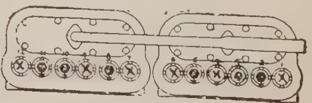


Fig. 99A

Fig. 99. Four-cylinder exhaust and inlet valves.

Fig. 99**A**. Six-cylinder exhaust and inlet valves. "X" are exhaust valves.

Although the valves vary in location and methods of operation, the principle or purpose remains the same; the inlet to admit fresh gas, and the exhaust valve opening at the correct time to expel the burned gas.

Valve Parts

Valve heads are made of cast iron, nickel steel, and tungsten steel. Cast iron is easily machined and works fairly well, but is heavy. Nickel steel does not heat as much as cast iron and does not expand as much as cast iron. Nickel steel heads are electrically welded to steel valve stems. Tungsten steel is hard and stands high temperature without heating. The **"poppet"-type valve** is the type in general use. We shall, therefore, confine our attention to this type. A "poppet"-type valve has **three parts:** a "head," a "stem," which forms the moving part, and a "valve face" which seats into a "valve seat." This valve face is beveled and is perfectly round. When seated, it must fit the valve seat perfectly tight, otherwise during the compression stroke the gas would leak, and on the power stroke, a loss of power would result by the valve leaking at the seat. Therefore it is ground to this seat.

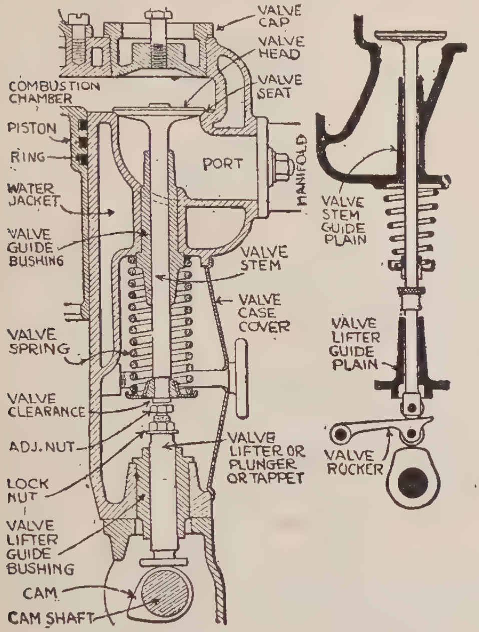


Fig. 100 Fig. 101

Figs. 100 and 101. Two methods of operating the lift of the valve. Note in Fig. 100 that the lift is direct from the cam to the tappet, thence to valve stem, whereas in Fig. 101, a valve rocker arm takes the place of valve tappet. The method shown in Fig. 100 is the one in general use.

The expression **"valve-head diameter"** usually refers to the clear opening of the valve. The "valve-head" is the upper part of the valve and usually measures from one-third to one-half of the cylinder diameter. For instance, on the Continental model "7R" six-cylinder engine, which has a cylinder bore of 3¼", the diameter of the valve at the clear opening, or the small end of the bevel, is 1½", and at the head, or largest diameter, it is 1⅝". Both inlet and exhaust valves on this engine, as also on many others, are the same size.

The **valve lift** of this engine ("7R"), is 5/16". On the Pierce-Arrow, the valve lift is 11/32". "Valve lift" means the height the valve is raised from its seat by the cam. Therefore it is clear that if the valve stem clearance is not correct (the space between the end of the valve stem and the valve lifter), the lift would not be correct, and thus power would be lost, owing to the smaller valve opening. As a result of this, less gas would be drawn into the cylinder.

Valve seats are usually beveled at an angle of 45°. The diameter of the exhaust pipe should at least be equal to the diameter of the valve.

The valve spring holds the valve tight in its seat and must have sufficient tension at all times. If too strong, the valve will close with more noise. If too weak, the valve will not seat properly. The exhaust valve spring usually weakens first on account of being subjected to greater heat.

The valve-spring-retainer-and-lock, originally called the "valve spring washer," is placed at the bottom of the spring and held in place by a two-part lock. Formerly, a "key" was passed through a hole in the valve stem as in Fig. 104, but, as stated, a two-part lock is now placed in a groove in the valve stem under the retainer (washer).

The **valve face** is the beveled part of the valve head. The **valve seat** is the part of the cylinder head in which the valve face is placed. The valve face and seat can be conical or flat. It is usually conical, as in Figs. 100 and 102.

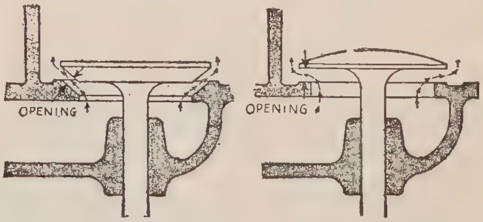


Fig. 102 Fig. 103

Note the conical type of valve in Fig. 102 and the flat type in Fig. 103. It is said that the flat valve gives a greater opening for the same valve lift and has greater possibilities for high-speed work. Seldom used.

The **"tulip"-shaped valve** is another type, formerly used on the Cadillac for inlet valves. It is now seldom used (see Index).

The **valve stem** is the stem part of the valve head. The stem of a mechanically operated valve on the "L"- or "T"-head cylinder of the "side valve" principle usually extends about half-way down to the cam shaft. A valve lifter then lifts the valve stem by action of a nose on the cam as the cam revolves. To set this cam to raise the valve at the proper time, is called "valve timing."

On engines with overhead-valves, there is a rod, called the **"push rod,"** or **"valve rod,"** between the valve tappet and the rocker arm (see Fig. 92, page 53).

Note that a spring is placed between the valve tappet and the valve rod, which tends to keep the tension of the valve rod up and to reduce noise.

Valve-stem-clearance, also called "air-gap," is the distance between the lower part of the valve stem and the valve tappet. On the overhead, or valve-rod type, it is usually between the rocker arm and the end of the valve stem. This distance is regulated by an adjusting nut.

The **valve-lifter,** also called "valve plunger," "valve tappet," and other names, is the part placed between the valve stem and the cam. The top part has an adjustable screw which can be slightly raised or lowered to obtain correct valve clearance.

Exhaust cams usually have a broader nose than the inlet cam, because the exhaust valve remains open longer.

The bottom of the valve lifter is sometimes fitted with a "roller," (**R**), (Fig. 106). The "mushroom" type (Figs. 100, 104 and 105) is the type used most.

A valve rocker—upper—is used on all overhead valves, also called "rocker arm." A valve rocker—lower—is the principle shown in Fig. 101. It is also called a "side tappet lifter." The latter is seldom used.

A valve-stem guide holds the part through which the valve stem passes (Fig. 100). Sometimes it is bushed as shown in Fig. 100. Quite often it is plain, as in Fig. 101.

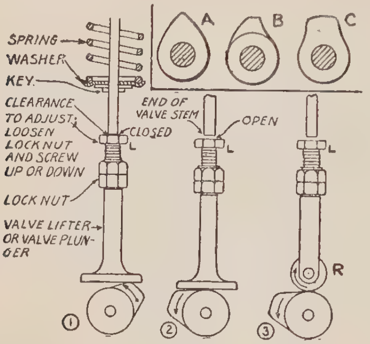

A
B
C
SPRING
WASHER
KEY
CLEARANCE TO ADJUST; LOOSEN LOCK NUT AND SCREW UP OR DOWN
LOCK NUT
VALVE LIFTER OR VALVE PLUNGER
END OF VALVE STEM
CLOSED
OPEN
L
L
L
R
①
②
③

Fig. 104 Fig. 105 Fig. 106

Figs. 104, 105. Mushroom type of valve lifter.

Fig. 106. Roller type of valve lifter.

Note in Fig. 104 the valve just starting to lift. In Figs. 105 and 106, the valve is just closed.

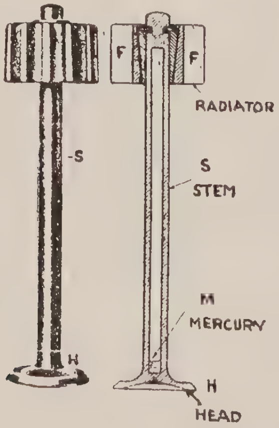
A **valve-lifter guide** (also called "plunger" and "tappet" guide) is shown in Fig. 100, which is fitted with a bushing and can be renewed when worn. It is bolted, sometimes screwed, to the crank case. In Fig. 101, a plain guide is shown.

Enclosed valves are where a cover fits over the valves (Fig. 100). This deadens the noise of the lifter when striking the valve stem and keeps out dust.

Although valves may be placed overhead, or in a combination, as overhead and on the side, the principle of operation is very much the same in either case.

Mercury-Cooled Exhaust Valve

The mercury-cooled exhaust valve is a type of valve at one time used on one of the farm-lighting-plant engines. With high-duty internal combustion engines the exhaust valve is subjected to direct blasts of exhaust gases of about 1,800°F. The only provision heretofore made for radiating the heat from valve head (H) and the stem was through the valve guide. As a result, the stem often became red hot, with the consequent result, warping and loss of compression at the valve seat.



Principle: The effect of the mercury contained within the valve is of course to transmit the heat from the hottest part of the valve up to the portion of the valve stem which is exposed to the atmosphere, and which has a series of aluminum radiating fins (F) connected therewith, to facilitate the cooling of the valve.

The mercury (M) under normal temperature is in liquid state and rests at the bottom of the valve stem. As heat is absorbed by the valve stem and transmitted to the mercury, the mercury is vaporized and immediately rises, until, coming into contact with the cooler part of the valve stem, it will undoubtedly condense and flow back to the bottom of the stem to be again vaporized and to repeat the previous operation.

Purpose of Valve Grinding

The **exhaust valve** is surrounded by a flame when open, and will become "pitted" in time, as shown in Fig. 107.

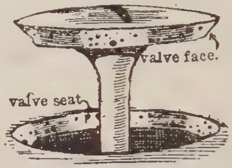


Fig. 107

The exhaust valve requires more grinding than the inlet valve because the hot gases pass out between the valve seat and the valve face when the valve is raised. When the valve is opened, there must be sufficient space to permit the burned gas to pass freely.

The **inlet valve,** admitting gas instead of ejecting a flame, does not pit as badly as the exhaust valve.

In **a perfect seated valve,** the valve face and seat are smooth and even, with dull-gray surface. **A pitted valve** is rough, uneven, and full of tiny holes, and cannot come to a tight seat. A valve in this condition, therefore, must be ground.

The process of grinding a valve is the placing of a grinding paste between the valve face and the seat, and revolving the valve until the roughness is worn down. See Index under "Valve grinding" and "Valve re-seating."

There are several prepared valve-grinding pastes on the market, but a very satisfactory abrasive may be had by mixing flour of emery, of the grade known as No. 120, with a little kerosene or thin lubricating oil, until it has the consistency of paste.

To grind valves in an engine where valves-are-on the-side, the usual plan is to remove the valve caps, if the cylinder head is solid, as in Figs. 108, 109 and 110, and to grind the valves in their seats.

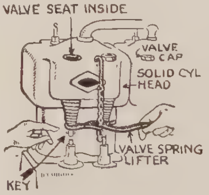


Fig. 108

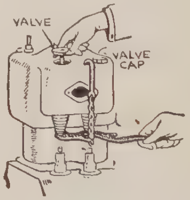


Fig. 109

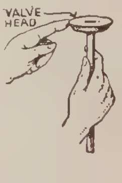


Fig. 110

Fig. 108. **To grind valves in a solid cylinder head,** remove the valve caps; remove the pin (or valve retainer) at bottom of the valve stem. A spring lifter is used to compress the spring.

Fig. 109. Lift valve out of cylinder.

Fig. 110. Smear valve grinding compound around edge of valve. Replace valve in its seat and grind, by turning valve back and forth on its seat until both the valve and seat show a bright ring about 1/32" wide all the way around. Remove all abrasive matter carefully before replacing.

To grind valves in an engine with valves-on-the-side, with a detachable cylinder head, the cylinder head is removed as shown in Fig. 111, and the valves are ground in their seat on the cylinder block as in Figs. 108, 109, 110.

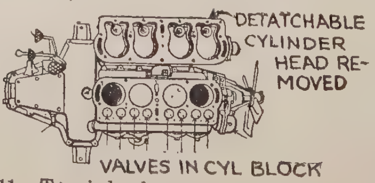


Fig. 111. To grind valves on an engine with valves on the side and detachable cylinder head (Ford engine).

To grind valves in an engine with valves-overhead and with a detachable head, the cylinder head is removed and valves are ground in the head as in Figs. 111 to 115. (The Chevrolet is shown as an example.)

To grind valves in an engine with valves-in-the-head and in cages, remove the valve cage and grind the valve in the seat of the cage. See Index under "Valve grinding, cage type."

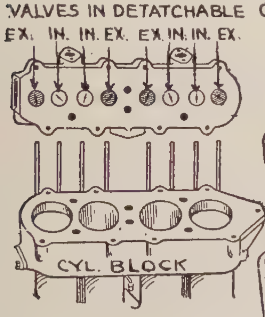

VALVES IN DETATCHABLE CYLINDER HEAD
EX. IN. IN. EX. EX. IN. IN. EX.
CYL. BLOCK

Fig. 112

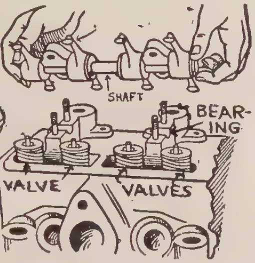


Fig. 113

Fig. 112. Cylinder head removed.

Fig. 113. Remove shaft and rocker arms.

Procedure: Disconnect the upper radiator hose connection. Remove each of the bolts holding the cylinder head to the cylinder casting and lift the head off. The valves, rocker arms, and bearings, being attached to the head, will remain with it as shown in Fig. 112. Next remove the rocker arms and shafts as shown in Fig. 113. Before removing, the bearing caps should be marked with a center punch, so that they will not become mixed when replacing. Next remove the small wire holding the valve-spring cap pin in place (Fig. 114). With a screwdriver and your fingers press down upon the valve spring cap until a spring has been compressed enough to admit pulling out the pin. Remove each valve separately, using care not to mix them in any way, as they must go back into the same valve holes.

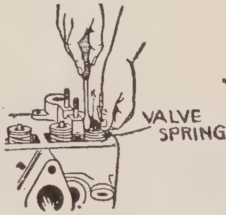


Fig. 114

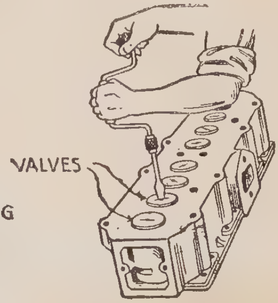


Fig. 115

Fig. 114. Remove valve springs.

Fig. 115. Grinding the valves in the cylinder head.

Grinding: Secure a light coil spring and place it around the valve stem before replacing it for grinding. Smear the compound thinly on the beveled edge of the valve head and on the seat in the cylinder head. Place the valve in the up-turned cylinder head and grind as shown in Fig. 115.

Before replacing the valves it is a good plan to scrape off all carbon deposit from the combustion chamber and piston. Also examine the copper asbestos gasket before replacing the cylinder head. If not perfect, a new gasket should be used.

When replacing the cylinder head bolts, turn each one until the head just touches the cylinder head, then tighten each one evenly, a little at a time. None should be drawn tight until all are set snug.

Refacing Valves and Reseating Valve Seats

If valves become pitted and leak, they need regrinding. If warped, or shoulders form in the seat, then the seat and valve ought to be refaced. See Index under "Reseating valves." This subject is covered in the section devoted to "Repairs." Tungsten valves are hard and when pitted or leaking must be refaced.

INSTRUCTION No. 9

VALVE TIMING: Valve-Stem Clearance; Valve Lift; Setting the Valves; Meaning of Degrees.

VALVE-STEM CLEARANCE

If no space was left between the end of valve stem and tappet, even very slight wear of the valve and seat would prevent the valve from closing properly. Furthermore, there must be some cognizance taken of the expansion due to heat. As the stem expands, it gets longer, so if no clearance were provided the stem would rest against the tappet and would be unable to seat properly.

Valve clearance, also called "air-gap" space, is the space between the end of the valve stem and the lifter ~~or~~ plunger. The width of this air gap ranges from the thickness of tissue paper to 1/16″. The average gap is somewhere about, or slightly less than, postal-card thickness.

Some manufacturers give about 1/1000″ less space to the inlet than to the exhaust, because the exhaust valve stem lengthens more, owing to greater heat. For instance, Hudson gives .004 of an inch to the "air space" on the inlet valve and .006 to the exhaust. It is necessary to adjust the valve-stem clearance when valves become worn and thus lowered, as a result of repeated grinding, or where the valve is in a cage the end of the valve stem or rocker arm or push rod becomes worn, owing to the constant tapping, which causes natural wear in time.

When the distance is too great between the valve stem and the tappet, as a result of wear or improper adjustment, this will produce a clicking noise and can be overcome by proper adjustment. Often a noise which sounds as if coming from the valve stem will be found in a worn valve tappet in its guide, and the noise is thus caused by the cam shifting the valve tappet against its worn guide. In fact, this is a very common trouble. The remedy is to replace the tappet with a new one.

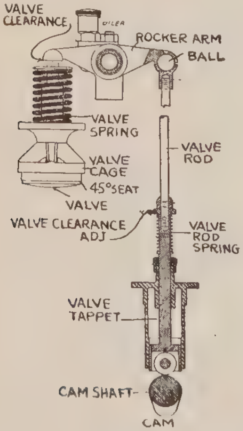


Fig. 1

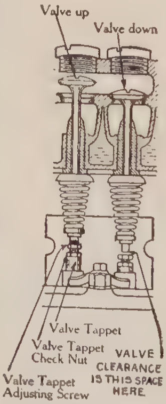

Valve up
Valve down
Valve Tappet
Valve Tappet Check Nut
VALVE CLEARANCE IS THIS SPACE HERE
Valve Tappet Adjusting Screw

Fig. 2

Fig. 1. Valve clearance on valves-in-the-head is measured between the end of the rocker-arm and the top end of valve, as above.

Fig. 2. Type of valves on side of "L"-head engine. Clearance is adjusted as shown in illustration. (Hudson six.)

Adjustment of valve clearance where the valves are on the side, as in Fig. 2, can be made by screwing up the adjusting screw if there is too much clearance, or screwing down the adjusting screw if clearance is not great enough. When the correct position is found, the valve-tappet adjusting screw is locked in position with the lock nut.

Adjustment of valve clearance where the valves are in-the-head and rocker-arms over head can be made at the lower part of the valve push rod, if arranged as shown in Fig. 1, which adjusts the clearance between the end of the valve stem and the rocker arm.

On the valve-in-the-head type (Fig. 92, page 53), the adjustment is on the top of the valve push-rod (J). The clearance given to valve stems in this instance is .003″ to .010″ between the valve stem and the rocker-arm, when the valve rod is entirely free from the cam, or when it is not riding the cam. The adjustment is made when the engine is warm.

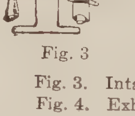


Fig. 3

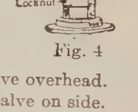


Fig. 4

Fig. 3. Intake valve overhead.
Fig. 4. Exhaust valve on side.

The **Essex overhead inlet valve** is adjusted between the upper push rod and overhead rocker-arm (Fig 3). The exhaust valve is adjusted on the side between the tappet and valve stem (Fig. 4). The inlet is overhead and the exhaust on the side, both mechanically operated from one cam shaft on the side. On the Continental model "7R" engine (side-valve type) the inlet valve is given .004″, and the exhaust valve .005″ clearance. The exhaust valve is given slightly more clearance because it is subjected to a higher degree of heat than the inlet, and, when iron is heated, it expands. The instructions are to adjust when the engine is warm.

Hupmobile instructions call for .004″ clearance for both valves, when the engine is warm.

Pierce-Arrow instructions are to adjust the inlet for .003″ clearance and the exhaust for .005″ clearance, when warm.

Locomobile instructions for Model "48" are to adjust the inlet valves .001″ and the exhaust .004″, when the engine is cold.

Packard "twin six" gives for the inlet and exhaust valves a clearance of .004″ when cold.

Studebaker "Light Six" instructions are to adjust both valves for .004″ clearance with the engine warm.

Studebaker "Big Six" and "Special Six" should have .005″ clearance when the engine is warm, or .008″ when cold.

Some manufacturers give instructions for certain clearances when the engine is warm, and others when the engine is cold. When the engine is warm, appears to be the logical time for adjusting clearance, because the expansion and length of the valve stem are greatest at this time, as the stem expands or lengthens when warm and contracts or shortens when cold.

While it is true that the valve stem expands when heated, it is also true that the cylinders and other metal parts of the engine expand at the same time. In extreme cold weather, the probabilities are that the cylinder contracts and expands to a greater extent than does the valve. This is a problem that has never been definitely settled. Thus the subject of valve clearance is one where expansion and contraction of the metals are factors governing the clearance. Accordingly, one should follow the manufacturers' instructions as to the exact clearance to be given on an engine, as they have no doubt learned the correct clearance from experience.

The usual clearance is from .003″ to .005″, and most of the adjustments are made when the engine is warm. Clearance varies according to size of the engine and also according to the temperature; an engine running unusually hot would require more clearance, as expansion would be greater. By referring to the Index, a table will be found giving the diameter of valves and the valve clearance of different makes of engines.

In the absence of explicit instructions, give the engine .006″ clearance when cold, and after it has warmed up adjust it to about .003″. In this way one will be safe. It is also advisable to **check the valves** to see if they open and close at the proper time. This can be done by observing the marks on the fly wheel and noting if the valves close accordingly.

Valve-Clearance Adjustment

Adjustment should always be made after the valves of an engine have been ground, as the grinding may slightly lower the valve. When checking the adjustment of valve-stem clearance, turn the fly wheel of the engine over until the other tappet and valve in the same cylinder are up as far as they will go, or the valve is wide open. The first valve will then be closed. The clearance should then be measured between the end of the valve stem and the head of the tappet screw.

If it is found that the clearance is not right, loosen the lock nut on the tappet screw and turn the screw up or down, as may be required, to obtain the correct clearance.

It is best to use a "thickness gauge," but if a gauge is not obtainable a piece of newspaper will serve as a gauge. A sheet of ordinary newspaper is between .002″ and .003″ thick. After the tappet screw is adjusted so that the clearance is correct, tighten the lock nut. "Back lash" or lost motion in the cam-shaft driving gears should be taken up in the direction of rotation (crank-shaft drive gear) when clearance is adjusted.

A noisy valve tappet, resulting from wear, and where no adjustment is provided, can be, in some instances, remedied by placing fibre or steel washers under or over the valve ends.

The opening and closing time of the valve is not when the lifter begins to rise, or comes to rest, but when it makes or leaves contact.

Valve-Clearance Pointers

If the engine has good compression when cold and lacks compression and power when hot, this may indicate a lack of sufficient clearance between the valve tappet and valve stem. When cold, the valve seats properly, but when hot, metal expands. Therefore lengthening of the valve stem by expansion causes the valve to seat improperly, with a loss of compression and power. Experienced auto mechanics are aware of the fact that **when an engine has good compression the force of the combustion during the power stroke is greater** than if the engine has poor compression. Thus, since the force is greater with high compression, if there are any parts even slightly loose, such as bearings, too much piston clearance, loose piston pin, etc., a hammer-knock sound will occur and be the more noticeable the higher the compression. Frequently an automobile owner will drive his car in and tell the repairman to "take out the knocks." The repairman immediately proceeds to give the valves less clearance, which quiets the valves and at the same time relieves the knocks in the engine to a certain extent. This results from the fact that when the valves are given less clearance than they should have, the valve opens early and closes late, which reduces the compression, thus reducing the combustion and expansion force on the piston. As a consequence the noise is reduced, but power is sacrificed. **This is bad practice. The proper procedure would be** to properly adjust the valve clearance in the manner designed for the particular engine, and then to take up on the parts inside of the engine that are loose. And if there is a piston slap, be careful to replace the piston with a larger one.

Valve Lift

The inlet cam has a sharp nose. The exhaust cam has a broader nose, because it must hold the valve open longer. The **height of the nose, less the air gap, regulates the lift.** The average lift of either the exhaust or inlet valve is approximately 11/32″ to ⅜″. It is thus evident that if the air gap between the valve stem and the tappet is too large, the valve will not open at all.

If the air gap is increased, the valve will lift very slightly and stay open but a few degrees. If the air gap is **decreased,** the valve will open sooner, rise higher, and close later. This process can be repeated until there is no air gap left.

Therefore, suppose an engine was designed to have 1/16″ air gap and there was no air gap at all; the valves would open possibly 50° too soon, rise 1/16″ higher than intended, and close 50° too late.

In case of **wear of the end of the valve stem or tappet,** it is apparent that as the wear increases, the space or air gap increases, and valves will have less lift, open late and close early, and become more noisy, all of which will affect the power of engine. The valve lift on the **Continental** Model "7R," six-cylinder engine, with 3¼″ bore, by 4½″ stroke, with 1½″ valves, is 5/16″. The **Pierce-Arrow** six-cylinder engine, with a bore of 4″ x 5½″ stroke and using 1⅝″ valves, has a lift of 11/32″. The **Locomobile** six-cylinder engine, model "38," has 5/16″ lift; model "48," a larger engine, has ⅜″ lift.

VALVE TIMING

Before the reader can thoroughly master the subject of valve timing he must first learn the **four-cycle principle** as explained on pages 31 and 32, as it is with this principle we shall deal. In addition, the **meaning of degrees** as explained below, and the **relation of the valve-cam speed to the engine crank-shaft** speed and the importance of **valve clearance** adjustment must be thoroughly understood.

Meaning of Degrees

Suppose we take a fly wheel and divide its circumference into 360 equal parts (Fig. 1); each part would be a degree—expressed with a small "°" as 360°. In fact, any perfect circle can be divided into degrees. The crank shaft revolves in a circle; therefore we will designate the travel of the crank shaft in degrees. Any circle, or, say, travel of the crank pin, would represent 360° when it made a complete circle or revolution. One-half of the circle would be 180°, which would represent a stroke of the piston, or a half-revolution of the crank. One-quarter of the circle would be 90°; one-third of the circle would be 120°.

Note. The fly-wheel movement in the illustrations below is to the left, or counter-clockwise. We are supposed to be looking at the rear, or fly-wheel end of the engine for this purpose.

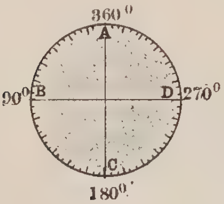


Fig. 1

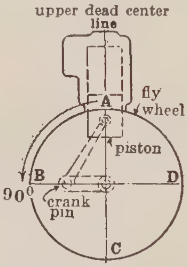


Fig. 2

In Fig. 2, the piston has traveled down from upper dead center, one-quarter of the circle, or one-half of a stroke; the crank pin and fly wheel have turned 90°.

Note. The piston in actual practice will have moved slightly more, depending upon the length of the connecting rod, as will be explained farther on.

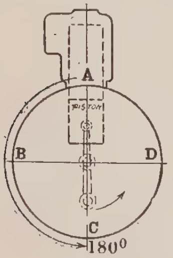


Fig. 3

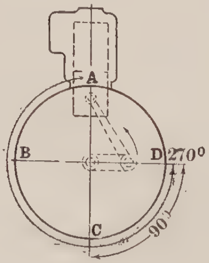


Fig. 4

In Fig. 3, the piston has traveled from top dead center to the bottom of the stroke; the fly wheel and crank pin have traveled 180°.

In Fig. 4, the piston has traveled up from bottom one-half of a stroke, the crank pin and fly wheel have traveled one-quarter of a circle from bottom, or 90° from **C** to **D**. In all, the crank pin and fly wheel have traveled from **A** to **D**, three-quarters of a revolution, or 270°.

In Fig. 5, the piston has made two strokes, one down and one up; therefore the crank pin and fly wheel have made a complete revolution, from **A** back to **A**, or 360° in all.

The idea is to learn that the crank pin travels in a circle and the fly wheel travels in a circle, and a revolution is a complete circle, and a complete circle is 360°. **The piston travels in strokes,** each stroke representing a half-revolution of the crank. If we spaced off 360 marks, equal distances apart, on any circle, then each mark would be called a degree. In Fig. 1, we have spaced off the marks as 5 degrees each.

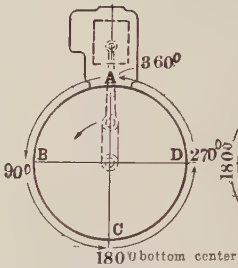


Fig. 5

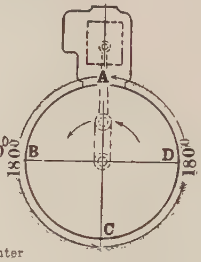


Fig. 6

Meaning of Minutes and Seconds

Now we can divide each degree into, say, sixty equal distances, and call each part or mark a "minute." We could go still farther, and divide each minute into sixty equal distances, and call each part or mark, a "second."

A minute is usually expressed with a single mark after the figure, as, 25′. A second is expressed with two marks, as, 25″.

Note. An inch is also designated with two marks, thus (″), and a foot with one mark, thus (′).

Example: Express ten degrees, six minutes, and five seconds. It would be as follows: 10° 6′ 5″.

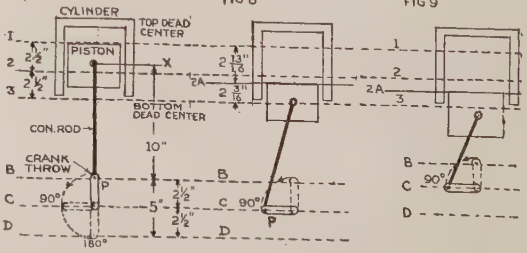
To find the circumference of a fly wheel: Multiply the diameter in inches by 3.1416. If the circumference is then divided by 360, the distance or portion of the fly wheel circumference equivalent to one degree may be ascertained.

Uniformity of Piston Movement Governed by Length of Connecting Rod Relative to Crank Throw

From the foregoing explanations of the piston movement relative to that of the crank throw, it would appear to the reader that when the crank pin moved 90° or one-fourth of a revolution from top dead center, the piston would have moved down exactly one-half of its stroke. This is not correct.

For example, the crank throw is always one-half of the stroke of the piston, or the piston stroke is twice the crank throw; that is, where the cylinders are centrally located, or in line with the crank shaft.

FIG. 7 FIG 8 FIG 9



Figs. 7, 8, and 9. Relative position of piston to crank on a centrally located cylinder.

As an illustration of this, see Fig. 7, in which is shown a connecting rod 10″ long from the center of the wrist pin in the piston (**X**) to the center (**B**). The crank throw is 2½″ from (**B**) to (**C**), therefore the stroke of the piston would be 5″ when the crank pin (**P**) moves from position (**B**) to (**D**).

The foregoing applies to a full stroke, or one half-revolution (180°) movement of the crank pin (**P**).

In the illustration (Fig. 8) the crank pin (**P**) has moved from top dead center (**B**), down 90° to (**C**), which would appear to indicate that the piston would have moved down from top dead center (1) to (2), or one-half of its stroke, which however, is not the case, as will be seen by referring to Fig. 8.

Note that the piston has actually moved down 2½″ plus about 5/16″, or 2 13/16″ instead of 2½″, which is about 5/16″ **more** than one-half of its stroke. Therefore when the crank pin moves the next 90° (**C**) to (**D**), the piston will have to move only one-half of its stroke less 5/16″ (2½″−5/16″=2 3/16″), which will be **less** than half of a stroke.

The shorter the connecting rod relative to the crank throw, the greater the difference in movement there will be between the upper portion of the stroke and the lower portion of the stroke, as represented by the first 90° movement of the crank pin and the second 90° movement of the crank pin.

An exaggerated illustration is shown in Fig. 9, in which the connecting rod has been shortened, but not the crank throw. Note the difference in piston stroke from (1) to (2**A**) in Fig. 9, as compared with (1) to (2**A**) in Fig. 8, while it will be noticed the crank pin has moved exactly the same in each case, that is, 90°.

Effect of Offset Cylinders

In the foregoing, we have taken as an example an engine with a centrally located cylinder (in line with the center of the crank shaft). Many manufacturers build their engines with offset cylinders; that is, the cylinders are placed to the left (when looking from the fly wheel) of the center of the crank shaft. The most peculiar feature of an offset cylinder is that the piston stroke or travel is no longer equal to twice the crank throw, as in the case of a centrally located cylinder. With an offset cylinder, the stroke is slightly longer than twice the crank throw.

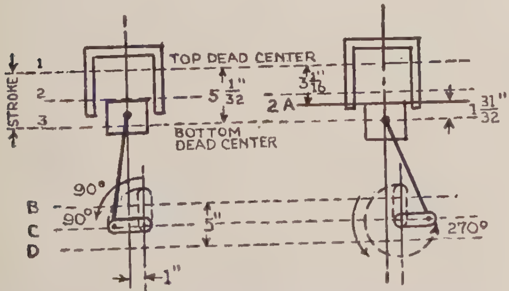


Fig. 10

Fig. 11

Figs. 10 and 11. Relative position of piston to crank on an offset cylinder.

In Fig. 10, we have the same crank throw and length of connecting rod as in Fig. 8, but it will be noticed that by offsetting the cylinder 1″, we have increased the stroke from 5″ to about 5 1/32″.

Another feature to be noticed is that when the crank has revolved 90°, the piston has descended just about one-half of the stroke. Contrast this result with that found in Fig. 8. **The offsetting decreased the effect of angularity during the downward stroke.**

In Fig. 11, when the crank has revolved 270°, it will be noticed that the piston rises only 1 31/32″ (approximately) from bottom dead center. This distance is still farther removed from one-half the stroke than was the case in Fig. 8, consequently **the offsetting increased the effect of angularity during the upward stroke.**

Remarks on Inlet-Valve Opening

It has been explained that the valves are raised by means of cams operated by a cam gear or sprocket placed on the front of the engine, in connection with a gear or sprocket driven from the crank shaft.

If one of the cams raises an inlet-valve just as the piston is starting down on the suction stroke, a charge of gas will be drawn into the cylinder as long as the piston is on the suction stroke and the valve is open. The valve should therefore open in time to give the piston a chance to draw in a cylinder full of gas.

If the valves were to open late in the stroke, a full cylinder of gas would not be drawn in and the power of the engine would be less than what it should be. If the inlet valve opens too early, it will cause back-firing; if too late, a sluggish engine and overheating will result. The inlet-valve timing gear is used for timing the inlet valve to open at the right time, this being done by meshing the gears or setting the sprockets at the right place.

The practice is to allow the piston to descend about an eighth of an inch in the cylinder on the suction stroke before the inlet valve opens, so as to reduce the pressure and create, if anything, a vacuum which causes a greater suction.

Inlet-Valve Closing

It is almost universal practice to leave the inlet valve open until the piston has not merely reached the bottom of the stroke, but has actually traveled slightly up again on the compression stroke. It would seem that under these circumstances part of the gas would be forced out of the cylinder, but this is not the case as the high speed at which the piston is traveling causes the suction to continue for a short time on the compression stroke. This will, of course, vary with the speed of the engine, so that a certain valve setting will not be correct for all speeds, since, if the inlet valve is closed at the correct time for slow speed, it will close too early for higher speeds and less gas will be drawn in than would be the case with correct setting.

However, there is an average speed for all engines, and the valves are set to it accordingly. This average speed on most engines is approximately 1,000 revolutions per minute.

Exhaust-Valve Opening

The exhaust valve must open considerably before the piston reaches the end of the expansion stroke, and although this may waste some of the force of the explosion, it is compensated for by the freedom afforded the piston in completing the exhaust stroke.

It would be wrong to keep the exhaust valve closed up to the very moment when the piston is about to move upward, for, on commencing the exhaust stroke, the piston would be confronted for an instant with the force that had just driven it down, and until the valve was wide open, it would be considerably impeded on its journey.

The exhaust valve is usually opened when the piston has moved through about seven-eighths of the power stroke; that is, before bottom of dead center. Exhaust valves opening too early, however, cause pounding and clatter.

Exhaust-Valve Closing

The exhaust valve must not close before the end of the exhaust stroke. Since the gas which remains in the cylinder head is slightly under pressure at the end of the stroke, the valve is often allowed to remain open until the piston has moved slightly down on the suction stroke, so as to give full opportunity for as much exhaust gas to escape as possible.

In order to understand just how important it really is to expel all of the burned or exhaust gas, it must be explained that one of its chief constituents is carbon dioxide—the most powerful anti-combustion agent known to science. Its presence, therefore, even in small quantities, retards considerably the speed of the combustion development.

It will now be obvious from the foregoing that, if the exhaust gases are to be entirely expelled from the cylinders, the valve must be made to close a little later than "top center," or—as it is technically described—must have a certain degree of "lag"; for it is evident that if we close it at the exact top of the stroke, the contents of the combustion head (which we wish to get rid of) will be imprisoned and will contaminate the incoming charge.

The amount of this "lag" will depend on several things—the shape of the combustion head, the weight of the valve, the strength of the springs, and design of the exhaust system.

Valve Effect of "Lag" or Bounce

Valve spring, strength, and weight have to be reckoned with on account of their influence on **inertia lag** as distinct from that which is **intentional,** for it is well known that as the speed of the engine increases the valve tends to "jump" the closing face of its cam and closes later and later as the speed increases. This is what we describe as "inertia lag." There is a point, however, past top center to which the exhaust extraction lasts, and pending this extracting effect the valve should remain open. But if carried beyond this point, a reverse of the exhaust gases may occur, for it must not be forgotten that the piston has now started down on its suction stroke. It becomes a question, therefore, of closing the valve when the scavenging is as complete as possible.

The best design of cylinder head for an **"overlap"** is the round or "I" head with overhead valves. The ordinary "L" head is not so good, and in certain kinds of heads in which the inlet and exhaust valves are small and close together in a small pocket an overlap is quite useless.

On the other hand, it has been found in racing practice, where the exhaust pipe is very long, straight, and open, and the combustion head suitable for scavenging, that a very considerable overlap can be allowed with advantage.

What Governs Valve Timing

The **size of cylinder,** especially in the stroke and in the type of ignition, shape of manifold, and the speed of engine, governs the valve timing.

Early **setting of valves** on an engine will cause irregular running at lower speeds, unless a very heavy fly wheel is used. It will also increase the gasoline consumption in short-stroke engines.

For high-speed work, the inlet may be opened and closed late. For slow-speed work, closing the exhaust and inlet on center gives the best control, and no blowing back.

The **time of opening and closing of valves** with reference to the engine speed of course has an important bearing on its performance. If the valves open too early it will cause **back-firing,** while if they open too late a sluggish engine and overheating will result.

High-speed (short-stroke) engines have a longer time of valve opening than medium or slow-speed engines. The slower-speed engines have the exhaust opening and the inlet closing nearer to bottom center, while some high-speed engines open the exhaust 65° before bottom center and close the intake 70° after bottom center.

Valve timing of different engines will vary according to the intended average speed and the length of stroke. Long strokes are for slower-speed engines than short strokes. Obviously high-speed engines are not efficient at slow speeds, because the inlet closes too late and the exhaust opens too soon, thus losing part of the charge and part of the power stroke. And slow-speed timing on a high-speed engine does not permit of receiving a full charge nor of getting rid of the back pressure during the exhaust stroke.

The value of the **design of the cam** may be, and nearly always is, lost through improper valve clearance or air-gap adjustment.

A point which suggests itself on the timing of the inlet opening, and which also holds true for other operations on the timing circle, is in the securing of a quiet cam. Quietness in the cams is generally secured at the sacrifice of power. A steep cam is as a rule more noisy and more powerful than one giving a slower opening.

To secure the full opening of the inlet valve at a point which will not be too late to permit a full charge to be taken into the cylinder, and yet at the same time to have a cam which will not be noisy, means that the inlet opening will have to be started fairly early. This is one of the points which often induces a maker to sacrifice the vacuum to some extent for the sake of quietness.

Meaning of Valve Lap

The word "lap" is often used in connection with valve-timing, as also in connection with the firing-order of cylinders.

In speaking of the **firing order** of cylinders we speak of one cylinder "lapping" another. For instance, on a certain eight-cylinder engine there are eight periods of 44 degrees travel of the crank when two cylinders are on power, or "lapping" at the same time.

The use of the word "lap" in connection with valve timing means the period of time that both valves are open at the same time, or + (plus lap).

Zero lap: If the exhaust valve closed just as the inlet valve started to open, we should term this, "zero lap" (no lap at all). "Zero lap" means that the exhaust closes at the same time the inlet valve opens. With zero lap there is no vacuum in the cylinder at time of the inlet valve opening.

Minus lap: If the exhaust valve closes before the inlet valve opens, we should term this "minus lap," designated with a (−) mark. The (−) "minus lap," which is the general condition in use on most engines, the exhaust closes an appreciable period before the inlet opens. This permits the piston to descend slightly on the suction stroke before the inlet valve opens, thus creating a vacuum in the combustion space. Therefore, the rush of gases into the cylinder is greater owing to this partial vacuum.

By referring to Fig. 6, page 32, the exhaust valve will be seen to be closed before the inlet starts to open; this would be termed (−) "minus lap."

Plus lap: If the inlet valve opens before the exhaust valve closes, it is termed "plus lap," designated with a (+) mark. The (+) "lap" means that both exhaust and inlet valve are open together for a period of the lap. In other words, the inlet opens before the exhaust closes. The theory is that the inertia or rush of exhaust gases passing out through the exhaust port is sufficiently great to create a partial vacuum, and causes a stronger inrush of fresh gas.

Owing to the fact that the exhaust and inlet gases should not conflict in their direction, the (+) plus lap is generally used on "T"-head engines.

Valve "Lag" and Valve "Lead"

If a **valve opens late or remains open** after it is supposed to close, it is said to "lag." For instance, the exhaust valve is usually allowed to "lag" about 10 degrees after leaving the top of its exhaust stroke before it closes.

The term **"valve lead"** usually applies to the valve opening before the piston reaches top or bottom center. This distance is called "lead"; and when it closes after center, this distance is termed "lag."

For instance, the setting of the spark is sometimes given a "lead," or the exhaust valve is usually given a "lead" of 46 degrees, meaning that it opens before bottom. The faster engines are designed to run, the greater the amount of "lead" or "advance" given the opening of the exhaust, and also the spark, when running.

Periods of Time Valves are Usually Open

Before taking up this subject in detail, we shall again review the relation of the speed of crank shaft to the cam shaft and get the names of the parts clearly in mind.

A stroke is the movement of the piston from the top to the bottom, or from the bottom to the top. This motion is called "reciprocating motion of the piston." When the piston goes either from top to bottom or from bottom to top, the crank shaft turns one-half of a revolution. (This does not hold true where the cylinders are offset.)

Therefore, four strokes of the piston would represent two revolutions of the crank shaft.

The **cam shaft** turns one-half as fast as the crank shaft, because the cam gear is twice the size of the crank-shaft gear which drives it.

The nose of the **inlet cam** is usually shorter on its length of face than the **exhaust cam**, because the exhaust cam holds the valve open a much longer period of time than the inlet cam holds the inlet valve open. The cams which operate the valves are steel forgings, turned and ground to correct shape. They are then case-hardened to decrease the wear, and are usually made as an integral part of the cam shaft.

The **shape of the cam** determines the actual lift of the valve and the time during which it shall stay open. The symbols, A, B, and C, over Figs. 104 to 106 (page 56) show several generally used shapes.

Cams which are pointed give a slow opening and slow closing, the greatest opening being at the middle of the valve-lift period.

Cams which are more nearly square open the valve rapidly, keep it nearly wide open until ready to close, and then allow it to close quickly.

It is customary to design the positioning of the cam shaft and valve tappets, so that the tappets are not directly over the center of the shaft, but are offset slightly on the lift side. This gives a more direct lift instead of a side thrust, as would be the case if they were centered.

In actual practice, **the inlet valve seldom opens on top,** usually after the top of stroke, varying from 5 to 15 degrees flywheel measurement as explained in Fig. 12, (page 64), which opening is 8 degrees after the top of the stroke.

The **inlet seldom closes when the piston reaches bottom,** but from 5 to 38 degrees after bottom. (Fig. 13, page 64.)

The **exhaust valve seldom opens on bottom,** but usually 40 to 50 degrees before bottom (Fig. 14, page 64).

The **exhaust valve seldom closes on top of stroke,** but usually 5 to 10 degrees after top. (In Fig. 15, page 64, the illustration shows the exhaust valve closing on top, in order that the reader may more clearly understand the illustration.)

The cam turns at the same speed as the cam shaft. The nose on the cam raises the valve. Therefore the inlet valve will be raised once during the four strokes, and the exhaust valve will be raised once during the four strokes.

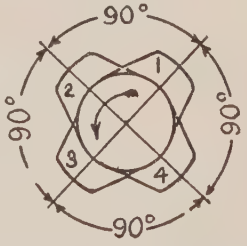


Fig. 11A. This illustration is supposed to represent the movement of the cams during a period of four strokes of the piston, as explained below and on page 33.

By referring to Fig. **11A**, the inlet cam on the first stroke will be found to be in the position of (1), and will turn from 1 to 2, or 90 degrees during the first stroke.

The exhaust cam will then be in position (2), and will turn from 2 to 3, or 90 degrees, during the first stroke.

During each stroke the cam moves 90 degrees, whereas during the same period the crank moves 180 degrees.

Inasmuch as a stroke of the piston is from top to bottom, or 180 degrees travel of the crank, it will be necessary to distinguish the difference between the time of opening and closing of the valves and the period of travel of the crank shaft during the four actions of suction, compression, explosion, and exhaust periods, as explained in the discussion that follows.

Note. When speaking of "top," it refers to **top dead center** (or upper dead center), or when piston is at the top of its stroke, and "bottom," refers to **bottom dead center** (or lower dead center), or when piston is at the bottom of its stroke.

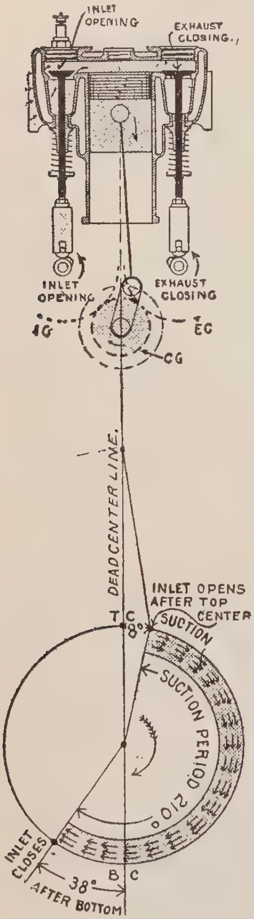


Fig. 12

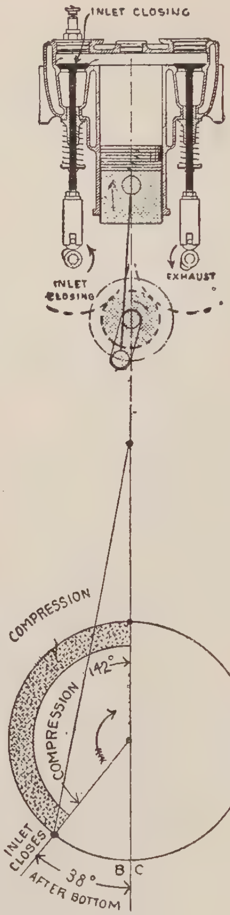


Fig. 13

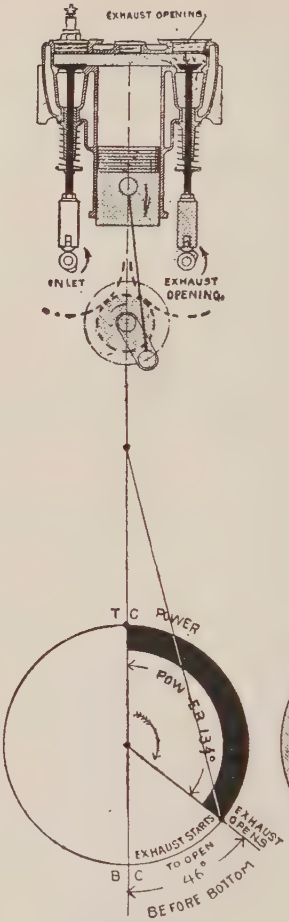


Fig. 14

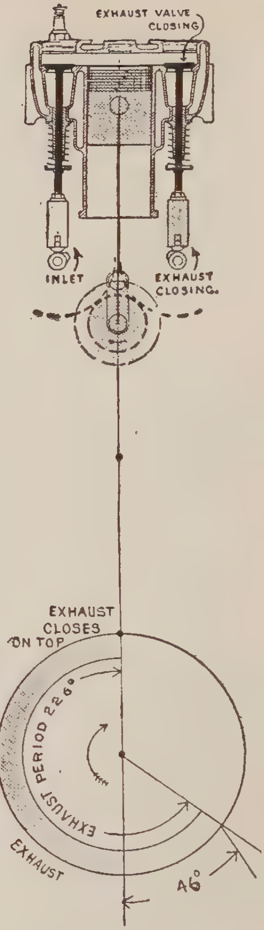


Fig. 15

Explanation of the Period of Suction, Compression Power, and Exhaust

Example: Inlet opens 8° after top, closes 38° after bottom. Exhaust opens 46° before bottom, and closes on top.

Fig. 12 shows the inlet valve starting to open 8° after top center ("TC") (viewing the engine from front); note that the inlet will remain open during the suction period until the crank is 38° after bottom center ("BC"). The period of travel of the crank during the suction period is 210°. The inlet valve is open during this period.

Fig. 13 shows the inlet valve closed. The piston will now travel up on compression to top center ("TC"). The period of travel of the crank during the compression period is 142°.

In Fig. 14, the spark occurs at top (in actual practice, just before the top), therefore, the next stroke down is a power stroke. Note that the period of travel of the crank pin during the power stroke is only 134°, as the exhaust valve starts to open at 46° before bottom. Note, too, that the exhaust cam is just starting to open the exhaust valve.

In Fig. 15, the exhaust opens 46° before the piston reaches bottom. The exhaust valve remains open during a period of 226°, the crank traveling from 46° before bottom, to bottom, thence to top ("TC"). In this instance the exhaust valve closes on top or dead center. In actual practice it usually closes a little after top dead center (about 5° to 10°).

Note. Fig. 15 shows shading of the exhaust period. This shading should extend to the right of the 46° mark.

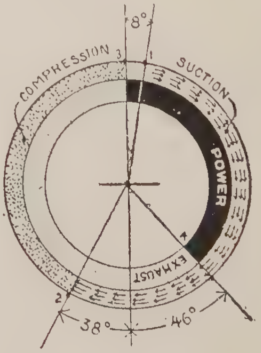


Fig. 16. Illustrates all that is shown in Figs. 12 to 15, combined in one illustration.

Observe the position of the cams during the various periods. The cam turns at one-half the speed of the crank shaft. Therefore, if the crank shaft revolves twice to complete the four strokes, the cams will make one revolution.

Valve-Timing Position

The **position of the crank shaft** determines the position of the piston.

The **position of the piston** determines the point where the valve is set to open or close.

Therefore the cam shaft must be so placed that the cam will raise the valve when the piston is at a certain position.

This is accomplished by **meshing the cam gear with the crank-shaft gear** when the piston is in correct position.

Marks are usually placed by the manufacturer on the cam gears which will indicate just where to mesh gears. The flywheel is also used for timing, if there are marks on it, which is usually the case.

It is also important to secure the proper valve clearance when timing the valve.

Setting Valves on a Single-Cylinder Engine

Suppose the valves are to be set on a single cylinder "T"-head engine, with exhaust to close on dead center, and inlet to open one-eighth inch after top on the suction stroke.

Setting the exhaust valve: First, place the piston (by turning the crank-shaft) to top dead center; then mesh the exhaust cam gear with the crank-shaft gear, so that the exhaust valve is just seating.

Setting the inlet valve: Move piston down one-eighth of an inch from top; mesh inlet cam gear with crank-shaft gear, so that the inlet valve is just starting to rise.

It will be noted that the inlet opens and the suction stroke begins right after the exhaust closes. Therefore the **closing of the exhaust and opening of the intake** is the point to work from.

A matter of importance to remember, is **the spark.** When setting valves, be sure the contact on timer or magneto is set to occur when the piston is on top of compression stroke, a full revolution from where the inlet valve starts to open. (This will be treated under "Ignition timing.")

Setting the Valves on a Multiple-Cylinder Engine

Setting the valves on a multiple-cylinder engine is identically the same operation as timing a single-cylinder engine.

If there is a multiple of cylinders, say four, then there must be at least one inlet and one exhaust valve for each cylinder. Therefore, there must be four cams for the four inlet valves and four cams for the four exhaust valves. The usual plan is to place the piston of No. 1 cylinder at the top of its stroke, and to work from that point.

If the engine cylinders are "T"-head, then there are **two cam shafts:** one for the inlet valves and one for the exhaust valves, placed on opposite sides of the cylinders.

If the cylinders are "L" or "round" head, with cam shaft on the side, then there is usually but **one cam shaft.**

Timing the Valves on a "T"-Head Multiple-Cylinder Engine

On a "T"-head engine, all exhaust cams are on the exhaust cam shaft and all inlet cams are on the inlet cam shaft. Therefore when setting valves on a "T"-head cylinder engine (Fig. 17), there are two cam gears to set, the inlet and the exhaust. If the cylinder is a four or six, or any multiple of these, setting, or meshing the cam shaft gear with the crank-shaft drive gear so that one cylinder is correctly timed, is all that is necessary, as the other cams are fastened permanently on the cam shaft, and must open and close all other valves at the correct time.

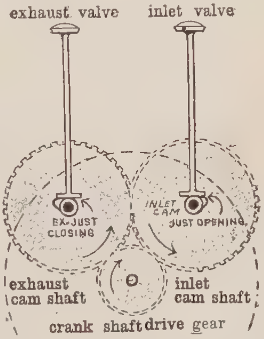


Fig. 17. View from front of engine.

For example, suppose the inlet valve opened on top dead center and the exhaust closed on top dead center. The piston of No. 1 cylinder (front of engine) would be placed at the top dead center of its stroke and the cam gears would then be meshed at this position.

The **setting of the inlet cam gear** would be such that the nose of the inlet cam was just starting to raise the inlet valve in the direction of rotation (see Fig. 17).

The **setting of the exhaust cam gear** would be such that the nose of the exhaust cam was just permitting the tappet to leave the stem of the exhaust valve (Fig. 17).

Timing the Valves on an "L"-Head Multiple-Cylinder Engine

To set the cam for valve opening on an "L"-head cylinder, it is only necessary to set the one cam gear, which is the exhaust cam, at the closing point (see Fig. 18). If the engine has a multiple of cylinders all other cams will then operate as they should, as all exhaust and all inlet cams are on the one cam shaft and are set permanently when the cam shaft is made.

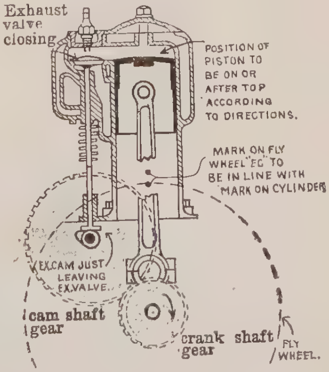

Exhaust valve closing
POSITION OF PISTON TO BE ON OR AFTER TOP ACCORDING TO DIRECTIONS.
MARK ON FLY WHEEL "EC" TO BE IN LINE WITH MARK ON CYLINDER
EX.CAM JUST LEAVING EX.VALVE.
cam shaft gear
crank shaft gear
FLY WHEEL.

Fig. 18. View from front of engine.

The usual plan is to place No. 1 piston in the position where the exhaust valve is to be closed, and mesh the cam-shaft gear with the crank-shaft drive gear at this point. Although it is only necessary to set the exhaust cam so that the exhaust valve will close, on an "L"-type engine, there are marks on the fly wheel which are used for checking the timing. This is explained farther on.

Timing Valves on an "I" or Round-Head Type of Engine

The **overhead valves** are usually operated by push rods, all from one side of the engine and from one cam shaft. Therefore the timing would be the same as for an "L" head.

With an **overhead cam shaft,** the valves are usually operated by one cam shaft. Therefore the principle is the same.

Remarks

It is well to note that even though there are four, six, eight, or twelve cylinders, each of the pistons must pass through the four strokes during two revolutions of the crank shaft, even though two of the cylinders are firing at once during part of the time (which they are in a six, eight, and twelve cylinder engine).

Just how these four strokes are made by each piston during two revolutions of the crank, is explained under "Firing order," farther on.

In a **four-cylinder engine,** remember that, owing to the shape of the crank shaft, pistons 1 and 4 are always up or in line when 2 and 3 are down, or vice-versa. In a **six-cylinder engine,** pistons 1 and 6, 3 and 4, and 2 and 5 are in line.

Before timing the valves on No. 1 cylinder, adjust the valve clearance on this cylinder.

After completing the valve timing on No. 1 cylinder, adjust the valve clearance on the remaining cylinders.

Timing Marks on Flywheel

Usually marks also appear on the circumference surface of the fly wheel, which indicate the position in which the crank shaft is to be placed for correct setting of valves and meshing of cam gear and crank-shaft gear.

The mark on the flywheel is placed in line with a center mark (or a "trammel," also called an "indicator," or a "pointer") on the cylinder, or elsewhere.

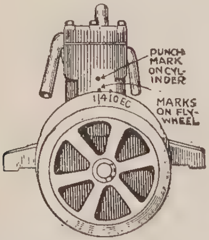


Fig. 19

Note. On engines with unit power plants, instead of the center line being on the cylinder, a small hole at the top of the fly-wheel case is provided, in order that the line and figures on the fly wheel can be seen through the hole.

Valve-Timing "Indicator" or "Trammel"

A trammel or indicator is a stationary starting point on which to base all work. It is sometimes attached to the base of a cylinder or other point, instead of a center line on the cylinder. It is usually directly over, or in front of, the fly wheel, as in Fig. 20 (flywheel indicator).

Example of timing the valves on an "L"-head six-cylinder engine by marks on the flywheel: The exhaust valve closes at 15° past top. It is not necessary to know this, however, as the marks are all that is necessary to follow.

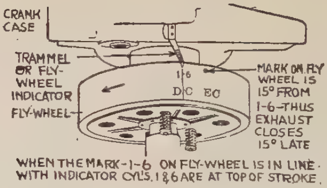

CRANK CASE
TRAMMEL OR FLY-WHEEL INDICATOR
FLY-WHEEL
1|6
D|C EO
MARK ON FLY WHEEL IS 15° FROM 1-6—THUS EXHAUST CLOSES 15° LATE
WHEN THE MARK-1-6 ON FLY-WHEEL IS IN LINE WITH INDICATOR CYL'S. 1 & 6 ARE AT TOP OF STROKE.

Fig. 20. Showing the purpose of an "indicator" or "trammel" as applied to a 6-cylinder engine.

Procedure: When the long mark 1-6 on the fly wheel is in line with "indicator" on the crank case, pistons Nos. 1 and 6 are at their highest points or upper dead center. After turning the fly wheel to this mark, then turn the fly wheel to the left (when behind it) until the small dot mark is under the indicator. This is the point (15°) at which to set the exhaust valve, just closing, and at which point the cam gear should mesh with the crank-shaft gear. Therefore it is plain that setting the exhaust valve just closing, on a 6-cylinder engine with valves on the side, is all that is necessary.

Variation of Valve-Timing Marks (on Fly Wheel)

Sometimes the **marks may vary.** For instance, instead of "1-4 UP" or "1-4 DC," it may appear as, "T C 1-4" (top center 1-4) or "U C 1-4" (meaning upper dead center), or some similar mark meaning the same thing.

Some manufacturers vary their marking on the rim of the fly wheel as follows: Inlet opens "IN-O" or "I. O." Inlet closes "IN-C" or "I. C."

Exhaust opens "EX-O" or "E.O." or "X.O." Exhaust closes "EX-C" or "E.C." or "X.C."

If the figures 1-4 or 2-3 appear after or before any of these marks, as "1-4-IO.," this means the number of the cylinders, as "1 and 4, inlet opens."

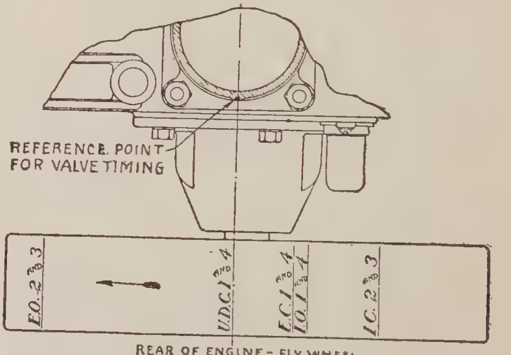


Fig. 20A. Valve-timing marks on the fly wheel of a Reo four-cylinder engine.

For an example of valve-timing marks on a four-cylinder engine fly wheel, see Fig. 20A. Here the engine fly wheel has upon its face the following marks:

I. O., meaning, inlet valve opens.
I. C., meaning, inlet valve closes.
E. O., meaning, exhaust valve opens.
E. C., meaning exhaust valve closes.
U.D.C., 1 and 4, upper dead center; cylinder 1 and 4.
U.D.C., 2 and 3, upper dead center; cylinder 2 and 3.

These points, marked upon the face of the wheel, show where the exhaust and inlet valves of each cylinder should open and close. A reference point (the small boss marked with a cross upon cylinder No. 4, next to dash), is used in this instance, instead of an indicator.

The engine cylinders are numbered 1, 2, 3, and 4, No. 1 being next to the radiator, and No. 4 next to the dash. By referring to Fig. 38, page 45 of crank shafts, previously given, it will be seen that cranks 2 and 3, and 1 and 4 are exactly 180 degrees apart. Therefore the same marking on the flywheel that serves for No. 2 also serves for No. 3, and the marking for No. 1 serves for No. 4, these points being exactly one-half revolution, or 180 degrees, apart, as before mentioned.

Checking the Valve Timing

Although it is only necessary to set the exhaust cam so that the exhaust valve will just close, on an "L"-type of cylinder engine there are marks on the fly wheel which are used for checking the timing.

As an example, a four-cylinder "L"-type engine is used (Fig. 21), with timing scale as an example of checking the timing, as follows:

Dead center of cylinders 1 and 4 are marked on fly wheel "1-4."

Dead center of cylinders 2 and 3 are marked on fly wheel "2-3."

Inlet valve opens 5° past top center, marked on fly wheel "1-4 IN. O."

Inlet valve closes 40° past bottom center, marked on fly wheel "1-4 IN. C."

Exhaust valve opens 40° before bottom center, marked on fly wheel "1-4 EX. O."

Exhaust valve closes 7° past top center, marked on fly wheel "1-4 EX. C."

The same marks appear for cylinders 2 and 3.

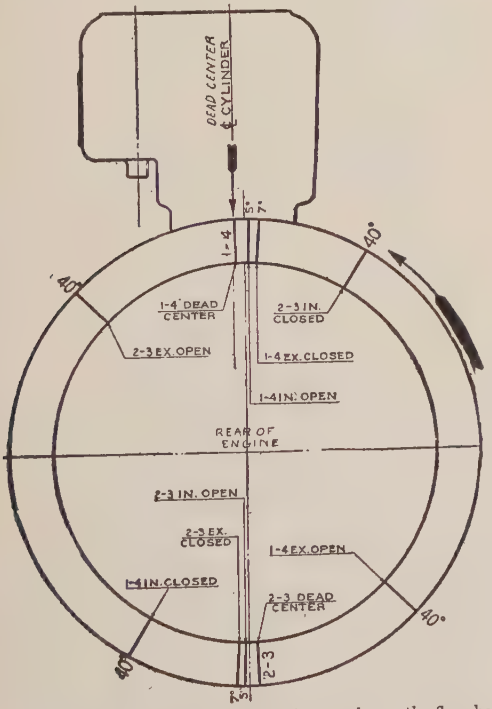


Fig. 21. An example of valve-timing marks on the fly wheel of a four-cylinder engine. See text for checking valve timing from these marks. View from rear of engine. Note that the fly wheel turns to the left.

The purpose of checking the valves is to see that they are opening and closing as marked on the fly wheel.

To determine whether or not the valves are properly timed, first open the relief cocks on top of the cylinders, then have someone crank the engine over slowly until the line marked "1-4" is opposite the center line of the cylinders. At this point the exhaust valve in either No. 1 or No. 4 cylinder should just commence to close. It will be the case in one or the other.

If you find that the exhaust valve in No. 4 cylinder is beginning to close and you wish to check up the valve timing in No. 1 cylinder, turn the fly wheel around to the left (standing in rear of engine) one complete revolution, until line "1-4" is again brought opposite the center line of the cylinder; then continue slowly turning the flywheel about three-quarters of an inch farther to the left until the line marked "7° (1-4 EX. C.)" coincides with the center line of the cylinders. This is the point at which the exhaust valve in the No. 1 cylinder should just seat itself or close.

To determine whether or not the valve is seated, see if the tappet or push rod underneath the valve can be turned with the fingers. If the tappet turns freely, the valve is seated; but if the tappet is hard to turn, that will show that the valve is still being held slightly open. If this is the case, loosen the lock nut on the tappet screw, and turn the screw down until the valve has the proper clearance, then turn the lock nut down tight against the tappet.

When the valves are closed there should be a clearance between the end of the valve stem and the tappet screw of from .003 to .005 of an inch. This amount of clearance is necessary to allow the valve to seat tightly.

Note. The opening and closing time of a valve is not when the lifter begins to rise or comes to rest, but when it makes or leaves contact.

To check the timing of the inlet valve in No. 1 cylinder, turn the fly wheel slightly to the right until the line "1-4" is in line with the center of the cylinders, and then turn the fly wheel about one-half an inch to the left until the line marked "5° (1-4 IN. O.)" coincides with the center line of the cylinder. At this point the inlet valve should just begin to open.

Continue turning the fly wheel half a turn to the left, stopping when the line marked "40° (1-4 IN. C.)" comes in line with the center of the cylinders. At this point the inlet valve should just close.

To see if the exhaust valve in No. 1 cylinder opens at the proper time, revolve the fly wheel still farther to the left, and stop when the line "40° (1-4 EX. O.)" comes up in line with the center of the cylinders. This is the point where the exhaust valve in No. 1 cylinder should just begin to open. This operation completes the checking of cylinder No. 1, with the exception of the **exhaust closing,** which can be checked by the 7° mark "(1-4 EX. C.)" being in line with the dead center line of the cylinder.

To check the timing of cylinder No. 2, turn the fly wheel until the line marked "2-3" is in line with the center line of the cylinders. If the exhaust valve in the No. 2 cylinder is closed, turn the fly wheel through one complete revolution, until the line "2-3" is up again; the exhaust valve in No. 2 cylinder should then be just starting to close. Proceed now the same as in timing the No. 1 cylinder. The valves in cylinders No. 3 and No. 4 are timed in the same manner.

Cylinders Nos. 1 and 4 are timed from the center line "1-4"; 5° to the left for inlet opening, and 7° for exhaust closing, and cylinders No. 2 and 3 from the line "2-3"; 5° to the left for inlet opening and 7° for exhaust closing.

It is advisable, when checking the opening and closing points of the valves with the marks on the flywheel, to make a note of the variation of each of the valves from the marks in the fly wheel.

Then, after all the valves have been checked, you can compare the variations for the different valves and in this way determine whether the variations are due to the large time gear on the end of the cam shaft not being properly set with relation to the timing gear on the end of the crank shaft, or to wear in any particular cam or valve tappet. A variation, not to exceed one-half of an inch either way from the lines on the fly wheel, is permissible, and will not make any material difference in the timing of the valves. If the variations exceed this and are uniform for the different valves, the correction should be made by resetting the cam-shaft gear.

Note. If one person feels the tappet head of the valve which is being checked, while another slowly pulls the fly wheel round in its proper direction of motion, the precise moment at which the valve commences to lift can readily be determined by the binding of the tappet head against the stem of the valve.

HOW TO CONVERT DEGREES ON THE RIM OF THE FLY WHEEL TO INCHES[1]

The following table is provided for converting degrees into fractions of an inch. For example, if a certain engine is to be timed when the inlet opens, say 10° after top of stroke, and there are no marks on the fly wheel to indicate this position, by referring to this table the distance in inches to measure on the fly wheel from upper dead center mark can be found.

It will be necessary however, to know the diameter of the fly wheel. Suppose the fly wheel is 17 inches; refer to first column and find 17, then go out to column under 10° and you have 1.48 (one and forty-eight one-hundredths of an inch). This would represent the distance to measure for the inlet opening mark on the fly wheel. Forty-eight one-hundredths (.48) is not so easy to measure on the rule. Therefore refer in the conversion table below, to .48 and note it is equal to 31/64 of an inch. Therefore we would have 1 34/64″.

Another example: What would 2½° represent in inches on a 17-inch fly wheel? Procedure: find 17, go out to column under 2°, and we find .30. Put this down. Refer to the conversion table and note .30 = 19/64. Now refer back to the column headed 1°, and we find .15, which is equal (below), to 5/32″ or 10/64.″ One-half of 10/64″ = 5/64″. Therefore 2°, or 19/64″ + 5/64″ = 24/64″ = ⅜″.

Diam. WHEEL	Circum.	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	20°	30°	40°	50°
12	37.699	10	.21	31	.42	.52	63	73	84	94	1 05	2 09	3 14	4.19	5.24
1/4	38.485	.11	.21	32	43	.53	.64	75	86	96	1 07	2 14	3 20	4.27	5.34
1/2	39.270	.11	.22	.33	44	.55	66	77	87	98	1 09	2.18	3 27	4.36	5 46
3/4	40.055	.11	.22	.33	45	.56	.67	78	89	1.00	1 11	2.22	3 33	4 45	5 56
13	40.841	.11	.23	.34	45	.57	.68	79	91	1.02	1 13	2.26	3 40	4.54	5.67
1/4	41.626	.12	.23	.35	.46	.58	.69	81	93	1.04	1.16	2.31	3.47	4.63	5.78
1/2	42.412	.12	.24	.35	.47	.59	.71	82	94	1.06	1.18	2.35	3.53	4 71	5.89
3/4	43.197	.12	.24	.36	48	.60	.72	84	96	1 08	1 20	2 40	3 60	4 80	6.00
14	43.982	.12	.24	.37	.49	.61	73	86	.98	1.10	1.22	2.44	3.66	4.89	6.10
1/4	44.768	12	.25	.37	.50	.62	.75	87	.99	1 12	1.24	2.48	3.73	4.98	6.21
1/2	45.553	.13	.25	.38	.51	63	.76	89	1.01	1 14	1.27	2.53	3.80	5.07	6.84
3/4	46.338	13	.26	39	51	64	.77	90	1 03	1.16	1.29	2.57	3.86	5 15	6.44
15	47.124	.13	.26	39	52	65	79	92	1.05	1.18	1.31	2 62	3.93	5.25	6.55
1/4	47.909	.13	.27	.40	.53	66	.80	93	1.06	1.20	1.33	2.66	3.99	5.31	6.65
1/2	48.695	.14	.27	.41	.54	.68	.81	95	1.08	1.22	1 35	2.70	4.05	5.40	6.76
3/4	49.480	.14	.27	.41	.55	.69	.82	96	1 10	1.24	1.37	2.75	4.12	5.49	6.87
16	50.265	.14	.28	.42	.56	70	84	98	1 11	1 26	1.40	2.79	4.19	5.59	6 98
1/4	51.051	.14	.28	.43	.57	71	85	99	1.13	1 28	1.42	2.84	4.25	5.68	7.10
1/2	51.836	.14	.29	43	.58	72	86	1 01	1.15	1.29	1.44	2.88	4.31	5.76	7.20
3/4	52.622	15	.29	44	.59	73	88	1 02	1 17	1.31	1.46	2.92	4.38	5.85	7.30
17	53.407	.15	30	44	59	74	.89	1.04	1 18	1.33	1.48	2.96	4.44	5.93	7.40
1/4	54.192	.15	.30	.45	.60	.75	.90	1.05	1.20	1.35	1.50	3.00	4.51	6.02	7.53
1/2	54.978	.15	.31	46	.61	.76	.92	1.07	1.22	1.37	1.53	3.05	4.58	6.11	7.65
3/4	55.763	15	.31	.46	.62	.77	.93	1.08	1.24	1.39	1.55	3.10	4.65	6.20	7.75
18	56.549	.16	31	.47	.63	.79	94	1.10	1.25	1.41	1.57	3.14	4.71	6.29	7.85
1/4	57.334	.16	.32	.48	.64	.80	.95	1.11	1.27	1.43	1.59	3.18	4.77	6.37	7.95
1/2	58.119	.16	.32	.48	.65	.81	.97	1.13	1.29	1.45	1.61	3.23	4.84	6.45	8.07
3/4	58.905	16	.33	.49	.65	.82	.98	1.14	1.31	1.47	1.63	3 26	4.90	6.54	8.18
19	59.690	.17	.33	.50	.66	.83	.99	1.16	1.32	1.49	1.66	3.32	4.97	6.63	8.30
1/4	60.476	.17	.34	.50	.67	.84	1.01	1.17	1.34	1.51	1.68	3.36	5.04	6.71	8.40
1/2	61.261	.17	.34	.51	.68	.85	1.02	1.19	1.36	1.53	1.70	3.40	5.10	6.80	8.51
3/4	62.046	.17	.34	.52	.69	.86	1.03	1.21	1.38	1.55	1.72	3.45	5.17	6.90	8.62
20	62.832	.17	.35	.52	.70	.88	1.05	1.22	1.39	1.57	1.74	3.48	5.24	6.98	8.73
1/4	63.617	.18	.35	.53	.71	.89	1.06	1.24	1.41	1.59	1.77	3.54	5.31	7.07	8.85
1/2	64.403	.18	.36	.54	.72	.90	1.07	1.25	1.43	1.61	1.79	3.56	5.37	7.15	8.95
3/4	65.188	.18	36	.54	72	.91	1.09	1.27	1.45	1.63	1.81	3.62	5.44	7.25	9.05
21	65.973	.18	.37	.55	.73	.92	1.10	1.28	1.47	1.65	1.83	3.66	5.50	7.33	9.15
1/4	66.759	.19	.37	.56	.74	.93	1.11	1.30	1.48	1.67	1.85	3.70	5.56	7.41	9.26
1/2	67.544	.19	.38	.56	.75	.94	1.12	1.31	1.50	1.69	1.88	3.75	5.63	7.50	9.38
3/4	68.330	.19	.38	.57	.76	.95	1.14	1.33	1.52	1.71	1.90	3.79	5.69	7.59	9.49
22	69.115	.19	.38	.58	.77	.96	1.15	1.34	1.53	1.73	1.92	3.84	5.75	7.68	9.60
1/4	69.900	.19	.39	.58	.78	.97	1.16	1.36	1.55	1.75	1.94	3.88	5.82	7.76	9.70
1/2	70.686	.20	.39	.59	.79	.98	1.18	1.37	1.57	1.77	1.96	3.93	5.88	7.85	9.82
3/4	71.471	.20	40	.60	.79	.99	1.19	1.39	1.59	1.79	1.98	3.96	5.95	7.94	9.92
23	72.257	.20	.40	.60	.80	1.00	1.20	1.40	1.61	1.81	2.01	4.02	6.02	8.03	10.03
1/4	73.042	.20	.41	.61	.81	1.01	1.22	1.42	1.62	1.82	2.03	4.06	6.09	8.13	10.13
1/2	73.827	.20	.41	.61	.82	1.02	1.23	1.43	1.64	1.84	2.05	4.10	6.15	8.21	10.23
3/4	74.613	21	.41	.62	.83	1.04	1.24	1.45	1.66	1.86	2.07	4.15	6.22	8.30	10.35
24	75.398	.21	.42	.63	.84	1.05	1.26	1.46	1.67	1.88	2.09	4.19	6.28	8.38	10 45

Conversion Table, Hundredths of an Inch to Sixty-Fourths

01, .02	1/64	.14	9/64	.26, .27	17/64	.39	25/64	.51, .52	33/64	.64	41/64	.76, .77	49/64	.89	57/64
03	1/32	.15, .16	5/32	.28	9/32	.40, .41	13/32	.53	17/32	.65, .66	21/32	.78	25/32	.90, .91	29/32
04, .05	3/64	.17	11/64	.29, .30	19/64	.42	27/64	.54, .55	35/64	.67	43/64	.79, .80	51/64	.92	59/64
.06, .07	1/16	.18, .19	3/16	.31, .32	5/16	.43, .44	7/16	.56, .57	9/16	.68, .69	11/16	.81, .82	13/16	.93, .94	15/16
.08	5/64	.20, .21	13/64	.33	21/64	.45, .46	29/64	.58	37/64	.70, .71	45/64	.83	53/64	.95, .96	61/64
.09, .10	3/32	.22	7/32	.34, .35	11/32	.47	15/32	.59, .60	19/32	.72	23/32	.84, .85	27/32	.97	31/32
.11	7/64	.23, .24	15/64	.36	23/64	.48, .49	31/64	.61	39/64	.73, .74	47/64	.86	55/64	.98, .99	63/64
.12, .13	1/8	.25	1/4	.37, .38	3/8	.50	1/2	.62, .63	5/8	.75	3/4	.87, .88	7/8	1.00	1

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[1] From *Horseless Age.*

HOW TO MARK A FLY WHEEL IN DEGREES AND INCHES

Most fly wheels of engines are marked in some manner. If, however, you know in degrees what timing to give an engine, and if the flywheel is not marked, then with the assistance of the table on page 68, the markings can be punched on the cylinder with a center punch.

The first procedure would be to make a punch mark, or place an "indicator" at the base of the rear cylinder (**A**), Fig. 23. Be sure it is exactly in the center of the cylinder (see Fig. **20A**, page 66); however, when the piston is on top dead center when the indicator is being located, it could be placed to one side, as on the Reo.

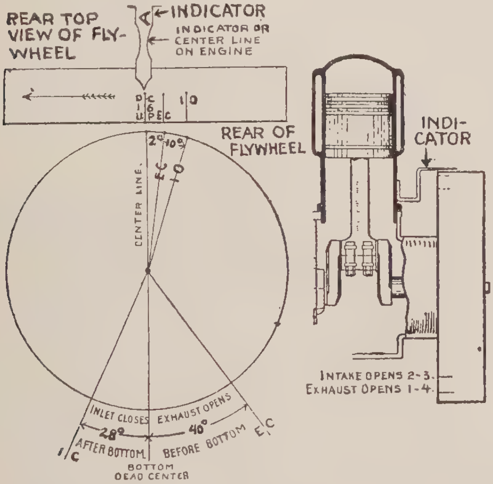


Fig. 22. (Left.) Looking down on top of the flywheel when standing in rear of it.

Fig. 22. (Right.) Side view.

Next, place the piston of No. 1 cylinder at the top dead center of its stroke.

Next, punch a mark or line on the flywheel directly in line with the indicator. Mark this line "DC-1-6," meaning that the pistons of cylinders 1 and 6 are at the top, or dead center. (We shall assume that it is a six-cylinder engine. If a four-cylinder, mark "DC-1-4".)

Suppose the **valve timing** is as follows: Exhaust valve closes 2° past top and opens 40° before bottom, and inlet valve opens 10° after top and closes 28° after bottom, as measured on the fly wheel, which is the usual method of following degree marks (Fig. 22).

The next procedure is to measure the diameter of the fly wheel. Suppose it measures 14″. Refer to the table (page 68) and find 14 in the first column under "Diam. Wheel." Note that 2° measured on the circumference of the fly wheel would be .24 (twenty-four one-hundredths of an inch). Refer to the conversion table in the same table, lower down on the page, and note that .24 is equal to 15/64 of an inch. Now, make another mark 15/64 of an inch to the right of the mark "DC-1-6," and mark it "EC" (exhaust closes).

Note. Looked at from the front of an engine, the fly wheel revolves clockwise, or to the right. Looked at from the rear of engine, which is the position from which we are looking at the engine in Fig. 22, the flywheel revolves counter-clockwise, or to the left.

When the flywheel is moved to the left so that the mark "EC" comes in line with the indicator, the "EC" represents a 2° movement of the flywheel, and the piston would be slightly down on its stroke from the piston dead-center position and the exhaust valve would just close.

If the engine was an "L"-head cylinder type, this marking would suffice, as the cam-shaft gear is usually meshed with the crank-shaft gear at the position where the exhaust closes.

If the engine was a "T"-head cylinder type, the inlet cam shaft would have to be timed as well as the exhaust. In our example (Fig. 22) the inlet valve opens 10° past top. Refer to the table and note 10° on a 14″ flywheel is 1.22 (one inch and twenty-two one-hundredths of an inch). Refer to the conversion table and note that .22 is equal to 7/32 of an inch. Now make another mark on the fly wheel 1 7/32 of an inch to the right of the mark "DC-1-6," and mark it "IO" (inlet opens).

When the flywheel is moved to the left so that the mark "IO" comes in line with the indicator, the "IO" represents a 10° movement of the fly wheel, and the piston would be slightly down on its stroke from piston dead-center position and the inlet valve would just begin to open.

The inlet cam-shaft gear is meshed with the crank-shaft drive gear at this position.

Marking of the position of other pistons on the fly wheel can be made in the same manner. This is not necessary for timing, but it is necessary for checking the timing.

Another Method of Marking a Flywheel in Degrees

Although the table on page 68 shows how to find in inches or a fraction thereof just where to mark a flywheel in degrees, another method is given below. Suppose there are no timing marks on the flywheel and you desire to mark it so that the exhaust valve closes 10° after top dead-center (see Fig. 23).

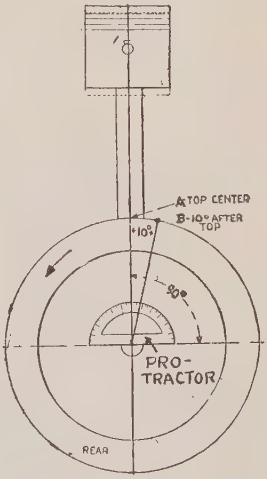


Fig. 23

Set the engine so that the piston in No. 1 cylinder, namely the cylinder nearest the radiator, is at the top of its stroke. With the use of the protractor or with a square, make a mark at **A** on the rim of the flywheel, on the inner edge, which mark will be directly above the center of the crank shaft when the piston is at top of its stroke.

Then, with the protractor placed against the flywheel so that the 90° mark points directly toward mark **A**, go 10° to the right on the protractor (standing in rear of engine), and then make a mark at **B** on the flywheel. This mark will be 10° to the right of mark **A**. Now turn the fly wheel until mark **B** is at top center.

With the engine in this position mesh the timing gears so that the exhaust valve of No. 1 cylinder is just closing.

It is understood that when standing behind the fly wheel it would turn to the left, as shown by the arrow point. Therefore, the piston must first reach top center (**A**) with the exhaust valve still open, and travel 10° farther to (**B**) before it closes.

This method is inaccurate. The method described under Fig. 22 is preferable.

To Locate Position of Piston

In the previous matter we have considered placing the piston on top dead center of the compression stroke. How to tell when the piston is on top of the compression stroke is explained below.

Usually a mark is placed on the fly wheel to indicate when the piston is at top of its stroke. For instance, in a four-cylinder engine, a mark will probably be on the fly wheel, such as "DC 1-4," meaning "dead center up 1 and 4," or pistons 1 and 4 are at top of stroke. In a six-cylinder the mark would probably appear as "DC 1-6 up," meaning pistons 1 and 6 are on top. Or the mark may be "1-4 up," or "1-6 up," meaning the same. These marks on fly wheel are placed in line with the center mark on the cylinder, or in line with an indicator. After finding the top, by moving the fly wheel to the right, the piston is placed before top; if moved to the left, it is placed after top.

On a four-cylinder engine, when No. 1 piston is on top, No. 4 is on top also. On a six-cylinder engine, when No. 1 is on top, No. 6 piston is also on top.

It is necessary, however, to find just what stroke pistons 1 and 4 or 1 and 6 are up on. Therefore watch the valves.

When No. 1 piston is at top on compression stroke, both valves would be closed; the exhaust cam of No. 4 would just be at the point of closing the exhaust valve; the inlet cam of No. 4 would be at the point of just starting to open No. 4 inlet valve, because when No. 1 starts down on power, No. 4 (or No. 6, if a six-cylinder engine) would have just completed its exhaust stroke and would start down on the suction stroke.

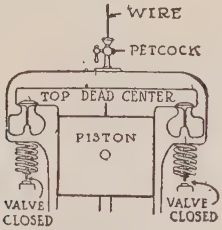


Fig. 24

If the engine happens to be a "T"-head engine with a compression cock in the center and there are no marks on the fly wheel, it is easy to find when the piston is on top by placing a wire or bicycle spoke through the pet cock and turning the engine over; when the wire rises to its highest point the piston is on top of dead center (Fig. 24). The next point is to find if it is on top of compression stroke, which position will be indicated by the position of the cams, as explained above.

If a cylinder is of the "L"-head type, and the fly wheel is not marked, it may not be possible to get a wire into the cylinder. In this case open the compression cock and place your finger over it; have someone crank the engine slowly until you feel compression; let this escape gradually. When the gas has ceased escaping, the piston is at or near top dead center. The compression stroke is found by watching to see when both valves are closed.

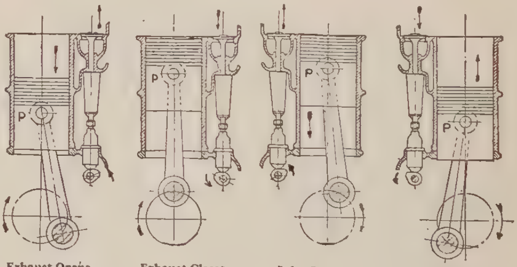
Another plan is to remove the lower crank case and turn the crank until the connecting rod is in a perfectly vertical line; at the same time watch the valves, as mentioned above.

Example of Valve Timing with Position of Piston

The illustrations below represent the **valve timing of the Locomobile "38" and "48" six-cylinder "T"-head engine.** The figures below are expressed in inches of piston travel from dead centers. Degrees are also mentioned.

To speak of timing an engine in inches of piston travel means that we set the valves to open or close when the piston is in a certain position with respect to the cylinder. For example: to set the exhaust valve to close ⅛" past top dead center, bring the piston to top dead center of the exhaust stroke; turn the engine in the normal direction of rotation until the piston has descended ⅛" on its stroke; set the valve to close at this point. These measurements may be made by means of a wire inserted through the pet cock, as shown in Fig. 24.

Speaking of timing an engine where the timing is expressed in degrees refers to the degrees motion of the crank shaft or flywheel. For example: to set the exhaust valve to close 10°27′ past top dead center, bring the piston to top dead center of the exhaust stroke; turn the engine in the normal direction of rotation a distance of 10° 27′, as measured on the flywheel, and set the valve to close at this point.



Exhaust Opens **Exhaust Closes** **Inlet Opens** **Inlet Closes**

Fig. 25. Relative position of piston to the opening and closing of valves (Locomobile).

"38"—exhaust opens .780" before bottom center, or 52°33′; closes ⅛", or 10°27′, past top center. Total exhaust opening is 248°59′.

"38"—inlet opens at top center; closes .67" or 48°3′ past bottom center. Total inlet opening is 228°3′.

"48"—exhaust opens 3/4" before bottom center; closes top center.

"48"—inlet opens 3/32" past top center; closes ¾" past bottom center.

Note. Locomobile "48" two-spark engine varies from the "48," in that the exhaust closes on top and the inlet opens 3/32" past top. The "38" was discontinued in 1918.

Hudson Valve Timing in Inches

The timing of the **Hudson "Super-Six" six-cylinder "L"-head engine, measured according to piston travel:**

Fig. 26—inlet opens 1/64" after top dead center.

Fig. 27—inlet closes 17/32" after bottom dead center.

Fig. 28—exhaust opens 57/64" before bottom dead center.

Fig. 29—exhaust closes 1/32" after top dead center.

The wire used for these measurements should be exactly 5 1/16" long.

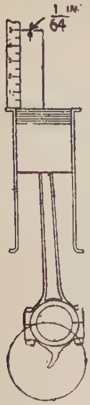


Fig. 26

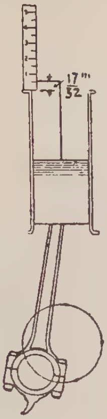


Fig. 27

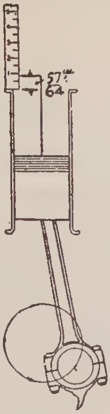


Fig. 28

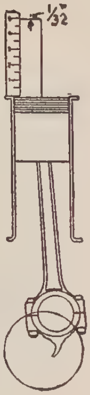


Fig. 29

The timing of the **Hudson in degrees relative to the movement of the flywheel:**

Intake opens 7° after top dead center; closes approximately 42° after lower dead center;

Exhaust opens about 55° before dead center; closes 8° after top dead center.

Dodge Valve Timing

Valve timing of the Dodge four-cylinder "L"-head engine: First see that the valve lifter or tappets are properly adjusted, which is .003 clearance for inlet and .004 for exhaust. Then turn the crank shaft clockwise until the top of piston No. 1 is 1/16" above the top of the cylinder on exhaust stroke, after passing top d.c. Turn the cam shaft counter-clockwise until No. 1 exhaust valve is just fully closed. Gears are then meshed. The **inlet opens** 10° after top and **closes** 35° after bottom; **exhaust opens** 45° before bottom and **closes** 8° after top. **Fly wheel** is 16¼" diameter for cars using a cone clutch and 15½" diameter for cars using the disk clutch. A degree on the larger wheel spans a distance of 0.1418", and on the smaller wheel, 0.1353".

To assemble timing gears on the Dodge: Turn the crank shaft clockwise until the top of No. 4 piston is ⅝" (or 5°) below top of the cylinder, on the compression stroke. Then rotate the cam shaft counter-clockwise until No. 3 exhaust valve is ready to open. The crank-shaft and cam-shaft gear should then be meshed so that the single punch mark in the latter is between the two on the former.

Timing the Valves of the 1921 Buick Six-Cylinder Engine

The exact point in the cycle at which the valves are opened and closed is determined by the shape of the cams which operate them and by the angular relation between the cam shaft and the crank shaft. If it should ever become necessary to remove one of these shafts or the gears which drive them, they must be replaced in proper relation to one another or the valves will be "out of time." To obtain this relation, the punch-marked tooth on the crank-shaft gear (Fig. 30) should be set to match with the punch-marked space on the cam-shaft gear.

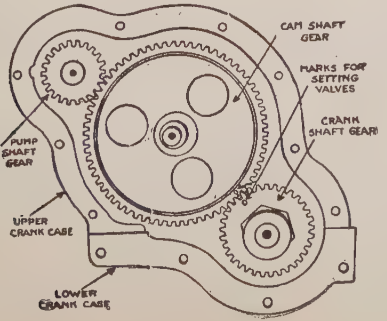


Fig. 30

Adjusting Buick-Six Push Rods

With the timing gears properly meshed, **the final setting of the valves can be made** by adjusting the push rods (valve rods), to proper length by means of the adjusting ball ends and lock nuts.

In making this adjustment, turn the engine by hand, in a clockwise direction, until the line marked "1 and 6" on the flywheel, comes into line with the line on the rim of the inspection hole. This is the firing position for cylinders Nos. 1 and 6, numbering from the radiator back, and one or the other of these cylinders will be found to have both valves closed, so that both rocker arms will have a slight amount of play.

The push rods for these rocker arms should then be adjusted from the back of the cams and while the engine is warm (see instruction plate on side of engine), so as to give .010" clearance between the end of the valve stems and the rocker arms. This is approximately the thickness of a sheet of heavy paper or very light card.

Push rods for the other cylinders may be adjusted in the same manner. Best results will be obtained if these adjustments are made while the engine is idle.

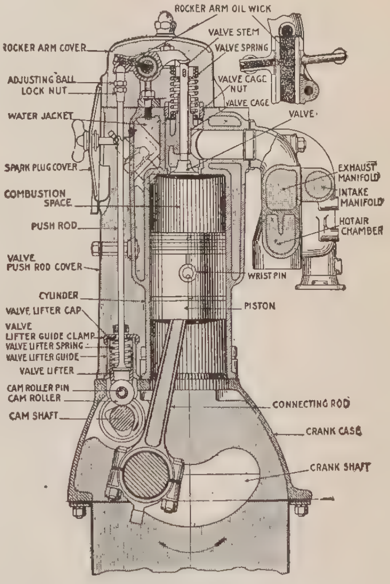


Fig. 31. The Buick six-cylinder engine has both inlet and exhaust valves placed in-the-head of the cylinder and is a typical modern type of engine with valves-in-the-head. The valves are in cages which can be removed for grinding.

One half-teaspoonful of kerosene inserted around the valve stem at least once a week while the engine is running will keep the valve free from carbon and prevent it from sticking in the valve cage.

In setting the marks on the flywheel be careful to turn the motor only in a clockwise direction, otherwise the backlash in the timing gears will affect the result. Caution: If adjustment is made while the engine is cold, the expansion of the push rods when the engine gets warm will cause the valves to be held open.

Grinding Buick-Six Valves

To keep the engine up to its maximum efficiency, the valves must be gas tight when closed. When **leakage occurs** the valves should be ground as follows: Compress the valve spring and lift the push rod out of the socket in the valve lifter. Loosen the valve cage nuts with the special drift furnished in the tool kit and remove by unscrewing. A light tap with a hammer on the end of the valve stem will loosen the cage so that it may be withdrawn. Be careful not to injure the small bronze packing ring on top. Remove the valve spring and after cleaning with gasoline or kerosene, smear the valve and its seat with fine emery flour and oil or with one of the grinding pastes now on the market. **Grind** by turning the valve back and forth on its seat until both valve and seat show a bright ring 1/32″ wide all the way around.

Be careful to clean out all traces of abrasive material before replacing valve. After grinding valves, it will usually be found necessary to readjust the push rods to compensate for the wear. For Buick ignition timing see the Index.

THE TIMING GEARS; FRONT END DRIVE SYSTEM BY GEARS

The cam shaft can be driven by **gears** or a **silent chain.** This subject relates to a gear driven front end system.

Since the position of the cam shaft is always the same with reference to the pistons (because the cam shaft is always in mesh with the crank-shaft gear), and since the cams are all integral parts of the shaft, the valve timing cannot change. If the gears are ever removed, they may be put back in the proper position by seeing that the marks on the edges of the teeth "dovetail" together.

If you find that the marked teeth do not come together, do not jump at the conclusion that the gears are improperly set, but first verify the setting by checking the timing of the valves with the marks on the flywheel.

If the timing of the valves of an engine is not correct, it is then necessary to re-mesh or re-set the timing gears. It will be necessary to place the piston of No. 1 cylinder at top of its stroke. Then remove the gear cover and turn the crank until the "EX. C" (exhaust closing mark of cylinder No. 1) is in line with the center mark on the cylinder (in rear).

Note. On engines with unit power plants instead of the center line being on the cylinder, a small hole at the top of the flywheel case is provided so that the line and figures on the flywheel can be seen through the hole. See Index for Continental engine, showing location.

Now remove the cam gear from its shaft and turn the cam shaft in its direction of rotation (it is the opposite of the direction of rotation of the crank shaft), until the exhaust valve on cylinder No. 1 is just closing; keep the cam shaft in this position; replace the large cam gear on the end of the cam shaft, properly meshing it with the gear on the crank shaft.

There are usually punch marks stamped on the gear teeth, as shown in Fig. 32. On some engines, figures are stamped on the gear teeth, as in Fig. 33, and, in some instances, a letter "O" or "C." These marks are stamped between the two teeth of one gear and in the center of a tooth in the other gear, both of which should be carefully noted when meshing the gears. At this point the valves are supposed to be correctly timed.

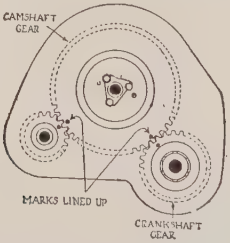


Fig. 32. Note the crank-shaft gear mark which meshes with the cam-shaft gear mark. On the left side a mark on the cam shaft is meshed with a mark on the gear which drives a magneto and which must be timed the same as the cam shaft. The magneto, however, is usually timed or set by loosening its coupling from the shaft with which it connects. See Index under "Setting the magneto."

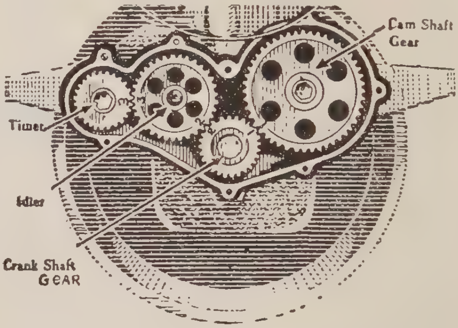


Fig. 33. Note the meshing of the crank-shaft gear mark (1) between the two teeth on the cam-shaft gear mark (1). Also observe that in this instance (Overland model 85), there is an idler gear interposed between the crank-shaft gear and the gear which drives the ignition timer. This idler gear runs free and is used to obtain a correct ratio and to drive the timer shaft. It must be meshed as shown when the ignition timer is in proper position, as will be explained under "Ignition timing."

Example of Setting the Cam Gear on the Reo Models "T 6" and "U 6"

The illustration (Fig. 34) **shows the timing gears** (with cover removed) and the relation which they bear to one another.

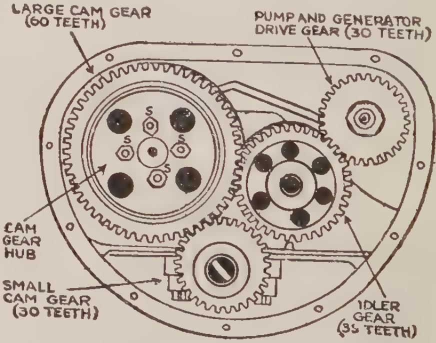

LARGE CAM GEAR (60 TEETH)
PUMP AND GENERATOR DRIVE GEAR (30 TEETH)
S
S
S
S
CAM GEAR HUB
SMALL CAM GEAR (30 TEETH)
IDLER GEAR (35 TEETH)

Fig. 34. Gears on the front of the Reo model "T6" and "U6" engine.

The small cam gear (usually termed "crank-shaft gear") is keyed to the crank shaft and revolves with it. This gear has 30 teeth.

The large cam gear is fastened rigidly to the cam shaft by four studs (S) and lock nuts. This gear has 60 teeth and, therefore, revolves just half as fast as the crank-shaft gear and in the opposite direction.

The pump and generator-drive gear has 30 teeth, and is driven through the idler gear at the crank-shaft speed, but in the opposite direction to that of the small cam gear. One of the studs is marked with a center punch so as to insure correct replacement, should the gear for any reason be removed.

The teeth of the large cam gear and the one on the crank shaft are also given center punch marks for meshing reference. These markings should dovetail.

The teeth of the idler gear and the one driving the water pump and generator are not marked, and can be meshed at any point.

If the timing gears are assembled as described above, the timing must be correct.

In case a new gear is assembled on the engine, the following may be of some assistance in obtaining the correct timing or setting:

Cam gear setting: The fly wheel on this engine is of such diameter as to require its turning through an angle of approximately seven degrees to produce a one-inch movement of its face with respect to some fixed point.

Now, since the error in cam setting must not exceed one half-inch, this movement is equivalent to 3½° movement of the flywheel or crank shaft.

If, for any reason, the valve closing is not within this limit, the setting may be corrected in the following manner:

The large or 60-tooth cam gear (and with it, of course, the cam shaft) would move 6°, or 360 divided by 60, if shifted one tooth; this is the equivalent of 12° on the fly wheel or crank shaft, since, it will be remembered, the gear on the crank shaft has but 30 teeth.

If one inch on the flywheel is equivalent to 7°, 12° would represent approximately a 1¾″ movement of the flywheel.

If the cam openings were off two inches on the fly wheel, it would be a simple matter to change the meshing of the cam gear one tooth in the direction required, and to have an error of ¼″, which would be within the ½″ limit.

If, however, the error of the cam shaft was but 1″, it would be impossible to get nearer than ¾″ by shifting this gear one tooth, which is ¼″ in excess of the limit desired. Means must, therefore, be provided for shifting the gear a fraction of a tooth, or, in other words, a fraction of 6°.

For example, if the gear had 54 teeth instead of 60 teeth, this could be accomplished by removing the gear from the shaft and shifting the former one quarter-turn; 54/4 equals 13½, which would, in effect, be the same as shifting one half-tooth. In order to obtain a shift of one half-tooth (3°) with a gear of 60 teeth, two of the four studs which hold the cam gear to the cam shaft are placed 3° off of the 90° center lines and three of the holes in the cam-gear flange are slotted, the fourth being a tight fit over the stud.

Therefore, if the gear is taken off and shifted 87° or 93°, the effect is the same as changing the meshing of the gear one half-tooth. We shall have changed the relative position of the gear teeth to the cam shaft just 3°, this being equivalent to 6° on the flywheel, or approximately ⅞″. This arrangement gives this engine a means whereby the greatest variation in cam-shaft setting may never exceed ½″.

Valve Timing of Reo

The fly wheel of the engine has upon its face the marks: "U.D.C.1 & 6," meaning upper dead center, cylinders 1 and 6; "INTAKE OPEN 1 & 6," meaning that the intake valve in No. 1 or No. 6 cylinder commences to open; "SPARK," meaning that a spark should take place in No. 1 or No. 6 cylinder with the spark fully retarded.

These markings on the face of the fly wheel register with the top of the right-hand motor support. The spark occurs 1½″ late at full retard. The intake valve opens at the upper dead-center point. Since the cranks for cylinders Nos. 1 and 6 are on the same side of the center, it will be understood that the marks which serve for cylinder No. 1 also apply to No. 6.

To check valve setting: First screw out the spark plug from each cylinder, thereby relieving compression and permitting the engine to be turned over easily. Selecting No. 1 cylinder (it being the most convenient), crank the engine slowly with the hand crank until the inlet valve for this particular cylinder just commences to open. This can be determined by placing a piece of fine tissue paper between the inlet valve stem and its lever. When there is just sufficient pressure of the lever on the valve stem to prevent withdrawal of the paper, the inlet valve is commencing to open. At this moment the marking "INLET OPENS 1 & 6" on the face of the flywheel should not be more than ½″ either way from the top of the right-hand engine support. Before checking the valve setting, it is important that all backlash of the valve tappets be removed.

If one cylinder checks, it will not be necessary to check the valves in the other cylinders, as the cam shaft is accurately ground and the cams are in correct relation to one another.

Relation of Valve Clearance and Valve Timing, and Meshing of the Timing Gears

After your engine has been overhauled a few times the cam-shaft gear will have developed a dozen or more meshing marks. Each workman will have added a few marks that may or may not be right and changed a few that were right, until finally it is hopeless to match any of them.

This need not seriously inconvenience you, for if you understand valve timing, you can forget the gear marks and work entirely from the fly-wheel marks.

A "trammel" is a stationary starting point from which to base all your work (see Fig. 20, page 66). The trammel generally is directly over or in front of the flywheel, but may be located elsewhere if some careless workman has removed your flywheel and replaced it in a different position (flange connection, or a new flywheel with the key in the wrong place). The trammel should be shifted until it registers properly when the cylinder indicated is at top center.

Check up the top center mark by making sure that the piston in the cylinder indicated is exactly at top center and that the trammel registers exactly in line.

Now that you are certain of the trammel, move the flywheel in the direction in which it should travel (generally counter-clockwise, if flywheel is between you and the cylinders) until the marks I. O. (intake opening) No. 1 and No. 4 register with the trammel. Leave the flywheel alone now, and turn the cam shaft until the nose of the inlet cam on No. 1 cylinder is down. Adjust the air-gap (valve-stem clearance) for post-card distance. Turn the cam shaft in the direction of its travel until the air-gap is gone and any further movement would start to lift the valves. Put on the cam-shaft gear, being careful not to move either the cam shaft or the crank shaft. Have the gear key in place, but do not permanently fasten the gear yet.

Turn the fly wheel in its proper direction and **check up the intake closing.** If both opening and closing of this valve are right, it means that the cam shaft and air gap are correct, and the gear can be permanently fastened.

If the valve opens on time but closes at the wrong time, it means that both the cam shaft and air gap are wrong. **If the valve closes too soon,** the air gap is too large and does not hold the valve open long enough. **If the valve closes late,** the air gap is too small and holds the valve open too long.

Make a mark with a lead pencil or with chalk on the fly wheel, midway between the actual closing and the proper closing. Turn the flywheel to this new mark and adjust the tappet to correspond. The tappet must be just barely in contact with the valve stem. The air gap is now O. K., but the cam shaft is still out of time.

Turn the fly wheel back to the opening mark and remove the gear. Turn the cam shaft until the air gap is gone, replace the gear and check up the closing. The cam shaft and air gap are now correct and the remaining tappets are adjusted after registering each mark with the trammel. Do not use a sheet of paper or post card to measure with. Turn the fly wheel and adjust each tappet by the flywheel marks.

If the valve opens a certain number of degrees early and closes the same number of degrees late, the cam shaft is right but the air gap is wrong.

If a valve opens a certain number of degrees early and closes the same number of degrees early, the air gap is right but the cam shaft is wrong.

Make a habit of checking up this air gap occasionally with the flywheel marks.

After the valves have been ground or new valves put in—check up. Don't let your engine overheat or lose power through the fault of the air gap.

It will be observed that valve clearance, referred to above as "air-gap," is a very important adjustment.

SILENT CHAIN FRONT END DRIVE SYSTEM

Where silent chains and sprockets are used instead of gears, the procedure is similar. Note, however, that the cam shaft revolves in the same direction as the crank shaft.

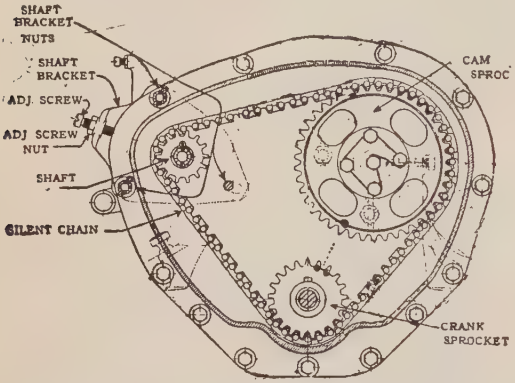


Fig. 35. Cam-shaft gear on the Studebaker "EJ" driven by a silent chain. Note that the chain has an exterior adjustment.

To set the cam shaft if silent chain has been removed: Fig. 35 shows one silent chain driving the cam shaft and generator in a Studebaker model "EJ" six-cylinder engine. If the engine was a four-cylinder engine, cylinders 1 and 4 would be up together, whereas with a six-cylinder engine, cylinders 1 and 6 are up at the same time.

Procedure: Crank the engine until cylinders 1 and 6 are on upper dead center of compression stroke by getting marks "UP-D-C 1-6" on the fly wheel opposite pointer, on the rear of the starter housing. With the crank shaft in this position turn the cam-shaft sprocket until the punch mark on the cam gear will be directly between the two punch marks on the teeth of the crank-shaft gear (Fig. 35). Replace the chain, being careful to see that the cam shaft or crank shaft are not moved.

It is not necessary to set the accessory shaft sprocket which drives the pump, generator, and ignition unit (the sprocket on the left side marked "shaft"). The ignition unit can be set by moving it on its own shaft. See Index under "Ignition timing."

Silent chains will stretch, especially when new, or after a few thousand miles or so of running, and will likely cause a **noise** by striking the bottom of the chain housing.

Adjustment can be made by moving the generator. There are three bolts holding the generator. They are to be loosened and the chain-adjusting screw given a turn or so, moving generator out, thus tightening chain. This movement usually allows about 1/16" movement of the generator sprocket. Be sure and tighten all bolts and nuts.

Too tight a chain adjustment will cause "singing" as well as undue wear on one side of the bearing.

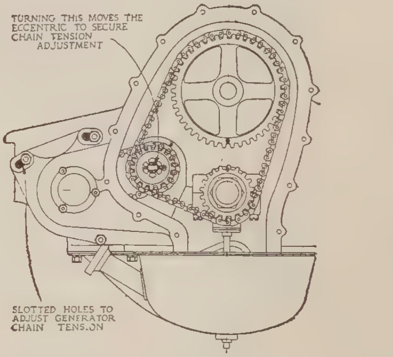

TURNING THIS MOVES THE ECCENTRIC TO SECURE CHAIN TENSION ADJUSTMENT
SLOTTED HOLES TO ADJUST GENERATOR CHAIN TENSION

Fig. 36. An example of two silent chains with two adjustments for slack. (King.)

To set the cam shaft on an engine using two silent chains (Fig. 36) the procedure is similar, except that the chain driving the generator is not considered.

Note in Fig. 36 that the crank-shaft gear (lower) drives the large cam-shaft gear and also a double sprocket from which another chain drives the generator.

To adjust the cam-shaft chain an eccentric shaft is provided.

To adjust the generator chain, the generator is moved as shown in Fig. 36. If a chain is adjusted too tight, it will hum or sing at high speeds. If the chain should stretch to such an extent that no more adjustment is available, then either install a hunting or off-set link section, or a new chain, if badly worn. See Index under "Silent chains."

In re-timing, or any other operation requiring the removal of the chain, be sure that the chain is replaced so that it runs in the direction indicated by the arrows on the sides of the links.

Note. In order to reach the silent chain and cam sprockets, it is usually necessary to remove the radiator, starting crank stud, fan, fan pulley, and gear-housing cover. When replacing, be sure the gasket of the housing is in good condition.

Should it be necessary to remove the cam-shaft sprocket from the shaft, see that it is replaced in the exact position in which it was when it came off. On most gears and sprockets there are holes provided for a **"gear puller"** which is used to draw gears off.

Hupmobile Valve Timing

When timing this engine, reference to the marks on the gears should not be made, because they have no bearing on the engine timing. The appearance of the chain with the front cover removed is shown in Fig. 37.

There are two timing methods. The first is as follows: turn the engine over until the marks "Intake Opening" on the fly wheel line up correctly with the line on the housing; turn the cam-shaft gear until the intake cam is just beginning to lift the intake valve of No. 1 cylinder; place the chain in proper position and allow just a little slack.

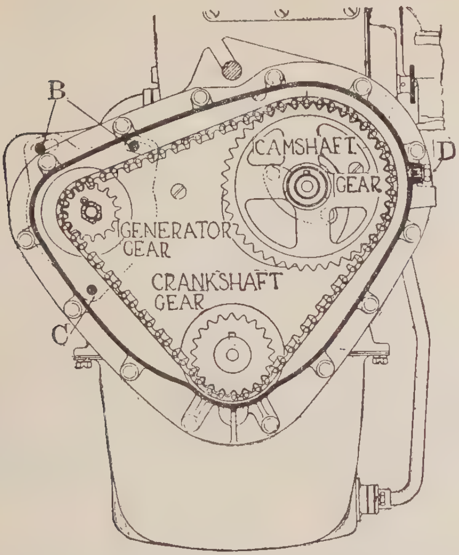


Fig. 37. Hupmobile front end drive system. Adjustment of slack in chain is taken up by loosening bolts (**B**) and (**C**) and sliding the generator to one side, at the top (**B**).

The second method is as follows: remove the cylinder head so that it will be possible for you to measure the distance of the piston travel. Turn the piston of No. 1 cylinder 5/16″ past top dead center on the intake stroke, which is, of course, when the piston is traveling downward. Turn the cam shaft so that the intake valve is just ready to open; then place the chain in its proper position.

In order to place the chain on the gears it may be necessary to loosen the rear engine bolt. Place a jack under the bottom of the oil pan near the front and raise the engine slightly.

Remarks on Front-End Drive Methods

Cars using silent chain front-end drive are the Ambassador, Ace, Ogren, Revere, Haynes, Jordan, Moon, Saxon, Brewster, Cadillac, Chalmers, Chandler, Cleveland, Hupmobile, King, LaFayette, Lincoln, Meteor, Mercer, National, Packard, R & V Knight, Stearns-Knight, Studebaker (one model), Templar, Willys-Knight, Winton.

Virtually all the other cars use the helical-gear front-end drive. Where the gear-type front-end drive is used, alternate gears are of different metals, such as iron and steel, and also of compressed cotton. The majority of gears are steel against cast iron, as this has been found to reduce "resonance."

Where both gears are of cast iron, or both of steel, the gears are prone to "sing."

Duralumin, which can be forged, is used for gears in the Continental and Marmon engines.

A Fabroil gear, which is a specially compressed, spirally wound cotton type of gear, made by the General Electric Co., is used on Buick, Paige, Wills-Saint Claire, and DuPont cars.

Where silent chains are used, it must be possible to reduce the length of the chain by degrees one full link, after which a link can be removed from the chain and the adjustment let out again. This gives unlimited adjustment. On those cars not provided with chain adjustments, it is, however, always best to renew a chain entirely if it is worn. The adjustment must also be accessible, so that it can be easily made when required.

There are several types of chains used and different methods of securing adjustment, as follows:

1. Movable idler.
2. Movable sprocket (Figs. 35, 36, 37).
3. Eccentric adjustment (Fig. 36).
4. Double adjustment.
5. Automatic idlers (Fig. 38).

The movable idler is used for adjustment or to take up chain whip.

The movable sprocket for adjustment is used on one of the shafts where it can be moved in or out without destroying any alignments or adjustments.

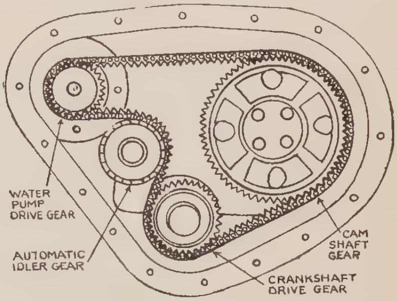


Fig. 38. A front-end drive system used on the model "75" Haynes. An automatic take-up for slack in the chain is provided. The cam gear operates the cam shaft, which operates the inclined valves.

The subject of silent chains is also dealt with elsewhere; see Index under "Silent chains."

Average Valve Timing

There is very little difference between the average timing of the four and the six-cylinder engine.

On the six, the average inlet opening is 10.7° past top center and the closing point 37.6° past bottom center.

On the four, the average for the inlet opening is 11.1° after top center, and the closing point is 36.8° after bottom center. The small difference would hardly be noticeable.

The exhaust on the average six **opens** 46° before bottom center and on the **four** at 46.3°. **The closing point of sixes** averages 7° after top, and on the four, 7.7°.

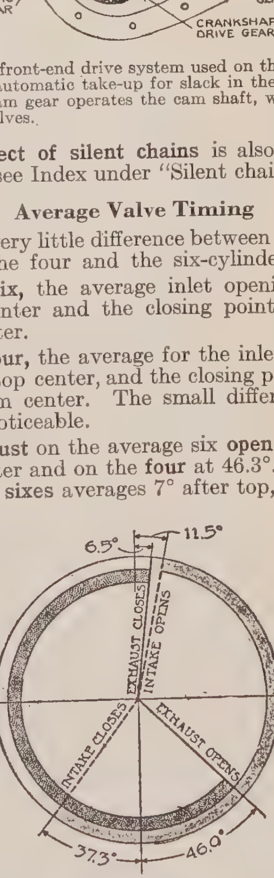


Fig. 39

On an average engine, therefore, the inlet would open 11.5° after top and close 37.3° after bottom. The exhaust would open 46° before bottom and close 6.5° after top.

The illustration (Fig. 39) is a **typical diagram of valve timing** with the timing designated in degrees. When reading such diagrams, imagine the circle being the rear of a fly wheel, which revolves to the left. The light shading represents the period of travel when the inlet valve is open, or 205.8°. The dark shading represents the period of travel when the exhaust valve is open, or 232.5°.

See also Index under "Valve timing" for the valve timing of engines on leading makes of cars; and under "Valve clearance" and "Diameter of valves."

INSTRUCTION No. 10

FIRING ORDERS: One, Two, Three, and Four-Cylinder Engines

Firing Order of One and Two-Cylinder Engines

There are four strokes to two revolutions of the crank shaft to complete a cycle operation, as explained on page 32.

A stroke of the piston means a travel from top to bottom, or from bottom to top, or 180° movement, or one-half of a revolution of the crank shaft. (This is not strictly true when offset cylinders are used.)

There are four strokes of 180° on all four-cycle engines; therefore there would be two revolutions of 360° each, or 720° travel of the crank.

There is but one power stroke (firing impulse) during the four strokes, or two revolutions of the crank shaft. Note, also, that the power stroke is a very short one, owing to the fact that the exhaust valve starts to open a considerable time before the piston reaches the bottom of its stroke. If the exhaust valve should open 46° before bottom, then the travel on the power stroke would be but 134° instead of 180°.

Therefore, if there is but one power stroke to two revolutions of the crank shaft (720° travel of crank shaft), we should have only 134° out of the two revolutions, or 720° on which there is power.

Fig. 1

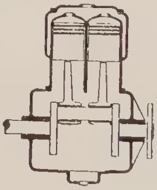


Fig. 2

Fig. 1. One-cylinder engine with a 360° crank shaft. Firing impulse every two revolutions; see diagram below.

Fig. 2. Two-cylinder vertical engine with a 360° crank shaft. Firing impulse every revolution.

CYLINDER NO.	1
1ST REVOLUTION	S
	C
2ND REVOLUTION	P
	E

1	2	CYLINDER NO
P	S	1ST REVOLUTION
E	C	
S	P	2ND REVOLUTION
C	E	

Fig. 1 shows a single-cylinder engine. There is **one explosion during every two revolutions of the crank shaft,** or, in other words, there is one stroke of the piston when power is being developed, and three when there is no power, the piston then being moved by the momentum of the fly wheel.

As the piston must be carried through the three dead strokes, it is necessary to use a heavy fly wheel, so that when it is started, it will continue to revolve for a sufficient time to move the piston until the next power stroke.

There is vibration from a one-cylinder engine on this account, for the weight of the piston sliding first one way and then the other has nothing to balance it.

It can be balanced to some extent by attaching a weight called a "counter-balance," to the crank shaft opposite to the crank pin, in the same manner that the wheels of a locomotive are balanced, but even then there is vibration owing to the power stroke at uneven intervals.

Note. In the two small diagrams under the illustrations, **P** means power stroke; **S,** suction; **C,** compression; **E,** exhaust. The "firing impulse," is the time at which combustion takes place at the beginning of the power stroke.

Fig. 2 shows a two-cylinder vertical engine with a 360° crank shaft. If the piston of No. 1 cylinder is on power (**P**), No. 2 would be on suction (**S**)—see diagram. Therefore we should get an even firing impulse, or **one during each revolution.** But as both pistons are moving together, there would be considerable vibration, as both are on top or bottom at the same time. Counter-weights are also used on the crank shaft of this type of engine in order to counter-balance. (Seldom used.)

Fig. 3 shows a two-cylinder vertical engine with a 180° crank shaft. There are **two firing orders** of this engine, each of which would cause vibration. Refer to diagrams. In the first, if No. 1 is on power (**P**), No. 2 would be coming up on compression (**C**), and would fire next. Therefore, there would be **two firing or power impulses during one revolution,** and on the second revolution there would be no firing impulse at all. With the other order of firing, if No. 1 was on power (**P**), No. 2 would be coming up on exhaust (**E**). The crank would therefore travel 540°, or 1½ revolutions with but one firing impulse.

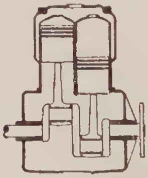


Fig. 3

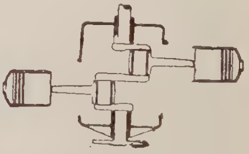


Fig. 4

Fig. 3. Two-cylinder vertical engine with a 180° crank shaft. Two different firing orders—see diagram below.

Fig. 4. Two-cylinder opposed type engine with 180° crank shaft. Firing impulse every revolution. Mechanically balanced.

CYLINDER NO	1	2
1ST REVOLUTION	P	C
	E	P
2ND REVOLUTION	S	E
	C	S

—OR—

CYLINDER NO.	1	2
1ST REVOLUTION	P	E
	E	S
2ND REVOLUTION	S	C
	C	P

CYLINDER NO	1	2
1ST REVOLUTION	P	S
	E	C
2ND REVOLUTION	S	P
	C	E

In the **two-cylinder type of engine with cylinders** opposite and the crank shaft set 180° (Fig. 4), one piston slides inward as the other slides inward, so that one balances the other. This type of engine is called an "opposed" type of engine. Cylinders are set 180° apart, and so also is the crank shaft. When one piston starts down on the power stroke, the other starts down on suction. Therefore, as shown in the diagram under Fig. 4, there would be a firing impulse at each revolution of the crank shaft or every 360°. Thus it is mechanically balanced.

The fly wheel of a two-cylinder engine need not be as heavy as that of an engine with one cylinder because it is required to carry the piston through only one dead stroke before another power stroke occurs. On 6, 8, and 12-cylinder engines, the fly wheel is very small in diameter.

The more cylinders an engine has, the more steadily it may run, for the explosions may be arranged to follow one another so closely that there is no moment when one of the pistons is not on the power stroke. This is termed "lapping" of power strokes.

Firing Order of a Three-Cylinder Engine

The three-cylinder engine fires 1, 3, 2 from the front of the engine, or 1, 2, 3 if from the rear.

The action of the firing of a three-cylinder engine is as follows: Taking three points of the circle, **A** at the top, **B** and **C** on either side below, the piston of No. 1 cylinder is connected with a crank at **A**, of No. 2 cylinder at **B**, and of No. 3 cylinder at **C**.

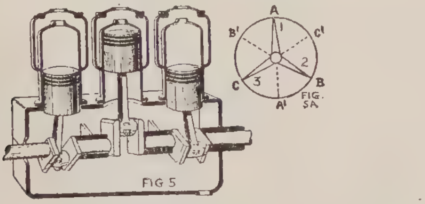


Fig. 5. A three-cylinder engine crank set in three positions of a third of a revolution, or 120° apart.

No. 1 cylinder will be at full compression, **No. 2 cylinder** at two-thirds inlet, and **No. 3 cylinder** one-third, exhaust 240°.

The crank of No. 1 cylinder performs its half revolution, bringing it to position **A′** (Fig. 5A); while it is doing this, No. 2 cylinder is completing its inlet stroke and two-thirds of its compression stroke, and the crank is passed on to position **B′**, leaving only one-third of a stroke to complete compression and to bring the crank to **A,** when the firing of **B** commences.

Meanwhile, **C** is completing its exhaust and inlet strokes, and has passed through two-thirds of its compression stroke, so that when No. 2 cylinder has completed its impulse, No. 3 has but to be carried over the small gap by the fly wheel, which gap represents the minus lap.

Each of the three cylinders fire once every 720° (two revolutions), or 240° apart. No. 1 **(A)** fires and moves 240°, which brings No. 2 **(B)** in firing position. No. 2 **(B)** fires and moves 240°, which brings No. 3 **(C)** in firing position. No. 3 **(C)** fires and moves 240°, which again brings No. 1 **(A)** in firing position.

No. 1 **(A)** has now made two revolutions or 720° which completes the four-cycle evolution.

The working, or power stroke is 134°; 240° less 134° equals 106°, during which time no work is being done, that is, the fly wheel carries the crank 106°.

Firing Order of a Four-Cylinder Engine

Four-cylinder engines are so arranged that there is a power or firing impulse every stroke, or two firing impulses every revolution, one beginning as the previous one ends.

In order to complete **the four-cycle evolution of suction, compression, explosion,** and exhaust for each piston, it is necessary that each piston have four strokes. As 1 and 4 work together and 2 and 3 work together, then during the four strokes (two up and two down), there are two revolutions of the crank shaft which will complete the cycle evolution for each piston, with a firing order of either 1, 2, 4, 3, or 1, 3, 4, 2.

The crank shaft of a four-cylinder four-cycle engine is always set at 180°.

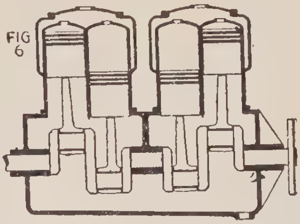


Fig. 6. Four-cylinder engine with crank shaft set at 180°. Power stroke every half revolution, or stroke of piston.

The construction of the crank shaft which is generally used on four-cylinder engines is shown in Fig. 6. This crank shaft would not permit the firing to be 1, 2, 3, 4, because, when No. 2 was ready to go down on the power stroke, No. 3 would have to be coming up on compression, but as No. 3 is always the same position as No. 2, then it could not be coming up, as it would already be up with No. 2. It follows, then, that the firing order must then be as given above: 1, 2, 4, 3, or 1, 3, 4, 2.

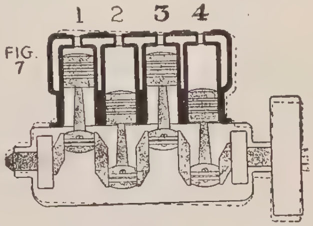


Fig. 7. Type of crank shaft which would permit a four-cylinder engine to fire 1, 2, 3, 4, but which is never used.

A four-cylinder engine which could be made to fire 1, 2, 3, 4, would have a crank shaft made as shown in Fig. 7, but it would vibrate excessively on account of the rocking motion of firing from one end to the other. Therefore the **firing order on all engines is arranged to decrease vibration** as much as possible. The alternate distribution of impulse (firing) tends to steady the engine, as in the sequence 1, 2, 4, 3, or 1, 3, 4, 2.

Cylinders are originally made to fire in proper order by the manufacturer, by setting the cams on the cam shaft and by wiring the distributor to connect with the proper spark plugs. **The order of firing** depends on the ideas of the maker, and may be either, 1, 2, 4, 3, or 1, 3, 4, 2, on a four-cylinder engine.

The eight "V"-type of cylinder engine uses a four-cylinder 180° crank shaft with two connecting rods to one crank pin.

The twin six or twelve "V"-type engine uses a regular six-cylinder crank shaft. This will be treated farther on, together with the firing order.

Relation of One Piston to the Other

On a four-cylinder engine, as already stated, the firing order must be 1, 2, 4, 3, or 1, 3, 4, 2.

The following explanation and charts will make clear just what action is taking place in cylinders when the engine is firing in the order 1, 2, 4, 3, or 1, 3, 4, 2.

If piston No. 1 is going down, say, on power, No. 2 must be coming up on either compression or exhaust. If coming up on compression it would fire next. No. 3 would then be coming up on exhaust and No. 4 going down on suction. In this case, the firing order would be 1, 2, 4, 3. (See chart No. 1, showing firing order 1, 2, 4, 3.)

If No. 1 was going down on power and No. 2 coming up on exhaust, then No. 3 would be coming up on compression and would fire next. In this case, the firing order would be 1, 3, 4, 2. (See chart No. 2, showing firing order 1, 3, 4, 2.)

Remember, the two down strokes are suction and **power.** The two up strokes are **compression** and **exhaust.** Each piston must be doing one of the four, during each of the four strokes or two revolutions.

The change of firing is accomplished by the movement of cams on the cam shaft, the cams on cylinders Nos. 2 and 3, being the only two affected. A study of charts No. 1 and No. 2, which represent a four-cylinder engine firing 1, 2, 4, 3, and 1, 3, 4, 2, will give the reader an idea as to what is taking place in each cylinder during the four strokes.

Relation of the Cam Movement to Crank Shaft

As we have seen, the only two firing orders that a four-cylinder engine can have is 1, 2, 4, 3, or 1, 3, 4, 2. To change from one to the other would necessitate changing the cams operating the valves on cylinders 2 and 3, which of course would necessitate putting in different cam shafts.

When No. 1 Piston is	No. 2 Piston is	No 4 Piston is	No. 3 Piston is
STARTING DOWN ON FIRING OR POWER STROKE	Just starting up on COMPRES-SION	Just starting down on SUCTION	Just starting up on EXHAUST
Just starting up on EXHAUST	TOP ON FIRING STROKE	Just starting up on COMPRES-SION	Just starting down on SUCTION
Just starting down on SUCTION	Just starting up on EXHAUST	TOP ON FIRING STROKE	Just starting up on COMPRES-SION
Just starting up on COMPRES.	Just starting down on SUCTION	Just starting up on EXHAUST	TOP ON FIRING STROKE

Chart No. 1. Firing order 1, 2, 4, 3.

When No. 1 Piston is	No. 3 Piston is	No. 4 Piston is	No. 2 Piston is
STARTING DOWN ON FIRING OR POWER STROKE	Just starting up on COMPRES-SION	Just starting down on SUCTION	Just starting up on EXHAUST
Just starting up on EXHAUST	TOP ON FIRING STROKE	Just starting up on COMPRES-SION	Just starting down on SUCTION
Just starting down on SUCTION	Just starting up on EXHAUST	TOP ON FIRING STROKE	Just starting up on COMPRES-SION
Just starting up on COMPRES-	Just starting down on SUCTION	Just starting up on EXHAUST	TOP ON FIRING STROKE

Chart No. 2. Firing order 1, 3, 4, 2.

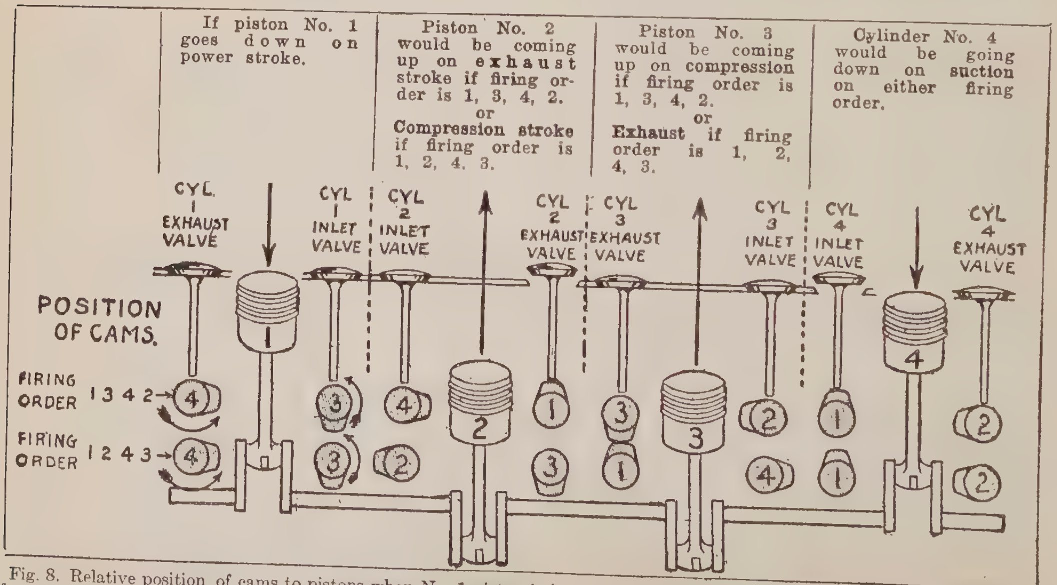
Fig. 8 below gives a good illustration of the position of the cams in relation to the two firing orders.

The lower row of cams shows the position of the cams on the cam shaft when the engine is firing 1, 2, 4, 3 and No. 1 piston is ready to start down on the power or firing stroke.

The upper row of cams shows the position of the cams on the cam shaft, when the engine is firing 1, 3, 4, 2 and No. 1 piston is ready to start down on the power or firing stroke.

Every stroke of the piston, or 180° movement, represents a half-revolution of the crank shaft.

Every half-revolution of the crank shaft represents one-quarter revolution, or 90° movement of the cam shaft and of the cams. A careful study of Fig. 8 is recommended.


If piston No. 1 goes down on power stroke.

Piston No. 2 would be coming up on **exhaust** stroke if firing order is 1, 3, 4, 2. or **Compression stroke** if firing order is 1, 2, 4, 3.

Piston No. 3 would be coming up on **compression** if firing order is 1, 3, 4, 2. or **Exhaust** if firing order is 1, 2, 4, 3.

Cylinder No. 4 would be going down on **suction** on either firing order.

Fig. 8. Relative position of cams to pistons when No. 1 piston is just starting down on power stroke. Approximate position of cams is shown with a firing order 1, 3, 4, 2 (upper row), and 1, 2, 4, 3 (lower row of cams). The figures in the center of the cams correspond with those on the cams in Fig. 10, page 33. At each stroke of the piston, or one half-revolution of the crank shaft, the cams travel 90 degrees or a ¼ revolution.

HOW TO DETERMINE THE FIRING ORDER OF A FOUR-CYLINDER ENGINE

Fig. 9 shows how the cam shaft with its cams is driven by a **silent chain sprocket.** Also note the **mark on the fly wheel** which is in line with the punch mark on the crank case, when pistons 1 and 4 are on upper dead center. Pistons 2 and 3 are on lower dead center. The setting of the valves and of the gears is determined when the pistons are in this position.

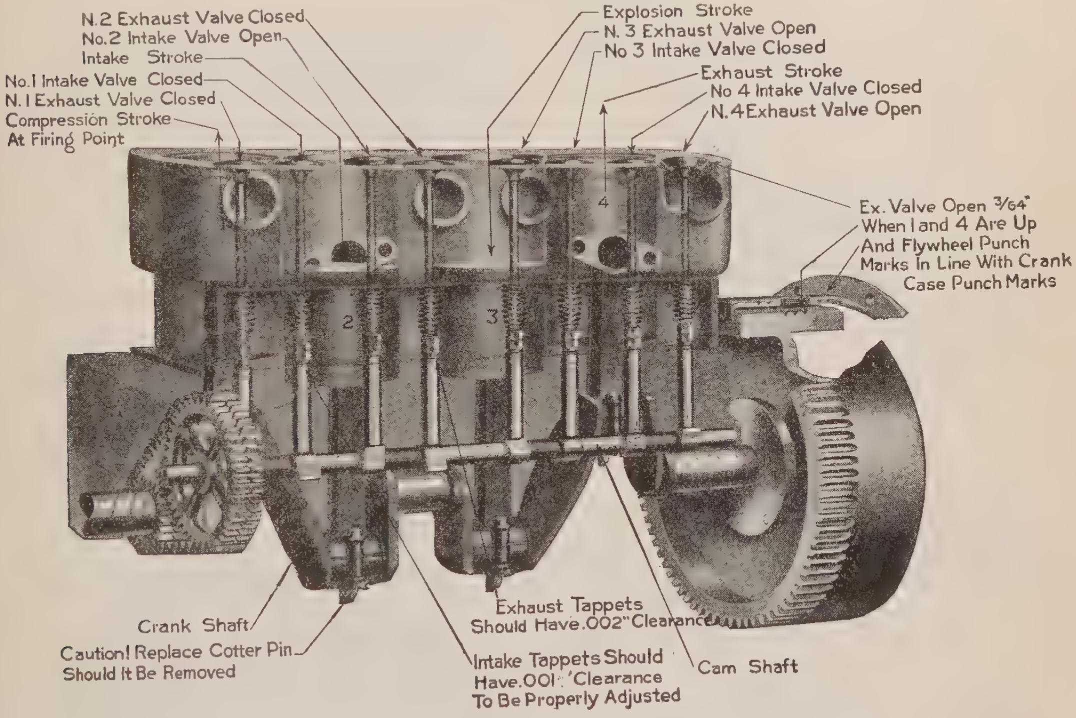

N.2 Exhaust Valve Closed
No.2 Intake Valve Open
Intake Stroke
No.1 Intake Valve Closed
N.1 Exhaust Valve Closed
Compression Stroke At Firing Point
Explosion Stroke
N.3 Exhaust Valve Open
No 3 Intake Valve Closed
Exhaust Stroke
No 4 Intake Valve Closed
N.4 Exhaust Valve Open
Ex. Valve Open 3/64" When 1 and 4 Are Up And Flywheel Punch Marks In Line With Crank Case Punch Marks
2
3
4
Crank Shaft
Caution! Replace Cotter Pin Should It Be Removed
Exhaust Tappets Should Have.002" Clearance
Intake Tappets Should Have.001" Clearance To Be Properly Adjusted
Cam Shaft

Fig. 9

For example: The exhaust valve on No. 1 cylinder closes at 10° past upper dead center. Therefore, as the piston of No. 1 cylinder is now on top dead center, the fly wheel must be revolved in the direction of rotation, 10° from upper dead center. At this point the exhaust valve of No. 1 cylinder should just close. This is sufficient, as all other valves will be timed to open and close at the correct time, since this is an "L"-head cylinder block with all valves on one side and all cams on one cam shaft. Note that the detachable cylinder head has been removed.

If the exhaust does not close at 10° past dead center, then it is either because the clearance of the exhaust valve tappet is set too close and holds the valve open too long, or the cam-shaft gear is not meshed properly.

The firing order of this engine can be determined by observing the position of the pistons and valves: The exhaust and inlet of No. 1 are closed; the piston of No. 1 cylinder is at the top of compression and will go down on power stroke. The piston of No. 2 cylinder is at the bottom of its intake stroke and will come up on compression; the inlet valve is still open and the exhaust closed. The piston of No. 3 cylinder is at the bottom of its stroke and will come up on the exhaust stroke; the exhaust valve is open and the intake valve is closed. The piston of No. 4 cylinder is at the top of its exhaust stroke and will go down on suction; the exhaust valve will close within a 10° movement of the crank shaft (note the exhaust cam just leaving the No. 4 exhaust valve tappet in the direction of its rotation), and the inlet will open immediately as the piston starts down.

To determine the firing order: If No. 2 will come up on compression as No. 1 piston goes down, and if the power stroke follows immediately after the compression stroke, then No. 2 will fire next. Therefore the firing order must be **1, 2, 4, 3.** The only other firing order it could possibly have would be 1, 3, 4, 2—but this would be impossible because No. 3's exhaust valve is open and it will come up on the exhaust, and after the exhaust comes suction. No. 3 has just fired, therefore No. 1 will fire next.

How to determine quickly the firing order of a four-cylinder engine[1]: When the nose of the first and third cam (inlet or exhaust) are on opposite sides of a shaft, the engine fires 1, 2, 4, 3. When the first and third cams are on the same side of the shaft, the firing order is 1, 3, 4, 2.

Note. The cam shaft is operated by a silent chain and sprocket which turns in the same direction as the crank shaft. The crank shaft turns twice while the cam shaft turns once.

The cams in Fig. 8, page 78, are made to open and close exactly on a full stroke of the piston, or 180° movement of the crank, which is unusual in actual practice.

On the engine in Fig. 9, the cams are set as in actual practice. For instance, the valves open and close as follows: Exhaust closes 10° after top. Inlet opens 6° after top. Exhaust opens 50° before the piston is at bottom dead center. Inlet closes 40° after bottom dead center. The bore of cylinders is 3¾″ diameter and the stroke of piston is 4¼″.

The make of the engine shown in Fig. 9 is the Golden Belknap and Swartz Co.'s model "E-M 31," four-cylinder side-valve detachable head engine. Horse power is 22½ at 935 feet of piston speed per minute; produces 36.9 h. p. at 2,800 r. p. m. on actual brake test and 31.9 h. p. at 2,000 r. p. m.

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[1] This applies to engines where the first valve is an exhaust valve, which is usually the case, as exhaust valves are placed next to the water jacket. On some early models of engines, the first valve was an inlet valve.

INSTRUCTION No. 11

SIX, EIGHT, AND TWELVE-CYLINDER ENGINES: Firing Order; Rotary-Valve and Rotary-Cylinder Engines; Sleeve Valve Engine; Overhead Cam-Shaft Engine

THE SIX-CYLINDER ENGINE

In the six-cylinder engine, **the variance in construction** from the four-cylinder engine is principally in the addition of more cylinders and the shape of the crank shaft.

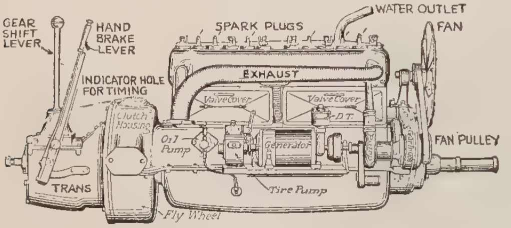


Fig. 1. Six-cylinder unit power plant, valve side. Cylinders of the "L" type. Thus the valves are all on one side.

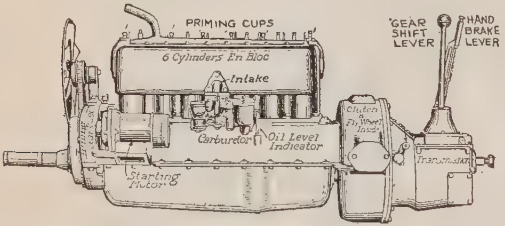


Fig. 2. Left side or carburetion side. The inlet pipe passes between the cylinders to the valve side.

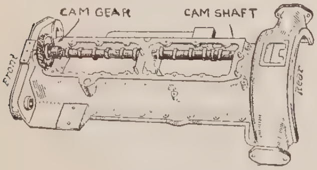


Fig. 3

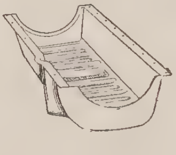


Fig. 4

Fig. 3. Upper part of crank case supporting cam shaft and bearings.

Fig. 4. Lower part of crank case or oil pan.

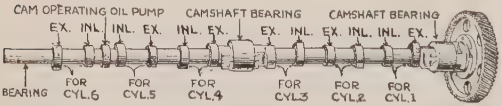


Fig. 5. Six-cylinder cam shaft. All cams on one shaft.

The cylinders may be in "pairs," in "triplets," or "in-block." The six-cylinder engine shown in Figs. 1 to 5 is the **Haynes,** and is a typical example of a "unit power plant." The cylinders are "in-block" with all valves on one side. This is, therefore, an "L"-head type cylinder block. The crank shaft shown in Fig. 8 is a three-bearing crank shaft and the cam shaft (Fig. 5) has three bearings.

The Pierce-Arrow six-cylinder engine (Fig. 97, page 54) is a "T"-head type with cylinders "in-block." The inlet valves are on the right side and the exhaust valves on the left side. There are two exhaust and two inlet valves for each cylinder on the Pierce-Arrow, and this is, therefore, a "dual" valve engine.

The Locomobile six-cylinder engine is also a "T"-head type, but with cylinders in pairs. The inlet valves are on the left side and the exhaust valves on the right side.

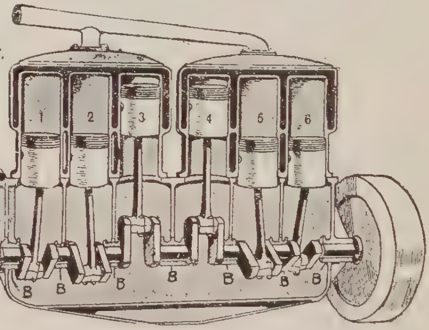
The Haynes, Locomobile, and almost all other six-cylinder engines have but one inlet and one exhaust valve for each cylinder.

Note. The right side of an engine or automobile is the side seen when seated in the car. That is why we designate the cylinders "right" and "left." The reverse is the case, of course, when facing the front of engine.

The six-cylinder engine operates on the four-cycle principle, the same as the four-cylinder; in fact, the general principle is that the crank shaft must turn two revolutions during the cycle or four strokes. The cam shaft turns one revolution.

Each piston completes the four strokes during two revolutions of the crank shaft. The crank shaft is divided into three pairs of "throws." A "throw" on a crank shaft is the part to which the big end of the connecting rod connects and is really the "crank pin." Each pair of these crank shaft "throws" (1 and 6, 3 and 4, and 2 and 5) are placed 120° or one-third the distance of a circle apart.

FIG. 6



There are **two kinds of six-cylinder crank shafts:** left hand and right hand (see Figs. 7 and 8). The cylinders usually fire on a right-hand crank 1, 5, 3, 6, 2, 4, while on a left-hand, the order is usually 1, 4, 2, 6, 3, 5. There are four firing orders which will be explained farther on.

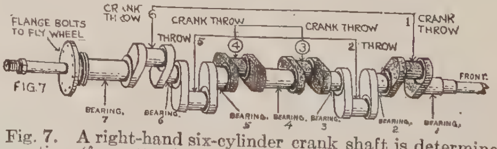


Fig. 7. A right-hand six-cylinder crank shaft is determined by noting (from the front end of the shaft) the position of the center throws, 3 and 4 to 1 and 6. If they are to the right of 1 and 6, as shown in Fig. 7, then it would be a right-hand crank (view from front). Being a right-hand crank, therefore, it will fire 1, 5, 3, 6, 2, 4, or 1, 2, 4, 6, 5, 3.

FIG 8

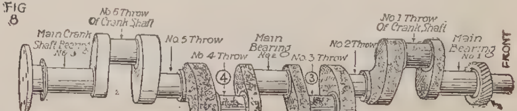


Fig. 8. A left-hand six-cylinder crank shaft. Note that 3 and 4 throws are to the left of 1 and 6, when looking at the crank shaft from the front end. Therefore it would fire 1, 4, 2, 6, 3, 5, or 1, 3, 5, 6, 4, 2.

The number of bearings for the six-cylinder crank shaft may be three, five, or seven. Three or five bearings is the usual number. Fig. 7 shows a seven-bearing six-cylinder crank shaft which is unusual and Fig. 8, a three-bearing crank which is in general use.

Carburetion: A six-cylinder engine usually requires special intake pipes and a double or multiple jet type of carburetor to meet the demand of the multiple of cylinders and the distance which the carburetted gas must travel.

The timing of six-cylinder valves is identical with that of the four. The process is gone through with in just the same manner. It is only necessary to time with the exhaust valve closing on the first cylinder on the "L" type, and with the exhaust valve closing on exhaust side and the inlet opening on inlet side on the "T"-head type.

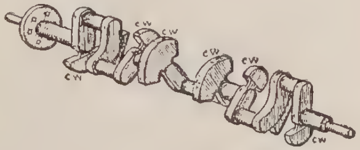


Fig. 8A. One method of balancing a six-cylinder crank shaft.

Counter-balance weights are sometimes applied to a six-cylinder crank shaft to relieve the "whip" or vibration at high speeds. Fig. 8A above shows the counter-balance weights (CW) electrically welded to the crank-shaft arms.

There are six power impulses or explosions during two revolutions of the crank shaft.

Another type of six-cylinder engine is the engine used on the Rumpler, a German make of car. This engine uses three pairs of cylinders placed 60° apart. One pair of cylinders is set vertically over the crank shaft, and there is a pair of cylinders placed at an angle of 60° on each side.

Firing Order of a Six-Cylinder "Right"-Hand Crank

The throws of a six-cylinder crank shaft are divided into three positions, or 120° apart.

1 and 6 are always in line
3 and 4 are always in line
2 and 5 are always in line

They may be placed to the right or the left, as shown in Figs. 9 and 10.

In Fig. 9, the first firing order is 1, 5, 3, 6, 2, 4 (it could also be 1, 2, 4, 6, 5, 3).

Fig. 9, right-hand crank shaft, shows pistons 1 and 6 up. If No. 1 starts down on "firing," No. 5 would be coming up on compression, as it would fire next. No. 3 would be 120° behind No. 5 and would fire next. No. 6 being 120° behind No. 3, it would fire next, then No. 2, then No. 4.

For the second firing order (1, 2, 4, 6, 5, 3) start with No. 1, then 2, 4, 6, 5, and 3 (Fig. 9).

Note. The view is from the front of the engine. Although the pistons are shown out of line, this is necessary in order for the reader to understand the relative positions, one to the other. When in cylinders, they are all in line and the connecting rods are out of line.

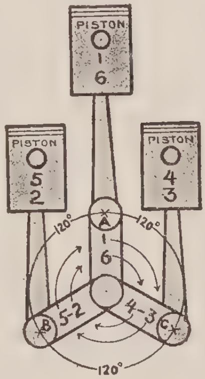


Fig. 9

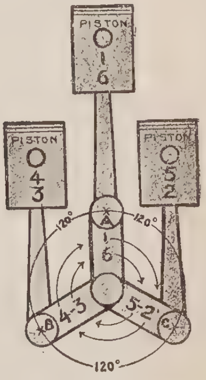


Fig. 10

Firing Order of a Six-Cylinder "Left"-Hand Crank

In Fig. 10 first firing order is 1, 4, 2, 6, 3, 5 (it could be 1, 3, 5, 6, 4, 2). If No. 1 starts down on firing, No. 4 would fire next, then No. 2, then 6, 3, and 5 in their respective order.

For the second firing order (1, 3, 5, 6, 4, 2), start with No. 1, then No. 3, 5, 6, 4 and 2 (Fig. 10).

Relation of One Piston to the Others for Two Firing Orders of a Six-Cylinder Engine

The chart below shows what action is taking place in the cylinders, when the engine is firing 1, 4, 2, 6, 3, 5 (top row and Fig. 10), and when firing 1, 5, 3, 6, 2, 4 (second row of figures and Fig. 9).

When No. 1 Piston is	No. 4 Piston is	No. 2 Piston is	No. 6 Piston is	No. 3 Piston is	No. 5 Piston is
When No. 1 Piston is	No. 5 Piston is	No. 3 Piston is	No. 6 Piston is	No. 2 Piston is	No. 4 Piston is
TOP ON FIRING	1/3 of a revolution from top of up compression stroke	1/3 of a revolution from top on down intake stroke	Top on Exhaust	1/3 of a revolution from top on up exhaust stroke	1/3 of a revolution from top on down firing stroke
1/3 of a revolution from top on down firing stroke	TOP ON FIRING	1/3 of a revolution from top on up compression stroke	1/3 of a revolution from top on down intake stroke	Top on Exhaust	1/3 of a revolution from top on up exhaust
1/3 of a revolution from top on up exhaust stroke	1/3 of a revolution from top on down firing stroke	TOP FIRING	1/3 of a revolution from top on up compression stroke	1/3 of a revolution from top on down intake stroke	Top on Exhaust
Top on Exhaust	1/3 of a revolution from top on up exhaust stroke	1/3 of a revolution from top on down firing stroke	TOP FIRING	1/3 of a revolution from top on up compression stroke	1/3 of a revolution from top on down intake stroke
1/3 of a revolution from top on down intake stroke	Top on Exhaust	1/3 of a revolution from top on up exhaust stroke	1/3 of a revolution from top on down firing stroke	TOP FIRING	1/3 of a revolution from top on up compression stroke
1/3 of a revolution from top on up compression stroke	1/3 of a revolution from top on down intake stroke	Top on Exhaust	1/3 of a revolution from top on up exhaust stroke	1/3 of a revolution from top on down firing stroke	TOP FIRING

THE EIGHT-CYLINDER "V"-TYPE ENGINE

The advantage of a multiple-cylinder engine is principally in the flexibility of control, by which is meant quick acceleration or quick pick up of the engine from slow to fast speed, the absence of gear shifting, and a more perfect control. The more cylinders firing or "lapping," the more flexible the control, or in other words, the power impulses are more frequent. In fact, the more cylinders, the more the lapping of one firing impulse with another, or the more cylinders are on power stroke at the same time. Thus we obtain a more even torque, or steady stream of power impulses.

The simplest arrangement of the eight cylinders would be all in line, just as the six or the four are arranged. But this would be impracticable, owing to the extreme length and also to the abnormally long crank shaft and the extra bearings which would be necessary, while the crank case for such an engine would be very heavy. To get around these difficulties the cylinders are arranged in two sets of four opposite to each other, at an angle of 90° in the form of a "V."

Note. The Lincoln and Wills St. Claire engines are at an angle of 60°.

Crank shaft: Arranged in this way ("V"-type), the eight-cylinder engine is no longer than a four-cylinder one of equal bore. As compared with a six, it has about 30 per cent less length, resulting in a shorter crank case—a weight-reduction factor. In addition, its crank shaft is of the same form as that of a four, the throws being all in one plane; whereas those of a six crank shaft are in three planes, which is a more difficult manufacturing job. Furthermore, the shorter shaft is less given to periodic vibration. The cam shaft is also shorter and less prone to whipping.

Let us next consider the **cylinder and connecting-rod arrangement of the eight "V"-type cylinder engine.** Where the cylinders are "opposite," this means the lower end of the connecting rod is "yoked." The cylinders are in line with the opposite cylinders when looking from the side of the engine.

Where the cylinders are "staggered," this means that the lower ends of the connecting rods are not together but are "side by side" on the same crank-shaft bearing. This naturally necessitates the cylinders on one side being placed a little to the side, or not exactly in line with the opposite cylinder when looking from the side of the engine. This arrangement is termed "staggered."

The cam shafts on the eight "V"-engine may be one or two. The majority use one cam shaft. The Cadillac uses a cam shaft with eight cams operating the sixteen valves, whereas some of the other eight "V"-type engines use one cam shaft with sixteen cams (one for each valve).

Example of an Eight-Cylinder "V"-Type Engine

As an example of an eight-cylinder engine and its construction, the Cadillac make is shown in the following illustrations.

Although a later model Cadillac is somewhat different in minor construction details, the illustrations of the model given will furnish a good general idea as to how a modern eight-cylinder engine is constructed.

On the later model Cadillac, the engine is of the same bore and stroke as formerly: 3⅛″ bore by 5⅛″ stroke; piston displacement 314 cubic inches. Cylinder heads are now detachable. It is no longer necessary to remove the radiator to take out the water strainer between the radiator and water pump. Other changes also have been made.

The front end of the Cadillac eight-cylinder engine is shown in Fig. 11. There are two groups of cylinders, each of a block casting of four cylinders, mounted at 90° to each other on an aluminum crank case. **The cylinders** are 3⅛″ bore and 5⅛″ stroke. **The piston** displacement is 314 cubic inches; the horse-power rating is 31.25. In dynamometer tests the engine shows 70 h. p. at 2400 r. p. m.

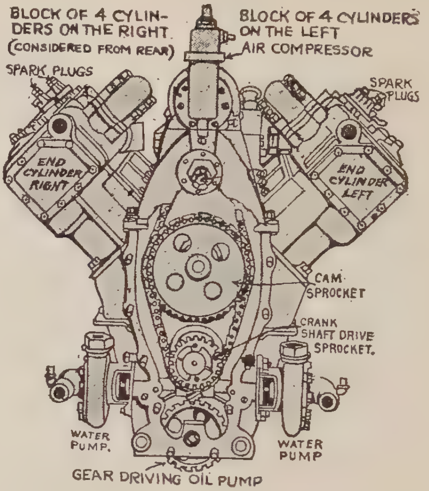


Fig. 11. Front view of an eight-cylinder "V"-type engine.

The crank shaft is identical in design with that used in a four-cylinder engine, and the cam shaft carries the same number of cams as in a four-cylinder design. This engine weighs approximately 60 pounds less than the former four-cylinder Cadillac engine of equal horsepower. There is but one carburetor used.

Each of the two cylinder castings contains four L-shaped cylinders with detachable heads.

The exhaust valves are of the conventional poppet shape. The inlet valve on the early models (as shown in Fig. 11), was of the "tulip" shape. This is not now used. Over each cylinder is a removable cap which gives access to the water jacket and to the combustion chamber. Between the second and third cylinder in each block the breather pipe is brought up through the cylinder casting (now on the valve cover plates). In rear of the fan is the power tire pump for tire inflation (now bolted to right-hand side of the transmission case).

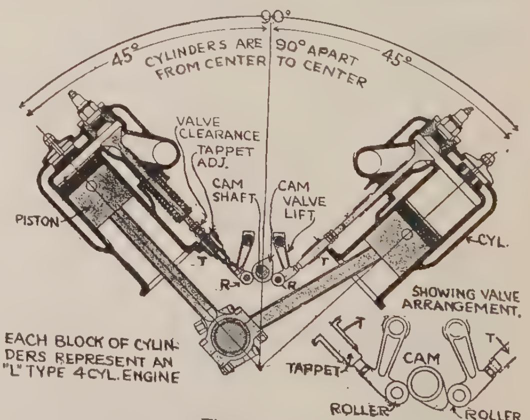

90°
45°
45°
CYLINDERS ARE 90° APART FROM CENTER TO CENTER
VALVE CLEARANCE TAPPET ADJ.
CAM SHAFT
CAM VALVE LIFT
PISTON
CYL.
T
T
R
R
SHOWING VALVE ARRANGEMENT.
EACH BLOCK OF CYLINDERS REPRESENT AN "L" TYPE 4 CYL. ENGINE
TAPPET
CAM
T
ROLLER
ROLLER

Fig. 12

Fig. 12A

Fig. 12. Valve-operating mechanism of the eight cylinder "V"-type engine (Fig. 11).

A cross-section view of the engine with the cylinder mounted in two groups of four cylinders each at an angle of 45° from vertical center, or 90° from cylinder centers is shown in Fig. 12.

The single cam shaft is located directly above the crank shaft, and the means whereby one cam operates the two intake valves for the opposite cylinders is shown.

The valve operating mechanism is shown in Figs. 12 and 12A. Note how one cam operates two opposite valves. The cam bears against the rollers (**R**) at the ends of the small arms which are pivoted to the plate above, and which are interposed between the ends of the push rods and the cams, so that the lift will be straight upward instead of having a side thrust.

Adjustment of valve clearance is obtained in the usual way by lengthening the tappet (**T**). The upper part of the tappet screws into the lower and the two are locked by a nut. The position of the cylinders makes the valves easily accessible.

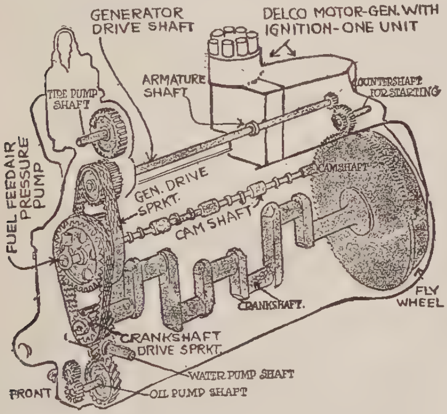


Fig. 13. Note the silent chain of the engine front-end drive from crank shaft to cam shaft and generator shaft. In the later models of the Cadillac the distributor is not mounted on the generator housing, as shown, but is mounted behind the fan housing.

Note the single cam shaft shown in Fig. 13. There are eight cams which operate the sixteen valves (eight inlet and eight exhaust valves). Each cam operates two valves through the rollers shown on opposite sides (Fig. 12A). The shaft is carried on five bearings.

On another make of "V"-type engine, there are two cam shafts. This permits the direct opening of valves without the rocker arms between cams and tappets, and also permits any desired timing.

The front-end drive system is shown in Fig. 13. Note the two silent chains, one driving the cam shaft; the other is driven from the cam shaft which drives the Delco electric system. There are **two water pumps** on the cross-shaft below the crank shaft, and this shaft in turn drives the gear-type oil pump. The tire pump was formerly driven by a spur gear, as shown, but is now driven from the side of the transmission and is driven by a sliding gear.

Crank shaft: A three-bearing crank shaft is used, with the throws at 180°, as in a four-cylinder design.

Connecting rods are "yoked." Two connecting rods attach to each crank pin, this being made possible by having one connecting rod with a split or forked lower end, and the other with a single end to fit between the forks; this is called the "yoked" design.

Note how the two connecting rods are attached to one bearing in Fig. 14. The outer connecting rod fastens to the outer ends of the split bushing with a two-bolt cap for each arm of the yoke. The bushing is fixed to this rod by pins.

The other, or inner connecting rod goes between the two arms of the yoke, as shown by the dotted outline.

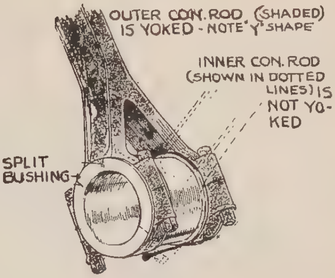

OUTER CON. ROD (SHADED) IS YOKED - NOTE 'Y' SHAPE
INNER CON. ROD (SHOWN IN DOTTED LINES) IS NOT YOKED
SPLIT BUSHING

Fig. 14

This inner rod is free to move on the bushing. Therefore, the bearing for the yoke-end rod is the inner surface of the bushing against the shaft, while that of the inner rod is the outer surface of the bushing.

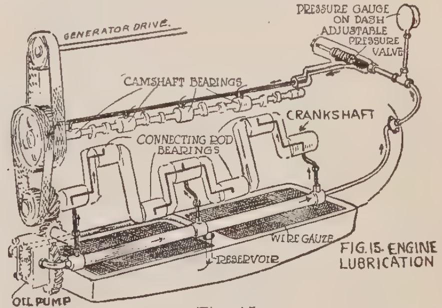


Fig. 15

Lubrication: The oil pump draws the oil up from the reservoir and forces it through the pipe running along the inside of the crank case (Fig. 15). Leads run from this pipe to the crank-shaft main bearing and thence through drilled holes in the shaft and webs to the rod bearings. It also is forced from the reservoir pipe up to the pressure valve, which maintains a uniform pressure above certain speeds, and then overflows from this valve to a pipe extending parallel with and above the cam shaft. Leads from this latter pipe carry the oil by gravity to the cam-shaft bearings and chains. Pistons, cylinders, etc., are lubricated by the overflow thrown from the rods.

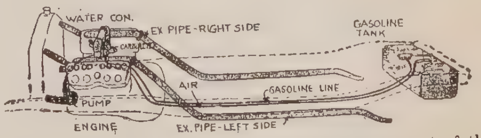


Fig. 16. Diagram showing the general arrangement of the fuel, water, and exhaust systems of the Cadillac chassis. There are two exhausts and two mufflers, one for each set of cylinders; while the gasoline is fed by pressure to the carburetor, which is between the two cylinder blocks. The air-pressure pump for forcing the fuel is at the front of the engine. There are two water pumps and two sets of water connections to the radiator. Carburetion and thermostat cooling are explained in the section on "Carburetion and Cooling."

Firing Order on an Eight-Cylinder "V"-Type Engine

The firing order of an eight-cylinder "V"-type engine is shown in Fig. 17.

On a "V"-type engine (Fig. 17) the right and left block of cylinders is the right and left sides observed when seated in the car. Therefore cylinder 1L would mean No. 1 cylinder of the left block, beginning with the front of the engine; No. 4 cylinder would be the rear cylinder.

The figures 1 to 8 at the side of each block represent the order in which the cylinders fire and do not refer

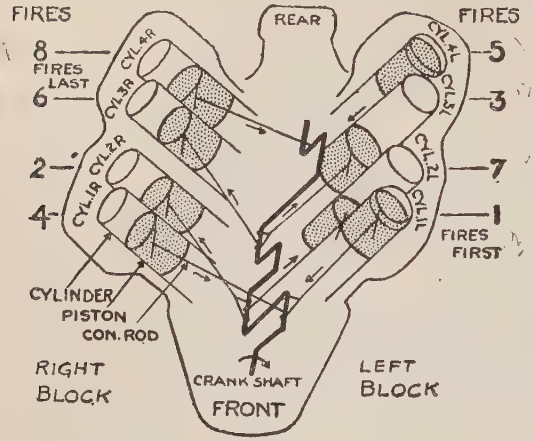


Fig. 17

to cylinder numbers. Therefore note that No. 1L fires first, then 2R, 3L, 1R, 4L, 3R, 2L, 4R.

Relative position of pistons: By observing piston No. 1 (Fig. 17), which is now ready to start down on its power stroke, or just commencing its working stroke, just what is taking place in all other cylinders can be seen by referring to the following:

1L:	Just starting down on power stroke.
2R:	Going up on compression; it will fire next.
3L:	Just starting up on compression; it will fire after No. 2 cylinder 2 R.
1R:	Going down on suction.
4L:	Just starting down on suction.
3R:	Going up on exhaust.
2L:	Just starting up on exhaust.
4R:	Going down on power.

It will be observed that No. 1 L and 4R will both be on power stroke; No. 2R and 3L on compression; No. 1R and 4L on suction; No. 3R and 2L on exhaust, for a certain period of time, which is termed "lapping" of strokes.

THE TWELVE-CYLINDER "V"-TYPE OR "TWIN SIX" ENGINE

The twelve-cylinder engine is referred to in this instruction as either a "twelve-cylinder" or a "twin six." Manufacturers use both terms. Literally, a twelve-cylinder engine would mean a type of engine having twelve cylinders placed in line on a crank shaft having twelve throws.

The "twin six" or twelve-cylinder "V" engine term, to be exact, consists of two sets of six cylinders placed at an angle of 60° over a regular six-cylinder crank shaft with six "throws" of the crank.

Note. The Liberty engine cylinders are at an angle of 45°.

Therefore, if the reader thoroughly understands the six-cylinder engine, it will not be a difficult matter to understand the twelve-cylinder "V"-type.

Before proceeding with the explanation of the "twin six," refer to the illustrations (Figs. 18, 19, and 20), and note the different angles in which cylinders are placed. Note, too, the evolution of raising the cylinders from 180° to 60°.

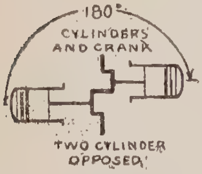


Fig. 18

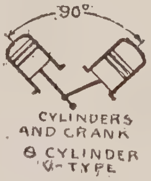


Fig. 19

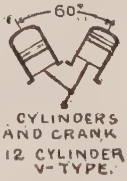


Fig. 20

Fig. 18 represents the two-cylinder opposed type of engine with cylinders 180° apart. Firing impulse every 360° of crank-shaft movement.

Fig. 19 represents the eight-cylinder engine with cylinders placed 90° apart. Firing impulse every 90° of crank movement.

Fig. 20 represents the twelve-cylinder engine with cylinders placed 60° apart. Firing impulse every 60° of crank movement.

Construction: As previously stated, by placing six more cylinders on a six-cylinder crank case and placing them "V"-type, at an angle of 60°, the same crank shaft and practically the same crank case can be utilized without materially increasing the size or weight of the engine, the addition being merely another set of cylinders and connecting rods.

The "twin six" engine offers more evenly divided impulses than the eight. Two cylinders are working together at all times, and part of the time three are working together.

On the eight-cylinder "V"-type, cylinders are set at an angle of 90°, or one-half the distance of firing of the four cylinders. In other words a four-cylinder fires every 180°, and by setting cylinders at 90° we get an impulse every 90°.

A six-cylinder engine fires every 120°. Therefore on a twelve-cylinder "V"-engine, we would place cylinders at an angle of one-half of 120°, which would be 60° instead of 90°, and thus get a firing impulse at every 60° movement of the crank shaft.

Firing order: The crank shaft of a "twin six" is a regular six-cylinder crank shaft. The crank may be a right-hand crank or a left-hand, as explained. The firing order of a "twin six" would then be the same as a "six," that is, if we consider each block of cylinders on a twin six as a separate six-cylinder engine.

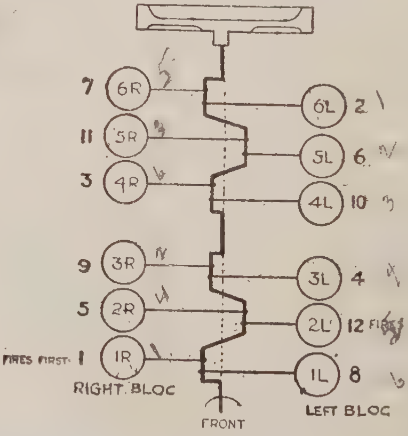


Fig. 21. If we consider each side as a separate six-cylinder engine, the firing order would be 1, 4, 2, 6, 3, 5 on each side. Note the crank shaft; the throws 1 and 6, 2 and 5, 3 and 4 are in line. This would be a left-hand crank shaft.

Taking each side separately as if a separate six-cylinder engine with the firing order 1, 4, 2, 6, 3, 5, note that the right block (Fig. 21), starting from front, would fire, 1R, 4R, 2R, 6R, 3R, 5R. Now start at the rear of the left block, 6L, 3L, 5L, 1L, 4L, 2L. If the cylinders were numbered from the rear, on the left block, as 1L, 2L, 3L, etc., the firing order would be 1L, 4L, 2L, L, 3L, 5L, the same as the right block, but from ear to front.

Combining the two six-cylinder engines, the firing rder of the "twin-six" engine would be as shown in ig. 21.

The figures outside of the circles indicate the order in which he cylinders fire on the Packard twin six. 1R fires first, then L, then 4R, 3L, 2R, 5L, 6R, 1L, 3R, 4L, 5R, 2L.

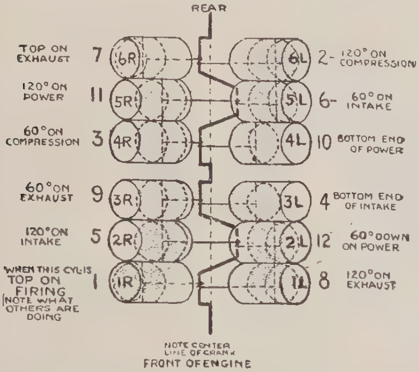


Fig. 22

The relative position of the pistons and what is taking lace in each cylinder when cylinder 1R is just starting ts power stroke is shown in Fig. 22.

The crank pins are 120° apart, whereas the firing mpulses are 60° apart.

The order in which the cylinders fire is designated y the numbers outside of the cylinders, in heavy type.

Note the position of the pistons when No. 1R is just eady to go down on power.

Laps of power strokes: Remembering that the xhaust valves open 46° before bottom dead center, hich is the same as saying that they open 134° fter top dead center, let us see how the cylinders ork together.

In Fig. 23, cylinder 1R has just fired, therefore it s delivering power. Cylinder 6L has completed 20° of its compression stroke. Cylinder 4R has ompleted only 60° of its compression stroke.

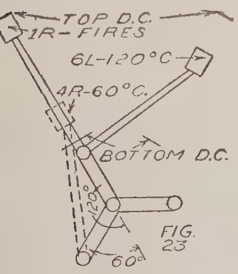


Fig. 23

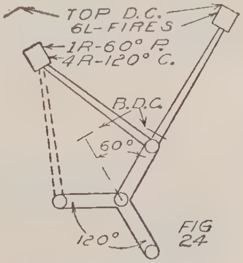


Fig. 24

Let us now examine the engine after the crank haft has revolved 60° to the position shown in Fig. 4. Cylinder 1R has completed 60° of its power troke and is still delivering power. Cylinder 6L as fully completed its compression stroke and now res; thus both cylinders 1R and 6L are delivering ower. Cylinder 4R has now completed 120° of its ompression stroke.

Let us now examine the engine after the crank haft has revolved another 60° to the position shown Fig. 25. Cylinder 1R has completed 120° of its ower stroke and is still delivering power. Cylinder 6L has completed 60° of its power stroke and is still delivering power. Cylinder 4R has now completed its compression stroke; it fires and therefore it is also delivering power. Therefore, at this point **all three cylinders are delivering power.**

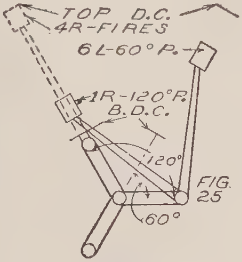


Fig. 25

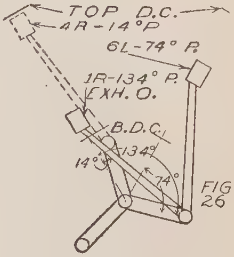


Fig. 26

Let us now examine the engine after the crank shaft has revolved another 14° to the position shown in Fig. 26. Cylinder 1R has now completed 134° of its power stroke and, at this time, the exhaust valve opens so that it has just stopped delivering power. Cylinder 6L has completed 74° of its power stroke and is still delivering power. Cylinder 4R has completed 14° of its power stroke and is still delivering power. Thus we see that during 14° of crank-shaft rotation (the time involved while going from the position shown in Fig. 25 to the position in Fig. 26), we had all three cylinders delivering power, but at the instant shown in Fig. 26, only two cylinders are delivering power.

These two cylinders will carry the load alone until the crank shaft has revolved another 46°, after which, cylinder 3L will start to fire, while cylinders 6L and 4R are still delivering power. Thus it is seen that the revolution of the crank shaft is made up of alternate intervals of 14° during which three cylinders are delivering power, and of intervals of 46° during which two cylinders are delivering power.

The cylinders on the Packard are staggered (see Fig. 21). Note that the left cylinders set ahead of the right. This is in order that the connecting rods may be placed "side by side" on the crank pin instead of being "yoked."

The cam shaft: One cam shaft with a separate cam for each valve is used.

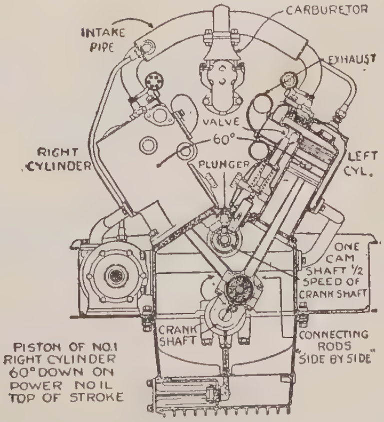

CARBURETOR
INTAKE PIPE
EXHAUST
VALVE
60°
RIGHT CYLINDER
PLUNGER
LEFT CYL.
ONE CAM SHAFT ½ SPEED OF CRANK SHAFT
CRANK SHAFT
CONNECTING RODS "SIDE BY SIDE"
PISTON OF NO.1 RIGHT CYLINDER 60° DOWN ON POWER NO. 1L TOP OF STROKE

Fig. 27. End sectional view of Packard "twin six" engine. Cylinder 1R is 60° down on power while 6L is on dead center.

Name of Parts

1 Valve-cover stud-nut assembly.
2 Valve—exhaust.
3 Valve-stem guide.
4 Valve spring.
5 Valve-spring collar.
6 Valve-spring collar key.
7 Valve roller-holder screw.
8 Valve roller-holder screw check nut.
9 Valve roller-holder screw plate.
10 Piston pin.
11 Connecting rod.
12 Valve roller-holder guide yoke.
13 Valve roller-holder guide.
14 Valve roller-holder and roller assembly.
15 Crank case upper to lower stud nut.
16 Crank-case overflow valve stud nut.
17 Crank-case overflow valve spring.
18 Crank-shaft oil thrower.
19 Fan driving pulley key.
20 Cam-shaft spiral gear, front.
21 Cam-shaft sprocket.
22 Distributor driving shaft nut.
23 Distributor driving shaft gear.
24 Distributor driving shaft.
25 Cam-shaft driving chain.
26 Cam-shaft driving chain oil tube assembly.
27 Gasoline power-pressure pump eccentric lock.
28 Gasoline power-pressure pump eccentric.
29 Motor-generator sprocket eccentric.
30 Motor-generator sprocket coupling, female.
31 Cam-shaft driving chain oil tube flange nut.
32 Distributor driving shaft bushing, upper.
33 Cylinder water-jacket plate.
34 Cylinder water-jacket plate screw.

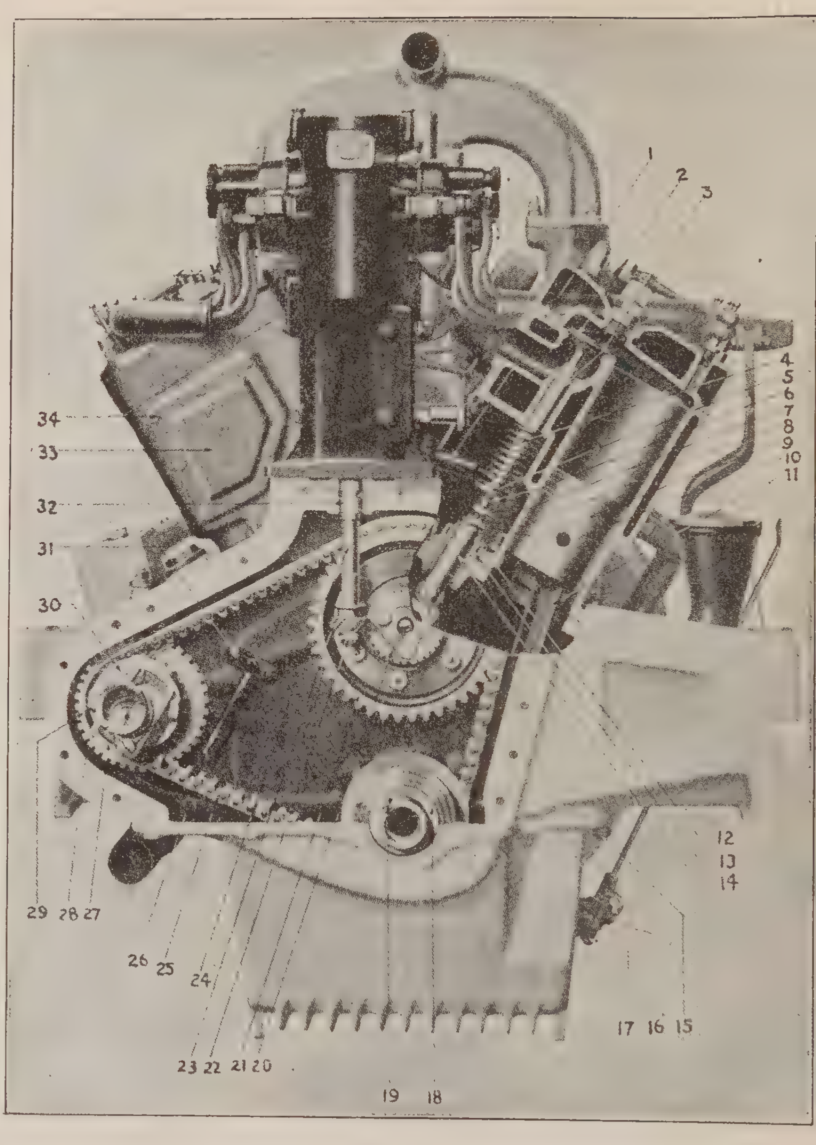


Fig. 28

Fig. 28. Front sectional view of Packard twin-six engine model "3-25" and "3-35." Four-cycle type with two blocks of "L"-head cylinders bolted to the crank case at an inclined angle of 60°. The cylinder bore is 3" and the stroke 5". The left block is set 1¼" ahead of the right block to permit the lower end connecting rod bearings from opposite cylinders being placed side by side on the same crank pin. This arrangement also permits the use of a single cam shaft with a separate cam for each valve operating directly on the valve push-rod roller.

Compression in all cylinders should be equal and up to the standard. Weakness or loss of compression is most probably due to imperfectly seated valves, which may be caused by insufficient clearance between the valve stems and lift rods, carbon deposits on the valve seats, or sticky valve stems and guides. Compression should be tested for uniformity in all cylinders at regular intervals.

To test the compression in a cylinder, remove the spark plug and replace it with a standard compression gauge. Then with the ignition switch off and pet cocks in all cylinders closed, crank the motor, using the electric starter. At cranking speed with the engine cold, the gauge should register 75 pounds plus or minus 3 pounds with the throttle wide open.

A change in the setting of the cam shaft is possible only by removal or disarrangement of the front end chain. Adjustments to the chain do not affect the valve timing.

In resetting the cam shaft, the arrows on both the crank-shaft and cam-shaft gears should point directly upward and should be in line with the arrow on the front end cover face of the engine. In this position, the inscription on the fly wheel, "exhaust closes 1 and 6-R," will be on the top dead center line of the engine, which is the center between the two cylinder blocks, and No. 1 right piston will be in the firing position.

The main and connecting rod bearings are of the babbitt-faced bronze type. The bearings are set with a .0015" to .002" clearance and are consequently flooded with a film of oil between the shaft and the bearing surface, making adjustment for wear necessary only at long intervals.

To grind the valves disconnect the carburetor inlet manifold and spark plug connections and remove the cylinder heads.

Valve clearance: Inlet and exhaust valves should have .004" clearance between valve stem and roller-holder set screw when the engine is cold. Be sure that the valve is fully seated when measuring clearance.

The vibration damper on the front end of the crank shaft should be adjusted to slip under a pull of approximately 140 lbs.

COMPARISON OF THE LAPS OF FIRING OR POWER STROKES OF A 4, 6, 8, AND 12-CYLINDER ENGINE

The eight and twelve-cylinder engines are "V"-type. The diagrams shown below as an example are based on the exhaust valve opening 46° before bottom. The point of the exhaust valve opening varies. However, the comparison would be the same.

Four-Cylinder Lap of Power Strokes

On a four-cylinder engine a power impulse occurs every 180°, or half-revolution, or four impulses during two revolutions of the crank shaft. There are four periods of 46° travel, or 184° in all, during the four strokes, in which there is no power impulse.

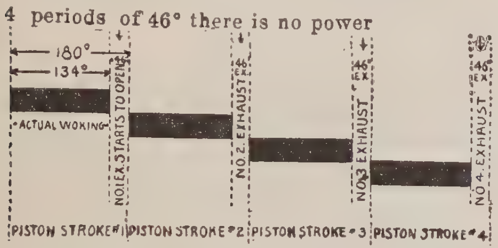


Fig. 1. 4-cylinder power-stroke periods.

Note in Fig. 1 that if piston No. 1 is firing, it does not travel its full stroke with a crank movement of 180° on power, because the exhaust valve starts to open, say 46°, before it reaches the bottom of its stroke, therefore it really travels but 134° on its power stroke. Consequently, before the next piston fires there is a gap of 46°.

Therefore, in a four-cylinder engine there are four periods of 134° when one cylinder is firing or working under a power impulse, and four periods of 46° when no cylinder is firing or working. The fly wheel must then take the pistons over center during the "no" working strokes.

Six-Cylinder Lap of Power Strokes

On the six-cylinder engine there is a power impulse every 120°, or one-third revolution of the crank shaft, or six power impulses during the two revolutions.

Each piston is working on all of its stroke of 180°, except 46°, leaving 134° actually working.

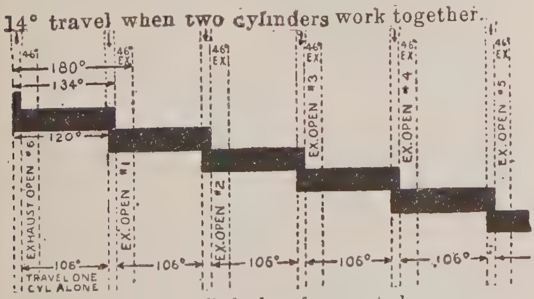


Fig. 2. 6-cylinder lap of power strokes.

The second cylinder to fire starts to work 120° after the first starts to work (Fig. 2), and works 14° before the exhaust opens or the impulse ends on the first cylinder. Consequently there is no idle space between the firing of the cylinders, but quite the reverse, for there is a "lapping" of power strokes.

Thus, there are, during the two revolutions of the crank shaft, six periods of 106° travel when one cylinder is working alone, and six periods of 14° travel when two cylinders are working together.

Therefore, 7/60ths of the time two cylinders are working together and 53/60ths of the time one cylinder is working alone.

The Eight "V"-Cylinder Lap of Power Strokes

The eight-cylinder "V"-type engine with cylinders 90° apart would act very much the same as a four-cylinder engine, if we consider each block separately.

There are eight power impulses or explosions during each cycle of two revolutions of the crank shaft. In other words, the four strokes of two revolutions are just the same as in a four, but there are eight power impulses or explosions during these two revolutions. There is a power impulse every quarter turn (90° movement) of the crank shaft, and thus there is no intermission between them, but rather an "overlapping" so complete that the turning effort is practically constant.

When one cylinder (Fig. 3) is firing, it would travel 134° on the power stroke, at which time the exhaust valve opens (46° before bottom, as an example).

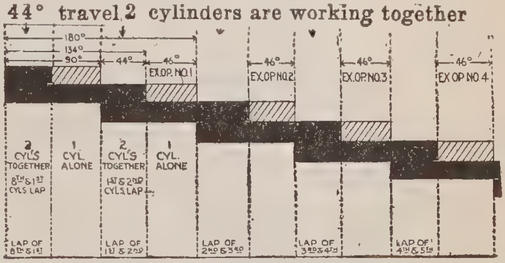


Fig. 3. 8-cylinder lap of power strokes.

The second cylinder starts to fire 90° after the first, and moves for 134° before its exhaust valve starts to open.

Therefore there are, during the four strokes, or two revolutions of the crank shaft, eight periods of 44° travel when two pistons are working together, and eight periods of 46° travel when one piston is working alone. Therefore 22–45ths of the time two cylinders are working together and 23–45ths of the time one cylinder is working alone.

Twelve-Cylinder Lap of Power Strokes

With the twelve-cylinder "V"-type engine with cylinders 60° apart, there are twelve power impulses during two revolutions of the crank shaft. There is a power impulse every 60° movement of the crank shaft.

When one cylinder is firing, it travels the same as those previously described, namely, 134° before the exhaust valve opens; it then continues for 46° more, till it reaches the end of its exhaust stroke.

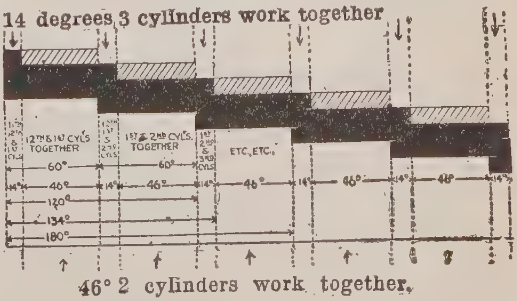

14 degrees 3 cylinders work together
11TH 12TH & 1ST CYLS
12TH & 1ST CYL'S TOGETHER
12TH 1ST & 2ND CYLS
1ST & 2ND CYL'S. TOGETHER
1ST 2ND & 3RD CYLS
ETC., ETC.
60°
14°
46°
120°
134°
180°
46° 2 cylinders work together.

Fig. 4. 12-cylinder lap of power strokes (only part is shown).

When the first cylinder fires (Fig. 4), and the piston has traveled only 60°, the second cylinder fires and joins No. 1; they then work together for a period of another 60°, when the third cylinder fires and joins No. 1 and 2. Now No. 1 has still 14° to travel before its exhaust valve opens; consequently the three work together until that occurs.

At the 134° point No. 1 cuts out and Nos. 2 and 3 work together for a period of 46° when No. 4 fires and joins them, and so it continues throughout the cycle.

Thus with every 60° movement of the crank shaft there is a period of 14°, during which three cylinders work together; or, in one complete revolution of the crank, or 360° movement, there will be six periods of 14° when three cylinders work together, and six periods of 46° alternating with these, when two cylinders work together. Therefore there are, during two revolutions of the crank shaft, twelve periods of 14° travel when three cylinders are working together and twelve periods of 46° travel when two cylinders are working together.

THE SLEEVE-VALVE ENGINE (STEARNS-KNIGHT AS AN EXAMPLE)

The sleeve-valve engine differs from any other four-cycle engine only in its method of admitting and exhausting the gas.

The sleeve valves: Instead of raising and lowering the poppet valves, to admit and expel the gas, there are two sleeves with ports or slots in them. At certain times, these ports on the same side of the cylinder come in line, as shown in Figs. 1 and 1A and Figs. A to F. These sleeves take the place of valves.

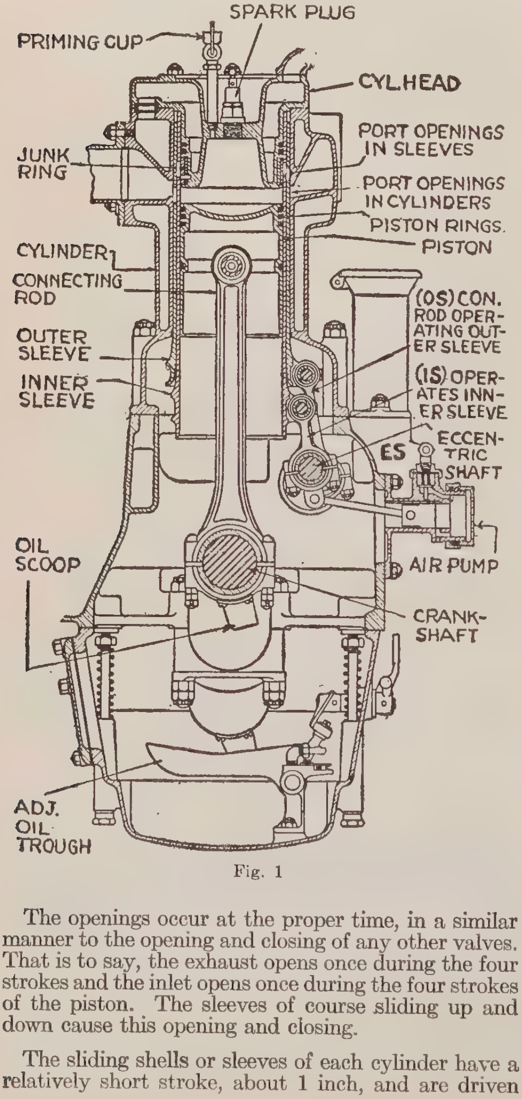


Fig. 1

The openings occur at the proper time, in a similar manner to the opening and closing of any other valves. That is to say, the exhaust opens once during the four strokes and the inlet opens once during the four strokes of the piston. The sleeves of course sliding up and down cause this opening and closing.

The sliding shells or sleeves of each cylinder have a relatively short stroke, about 1 inch, and are driven by two short connecting rods or side-arms working off a lay crank shaft, or eccentric shaft, the cranks having a very small throw.

Eccentric shaft: The sleeves are caused to slide up and down by an eccentric shaft (**ES**), which takes the place of a cam shaft, and which has eccentrics raising and lowering small connecting rods (**OS** and **IS**, Figs. 1 and A to F). This eccentric shaft is driven by a chain from a sprocket on the crank shaft of the engine. It is driven at the same speed as any other cam shaft, i.e., one-half the speed of the engine crank.

The eccentric pin operating the inner sleeve is given a certain lead or advance over that operating the outer sleeve. This lead, together with the rotation of the eccentric shaft at half the crank-shaft speed, produces the valve action illustrated in Figs. A to F, which shows the relative position of the piston, sleeves, and cylinder ports at various points in the rotation of the crank shaft.

Valve timing: The timing shown in Figs. A to F is not different from that ordinarily used in poppet-valve engines, but the valve area is greater than that of an ordinary poppet valve. The equivalent of increased valve area is gained also by the directness of the valve opening and the absence of restrictions in the gas passages.

Compression or junk ring: The sliding sleeves end right up in the deep cone-shaped combustion head, which is a detachable unit. This head is of a special design, inasmuch as it is provided with a set of piston rings, three narrow and one double, the latter being specially wide and termed the compression or junk ring. These rings prevent any escape of pressure in an upward direction.

Piston rings: The usual set of three rings on the working piston maintain pressure tightness in the lower direction.

The main principle of this engine (made under Knight's patent) is the substitution of sliding valves for the usual poppet or tappet valves. The sliding valves consist of two concentric shells of cast iron accurately turned, working in between the driving piston and the cylinder walls. These shells have two series of large area ports or slots cut in the upper ends, which register together at the required instant in the respective strokes of the piston. One pair of slots forms the **inlets** and the other pair the **exhausts.**

Setting ignition: Set cylinder No. 1 piston on top of compression. Retard contact-breaker box on Bosch magneto. Set points on interrupter just breaking. There is a mark on the flywheel which, when lined up with the mark on the cylinder, will show when 1 and 6 or 1 and 4 are up. Firing order on the six is 1, 5, 3, 6, 2, 4 and 1, 3, 4, 2 on the four.

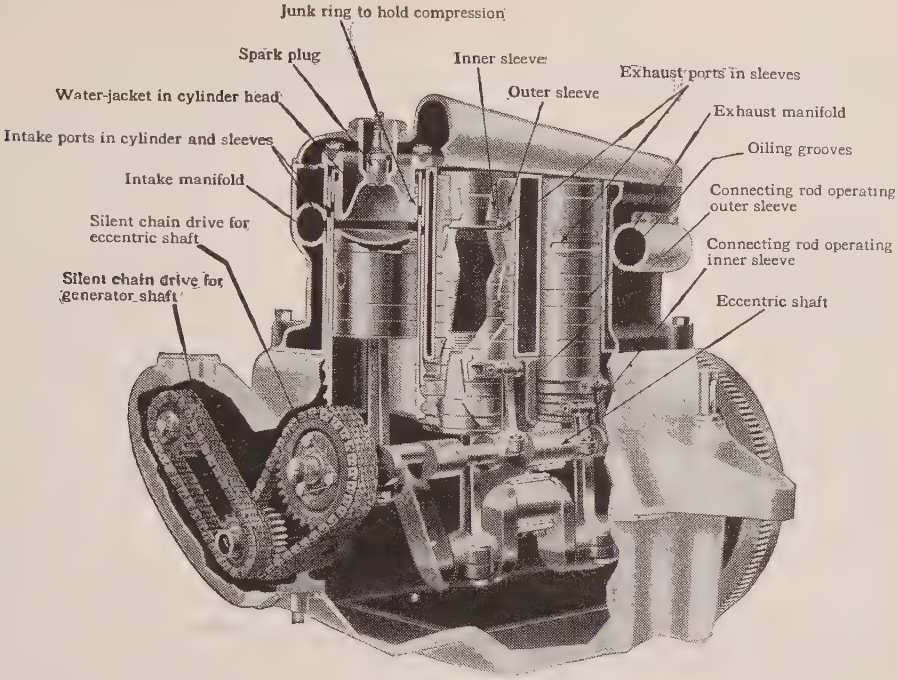

Junk ring to hold compression
Spark plug
Water-jacket in cylinder head
Intake ports in cylinder and sleeves
Intake manifold
Silent chain drive for eccentric shaft
Silent chain drive for generator shaft
Inner sleeve
Outer sleeve
Exhaust ports in sleeves
Exhaust manifold
Oiling grooves
Connecting rod operating outer sleeve
Connecting rod operating inner sleeve
Eccentric shaft

Fig. 1A. Side view showing a partly sectional view and front-end drive system of the Stearns-Knight sleeve-valve engine.

Explanation of Valve Opening and Closing, and Firing Order (Stearns-Knight Six-Cylinder Engine as an Example)

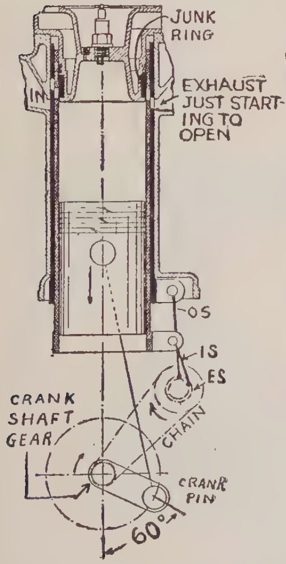


Fig. A

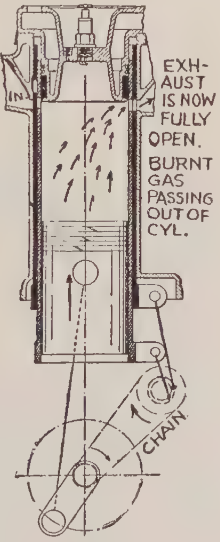


Fig. B

The eccentric shaft sprocket (ES, Fig. A) is twice the size of crank-shaft sprocket. It therefore revolves at one-half the speed of the crank shaft, the same as any cam shaft. (OS) means outer sleeve and (IS) inner sleeve eccentric rod.

The motion of the eccentric rods (OS) and (IS) is controlled by an eccentric on a shaft driven by sprockets.

Firing order, 1, 5, 3, 6, 2, 4. View is from front of engine.

The "ports" are the openings in the sleeves and cylinders.

In Fig. A, the **exhaust starts to open** at 60° before bottom. Toward the end of the power stroke, as in any four-cycle engine, the exhaust port is uncovered by a downward motion of both sleeves, the inner moving at a higher speed than the outer. Instead of a valve opening, the opening occurs in the sleeve.

In Fig. B, the **exhaust is fully open.** At the starting of the exhaust opening the outer sleeve port is approximately in register with the cylinder exhaust port, the full opening being obtained chiefly through the more rapid motion of the inner sleeve, its port "catching up" with the port in the outer sleeve.

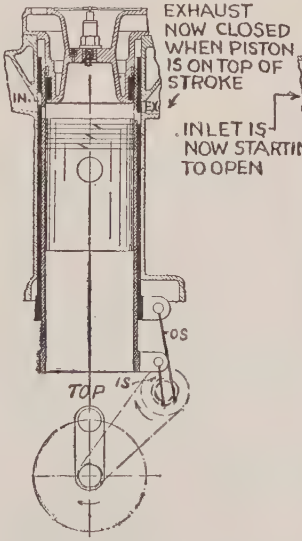


Fig. C

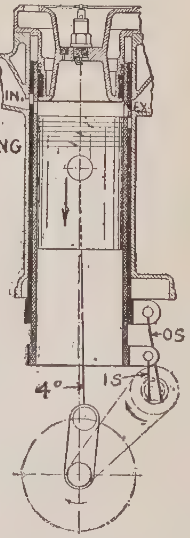


Fig. D

In Fig. C, the **exhaust closes** on top. The inner sleeve first reaches the bottom of its travel (note position of eccentric rod IS), and the outer sleeve, following it, closes the exhaust opening by over-running the cylinder port.

In Fig. D, the **inlet opens** 4° after top. At the closing of the exhaust, the sleeves are moving in opposite directions, the inner one up and the outer one down (see eccentrics **OS** and **IS**). The inlet ports in the sleeve then overlap, the opening being in line with the cylinder wall. The inlet ports in the sleeves are moving in opposite directions.

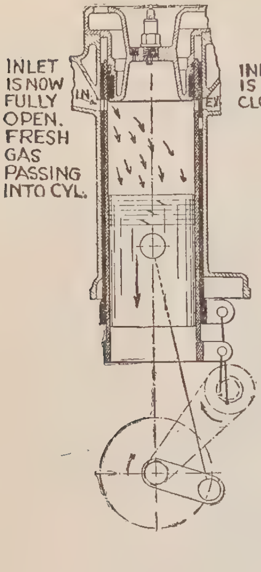


Fig. E

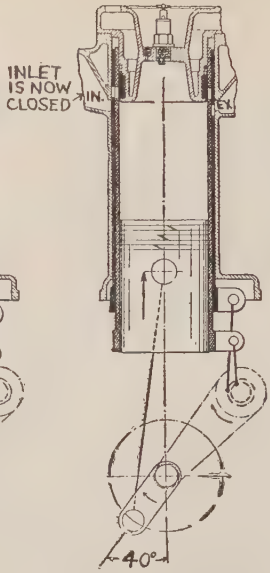


Fig. F

In Fig. E, the **inlet is full open.** The continued but slow downward movement of the outer sleeve, together with the increasingly rapid upward motion of the inner, causes the two sleeve ports to coincide with each other.

In Fig. F, the **inlet closes** 40° after bottom center. From the point of full inlet opening, both sleeves travel upward, the inner at a higher rate than the outer. This action is continued until cut-off is secured and the port closed by the lower edge of the inner sleeve port over-running the lower edge of the "junk" ring carried by the head casting of the cylinder.

As the inlet closes, the next stroke up would be the compression stroke, and when on top, the explosion would occur and the piston would go to the position shown in (A).

Valve timing of the Stearns-Knight early model four-cylinder engine is shown in Fig. G. Valve timing of the Stearns-Knight six cylinder (early model); the same except inlet opens 4 degrees instead of 8 degrees, and exhaust closes on top dead center instead of 4 degrees after.

This valve-timing diagram can more clearly be understood after reading under the subject of valve-timing, as on page 69, which gives an explanation of how a flywheel is usually marked. See "note" at bottom of page 63 for meaning of "top dead center," "bottom dead center," etc.

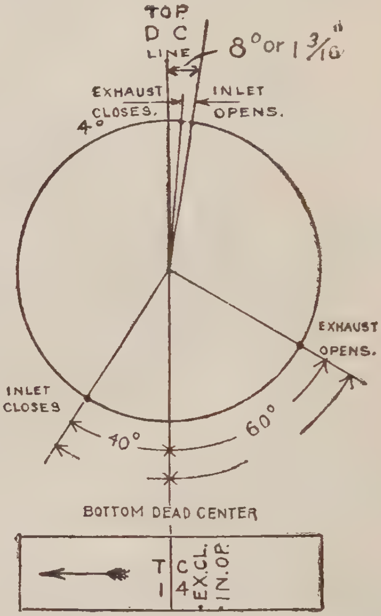
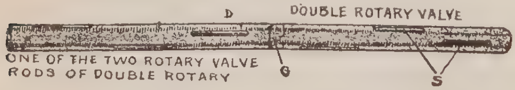


Fig. G. Knight 4-cylinder valve timing. The flywheel below is as if viewed from the rear. The diameter is 17".

THE ROTARY-VALVE ENGINE

This type of engine is the same as any other four-cycle principle of gasoline engine, except instead of the "poppet type" of valves the "rotary type" is used to admit gas to the cylinder and to permit burnt gases to pass out. The Speedwell was one make of car which used the double-rotary valve.



The rotary valve is nothing more than a long cylindrical piece of metal with holes in the shape of slots cut as at (S) and (D) above. Instead of valves popping up and down, this rod is placed alongside of the cylinder and is operated by a chain or gear from the crank shaft. As it turns, the openings in the rods (rotary valve) perform the same function as the poppet valves.

There are two types of rotary-valve engines, the double valve and the single valve.

The double rotary valve can be compared with the poppet-type valve engine using the "T"-head type of cylinder, which has the intake valves on one side and the exhaust on the other. On the double rotary valve we have an "intake rotary valve" on one side and the "exhaust rotary valve" on the other side (Figs. 1, 2, 3, and 4). On a four-cylinder engine, each valve would have four slots.

The single rotary valve can be compared with the poppet-valve type of engine using valves-in-the-head, operated by one overhead cam shaft. Instead of poppet valves and cam shaft, however, there is one long rotary valve, with openings as shown in Figs. 5, 6, 7, and 8. Note the position of these openings during the periods of intake, compression, firing, and exhaust.

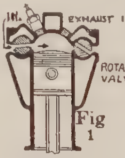


Fig 1

INDUCTION
JUST STARTING

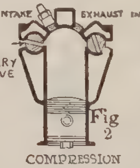


Fig 2

COMPRESSION
JUST CLOSING

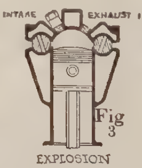


Fig 3

EXPLOSION

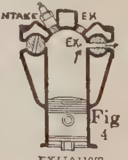


Fig 4

EXHAUST

Fig. 1 shows suction or induction stroke just starting. As the piston starts down, the opening in the intake valve (valve is rotating to the right) will be in line with the opening in the combustion chamber; therefore gas will be admitted.

Fig. 2. **Compression stroke:** The piston has reached and passed the bottom of the intake stroke and is starting up on compression stroke, therefore the intake valve is just starting to close. Note that the exhaust valve is closed in Figs. 1, 2, and 3.

Fig. 3. **Power or explosion stroke:** Openings in both valves are closed; piston will move down.

Fig. 4. **Exhaust stroke:** The piston is now starting up on exhaust, therefore the opening in the exhaust valve is open to the cylinder, and burned gases will pass out. Intake valve is closed.

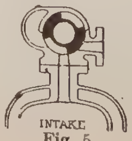


Fig. 5

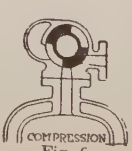


Fig. 6

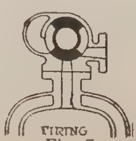


Fig. 7

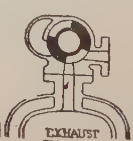


Fig. 8

THE ROTARY-CYLINDER ENGINE

Fig. 9 shows the Gnome aviation seven-cylinder engine which is treated fully in other sections of this book.

In the ordinary motor-car engine the cylinders are bolted to a crank case and the crank shaft is made to turn around by the force of the explosions in the cylinders.

In the rotary-cylinder engine the crank shaft is held stationary and the cylinders are mounted on a cylindrical crank case which can revolve. Connecting rods are fastened to crank-shaft pins (Fig. 10).

The revolving cylinder or "rotary-cylinder" type is a French invention. This style of engine was used extensively during the war in small, high-speed, single-seated machines; another is the La Rhone.

Principle of operation: When an explosion occurs in one of the cylinders the energy can do nothing else but force the piston down. This action turns the rodholder on the crank shaft, which causes the rods, pistons, and hence the cylinder to revolve as a unit. The crank shaft (Fig. 11) remains stationary, and, due to this fact, the pistons will assume different positions in the cylinders owing to the location of the rods on the crank pin. For instance, in the movement of the cylinder **A** from **X** to **Y**, the piston in the cylinder will travel downward, as shown in the illustration, until it reaches bottom of its stroke. This type of engine is not adapted for automobile work.

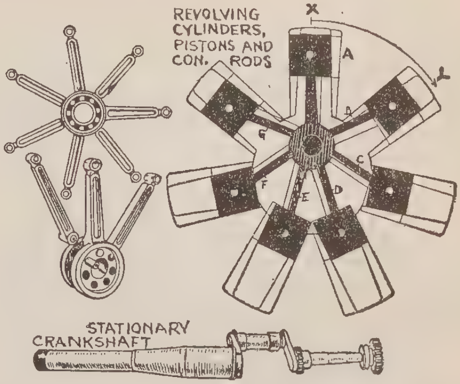


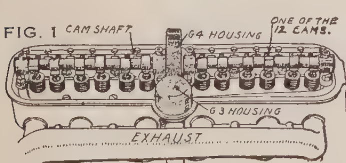
Fig. 10 (upper, left); Fig. 9 (upper, right); Fig. 11 (below).

Fuel system. Gasoline is fed to the crank case through the hollow crank shaft to a spray nozzle in the crank case. The gasoline in the tank is under 5 lbs. pressure per sq. in. by air pump. When the cylinders are within 20° of the end of the inlet half-revolution, a series of small inlet ports around the circumference of the cylinder wall is uncovered by the top edge of the piston whereby the combustion chamber is placed in communication with the crank chamber. The crank chamber is at atmospheric pressure, and the combustion chamber is below atmospheric; the result is, a suction is created which draws gas from the crank chamber to the combustion chamber. The air for mixture is provided by admission through the exhaust valve during the first part of the inlet stroke. Originally an inlet valve was located in the center of the piston head—this is not now used.

THE WEIDLEY ENGINE WITH OVERHEAD CAM SHAFT AND VALVES

Valves: In this type of engine the cam shaft is placed overhead as in Fig. 1, with the cams integral. There are two overhead valves for each cylinder (see Figs. 3 and 4); therefore there are twelve cams, one for each valve. Engine in this example is a six-cylinder.

FIG. 1



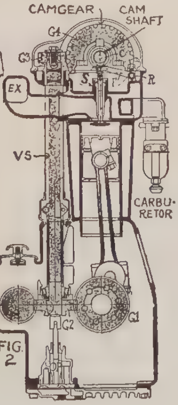
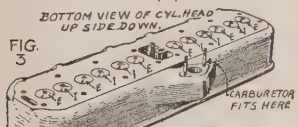


FIG. 2

FIG. 3



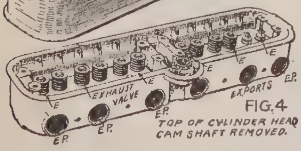


FIG. 4 TOP OF CYLINDER HEAD CAM SHAFT REMOVED.

The cam shaft is operated by a gear (G1) on the crank shaft, which operates a gear (G2, Fig. 2), which is called the lower timing gear; this gear is placed at the lower end of a vertical shaft (**VS**) with an upper timing gear (G3), which operates the cam-shaft gear (G4). By referring to Fig. 2, it will be seen how the cam (C) operates the tappet arm (**F**), which in turn opens the valve against the tension of the spring (**S**). While the construction varies, the principle, it will be noticed, is just the same as in any other engine. The cam shaft turns one revolution to two of the crank shaft.

The cam shaft mounted on the cylinder head has four bearings and these are 1 3/16″ in diameter. The end bearings are 1¼″ by 1¾″ long, and the middle ones, which are on either side of the driving gear, are 1¾″ by 1⅝″ long. A hole ⅜″ in diameter is drilled through the cam shaft for its entire length, and carries oil to the cams and bearings.

The cylinder head is detachable from the cylinder, and the cylinders are all in one block; therefore to grind the valves or to get to the valves, the cover is removed, and then the cylinder head. Fig. 4 shows the cylinder head removed and Fig. 3 shows the cylinder head turned up side down, exposing to view the valves seated in the cylinder-head casting.

To grind valves: First, remove head. If a single valve is to be ground the valve spring may be compressed and the pin holding the spring removed, when the valve can be dropped out and the seat ground, or the cam shaft may be removed, which is easily done. The springs and pins are removed and the cylinder head is turned over on a bench, as in Fig. 3, and the valves are ground as in any other engine. See Index for method of valve grinding.

To set the valves: The inlet opens 10° past top and the flywheel is marked "IO." The exhaust closes at 10° after top. Therefore, set the cam shaft with piston No. 1, 10° past top center; the cam is just leaving the exhaust valve (see **C**, which would be a little farther in the direction of rotation, as it now has the valve open). The gears are then meshed at this point. The timing of both inlet and exhaust is done by one cam shaft, the same as on an "L"-type cylinder.

FRANKLIN AIR-COOLED ENGINE

Engine: Six cylinder, 3¼ x 4 inches. Piston displacement 199 cubic inches. H. P. in accordance with the S. A. E. is 25.3, at maximum 31. About 1,700 r. p. m. is maximum speed. The gear ratio of the car on high gear is 3.9 to 1, the wheel being 32 inches, which means 1,950 revolutions of the engine per mile. Weight of car under 2,300 lbs. Maximum speed of car 50 m. p. h. or over.

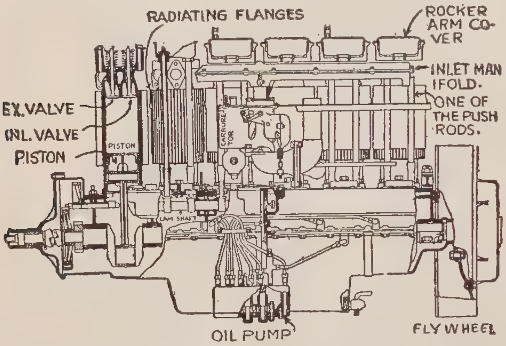


Fig. 5. Side view of Franklin air-cooled engine.

Overhead valve mechanism with one cam shaft on the side is used. Atwater-Kent ignition. Carburetor of Franklin design.

Pistons: As the normal working temperature in the Franklin engine is distinctly high, the makers were not very ready to believe in the aluminum piston, but they have now adopted it as a stock practice and consider that the better mean effective pressure of the new engine is largely due to the improved piston cooling obtained. At first there was a little trouble from wear on the skirt; it was difficult to get a close enough fit to insure absence of slap without abrasion. The trouble was overcome completely by turning a shallow, square groove of screw-thread form from the bottom of the skirt to just beneath the lower ring. This holds oil securely and allows a smaller clearance than is possible with a plain piston. Piston clearance is .005″. Three piston rings 3/16″ wide with .015 to .020″ clearance between ends are fitted to each piston.

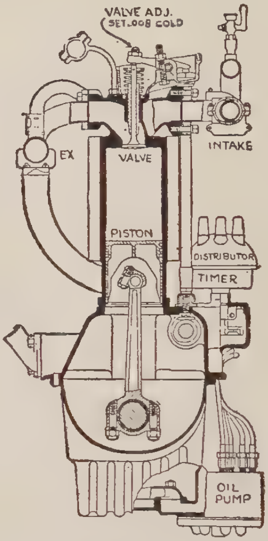


Fig. 6. End sectional view of Franklin engine.

There is an interesting **lubrication system** employed, individual oil supply being sent to every point. The oil pump, which is a conventional gear pattern, is mounted on a large plate, and the delivery from the pump is distributed to a number of oil leads by means of passages in the plate. Actually the plate is die-cast aluminum with distributing grooves, and these grooves are made into closed passages by putting a piece of thin sheet copper over the face. This gives direct-pressure feed to all bearings on the crank shaft and to various other points.

Valve Clearance

Valve clearance is .010″ when cold and adjustment is made between the end of the rocker arm and the adjusting screw. See Index for "Franklin cooling system and wiring diagram."

INSTRUCTION No. 12

THE CONTINENTAL ENGINE

Continental Model "7R" Red Seal Engine

Model "7R" is a popular six-cylinder engine as used on several makes of passenger automobiles.

Specifications: Cylinder, 3¼″ bore, 4½″ stroke; displacement, 224.00 cu. in.; horsepower, S. A. E. rating 25.35; B. H. P., 1,000 r.p.m., 26; 2,600 r.p.m., 55; weight 575 lbs.; cooling, centrifugal pump; lubrication "force-feed" with drilled crank shaft and gear-type oil pump; carburetor, vertical outlet type, 1¼″; provisions for standard makes of starter, generator and ignition systems; clutch, multiple disk or 10″ plate; construction, unit power plant; suspension, three point.

Valve Timing

Valve timing, 7R: Inlet opens 12° after top; **closes** 20° after bottom; **exhaust opens** 40° before bottom; **closes** 8° after top.

The timing marks on the flywheel can be seen through the inspection hole in the housing, directly over the flywheel. A steel pointer is used to line up the flywheel marks when checking the valve timing.

Valve timing, "7W" (an older model engine): **Intake opens** on upper dead center and **closes** 33° past lower dead center. **Exhaust opens** 67° before lower dead center and **closes** on upper dead center. This setting gives an inlet period of 213° and an exhaust period of 247°.

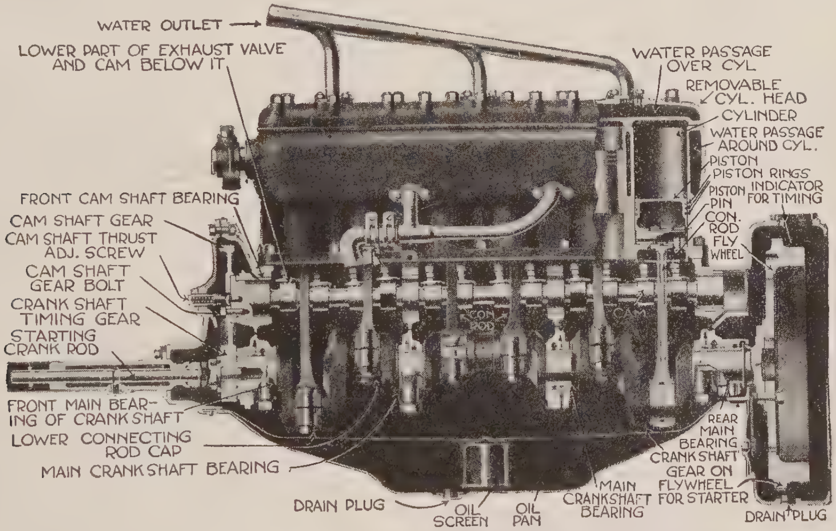


Fig. 1. Sectional view of model "7R" six-cylinder Red Seal Continental engine, left side.

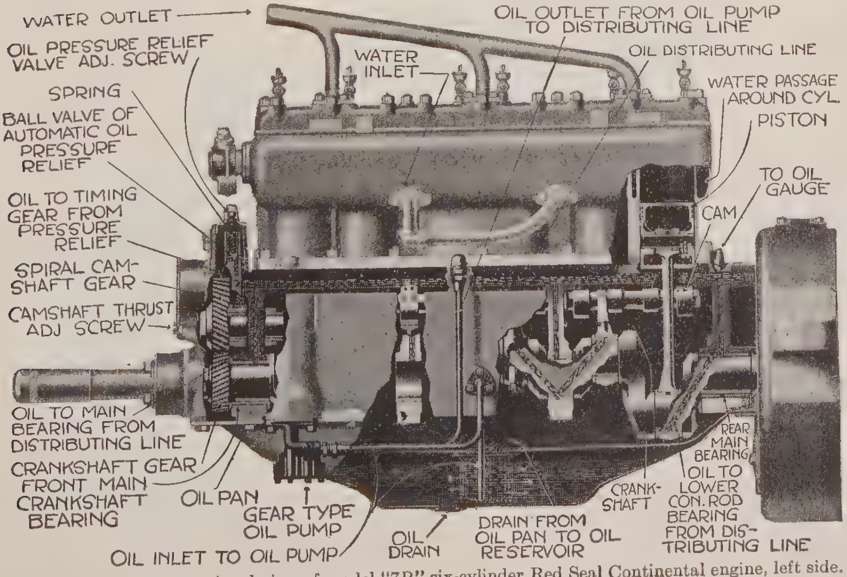

WATER OUTLET
OIL OUTLET FROM OIL PUMP TO DISTRIBUTING LINE
OIL PRESSURE RELIEF VALVE ADJ. SCREW
WATER INLET
OIL DISTRIBUTING LINE
WATER PASSAGE AROUND CYL.
PISTON
SPRING
BALL VALVE OF AUTOMATIC OIL PRESSURE RELIEF
OIL TO TIMING GEAR FROM PRESSURE RELIEF
TO OIL GAUGE
CAM
SPIRAL CAMSHAFT GEAR
CAMSHAFT THRUST ADJ SCREW
OIL TO MAIN BEARING FROM DISTRIBUTING LINE
CRANKSHAFT GEAR
FRONT MAIN CRANKSHAFT BEARING
OIL PAN
GEAR TYPE OIL PUMP
OIL INLET TO OIL PUMP
OIL DRAIN
DRAIN FROM OIL PAN TO OIL RESERVOIR
CRANK-SHAFT
REAR MAIN BEARING
OIL TO LOWER CON. ROD BEARING FROM DISTRIBUTING LINE

Fig. 2. Lubrication sectional view of model "7R" six-cylinder Red Seal Continental engine, left side.

See the instruction on "Commercial Cars" for valve timing of the Continental "L4" engine.

See Index "Questions and answers on Continental engines."

Lubrication of Continental "Model 7R" Red Seal Engine

Gear type of oil pump attached as a separate unit outside of the engine, near the front end of the crank case. Driven by spiral gears. Maintains a pressure of 5 to 30 lbs., depending upon car speed, temperature of oil, and general operating conditions.

Oil pressure is adjusted in the same manner as explained of the Continental "L4" engine in the Commercial car instructions, except that the amount of pressure should range from 10 to 15 lbs. at a car speed of 15 m.p.h. Oil is forced from the pump to the main oil line and distributed through ducts to the four main bearings. The crank shaft is drilled to conduct oil to the six connecting-rod lower end bearings. Through a secondary line connecting with the main reservoir, oil is fed to the timing gears and to the pressure-adjusting valve in the gear case. An oil spray lubricates the piston-pin bearings, cylinder walls, and four cam-shaft bearings, as well as the valve-spring chamber, valve stems, valve-spring bearings, and push-rod bearings.

Details of the Continental Model "N" Red Seal Engine

Model "N" engine is an engine with four cylinders, 3¾" bore, 5" stroke. It is designed for trucks ranging from ¾ to 1½ ton carrying capacity. When fitted with a governor, the recommended governing speed is 1,300 r.p.m. Pistons and connecting rods can be removed from below. At 1,000 r.p.m., 23 h.p., at 2,000 r.p.m., 34 h.p., weight 410 lbs., with flywheel. Carburetor 1¼". Cooling: thermo-syphon. Three or four-point suspension.

Lubrication would be termed force-feed and splash system. The forced-feed system supplies oil to the crank-shaft main bearings and the timing gears. The splash system serves to lubricate the interior of the engine, such as the pistons, cam shaft, push rods, and connecting-rod bearings. The oil pump is a horizontal plunger-type pump operated by an eccentric from the cam shaft. The oil pressure is automatically controlled.

To grind the valves, see Index under "Valve grinding."

To take up connecting-rod bearings, remove the lower half of the crank case. Shims are used and it is very necessary to remove one or two—being careful to remove equal number on each side and not to have a bearing too tight.

If the bearings are too far gone to take up by removing shims, it is then necessary to fit new bushings (see repair subject).

The pistons and connecting rods can be taken out past the crank shaft.

Renewing piston rings is accomplished by lapping new rings to the cylinder (see Index under "Fitting piston rings").

Valve Timing

Valve timing of the model "N" engine is as follows: **Inlet opens** 17° 53′ past upper dead center and **closes** 29° 25′ past lower dead center. **Exhaust opens** 42° 36′ before lower dead center and **closes** 8° 20′ past upper dead center.

This gives an intake period of **191° 32′ and an** exhaust period of 230° 56′.

Remarks

The words "Red Seal," as used with these engines, represents the highest grade of motors manufactured by the Continental Motors Corpn., Detroit, Mich. Many passenger and truck model engines are manufactured. The model "7R" is a popular passenger car engine, and model "L4" (see Commercial Car Instruction) and model "N," below, are popular truck engine models.

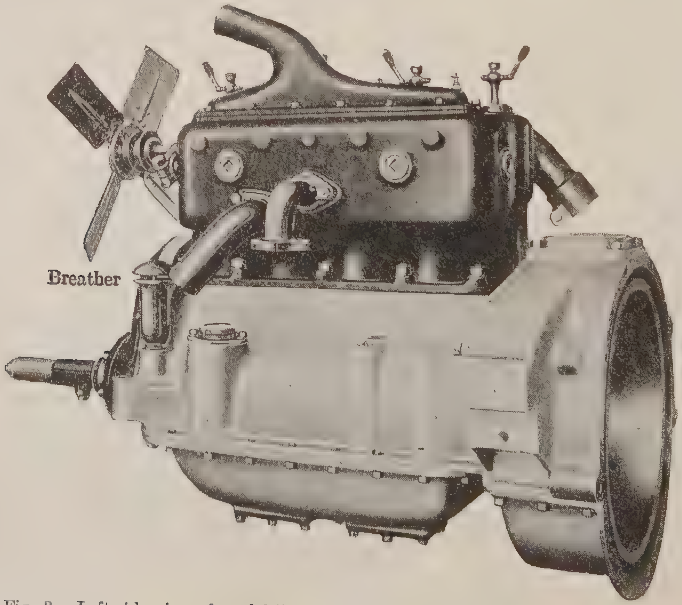


Fig. 3. Left side view of model "N" Red Seal Continental four-cylinder engine.

INSTRUCTION No. 13

CARBURETION: Early Carburetion Principle; Parts; Carburetor Principles; Gasoline; Priming Methods; Heating Methods; Vaporizing Gasoline; Size of Carburetor to Use; Gasoline Troubles; Gasoline Tank and Gauge; Fuel-Feed Methods; Vacuum Gasoline Feed System

EARLY CARBURETION PRINCIPLE

Meaning of carburetion: The mixing together of gasoline vapor and air is called "carburetion," and the device that keeps the two in proportion is called a "carburetor."

To get energy out of the gasoline it is necessary for it to be converted into a vapor and then mixed with a volume of air before it can be exploded in the cylinder.

There are two ways of producing this vapor, one being to expose a considerable surface of this liquid to the air, which is also caused to bubble through it and thus become impregnated with the gasoline vapor. This was the original method, and was called the "surface" type of carburetion.

The second method is to "spray" the liquid gasoline through a fine spray nozzle or jet into the mixing or vaporizing tube, into which air can be drawn to intermingle with the vapor.

The device in which this operation is performed is termed a "carburetor," and the operation itself is known as "carburetion," from the fact that the gasoline largely consists of carbon. The mixture might also be termed "carbureted" air.

Amount of gasoline and air: It has been found that the best explosive mixture, with the gasoline commonly used, is a proportion of 14 parts air to 1 part gasoline (this when maximum power is desired) and ranging to 17 to 1 (the latter for maximum economy), proportioned by weight of air and gasoline.

That is, 14 to 1, or rich mixture, is best for quick acceleration, or 15 to 1 or leaner mixture best for pulling with wide-open throttle, and 17 to 1, or still leaner mixture, for high-speed work (figures only approximate).

Pure gasoline vapor will not burn; it must be mixed with air before it can be used in an engine. To burn with the greatest rapidity and heat, the air must be in correct proportion to the vapor. The exact amount of air to be mixed with a certain amount of vapor depends on the quality of the gasoline, and other conditions. The carburetor, by which the proportions of the mixture are maintained, is so made that a current of air passes through it when the piston makes a suction stroke.

"Mixing Valve"—an Early Form of Carburetor

In the early days the method of mixing the gasoline and air in proper proportions was by means of a "mixing valve" (Fig. 1). It could also be termed a carburetor but without the float cut-off mechanism. The air was drawn in at "air intake," through valve (3), being opened automatically by suction of the piston, forming a vacuum in the crank case when going up (on a "two-cycle" engine), or when the inlet valve was open and the piston traveling down on suction stroke on a "four-cycle" engine. If, therefore, the gasoline needle valve was open, gasoline would also be drawn in, mixed with the air, and pass into the cylinder in a partially vaporized condition.

The mixing valve, also called a "generator valve," is still used to a small extent on two-port two-cycle engines. It takes the place of a check valve, as the valve (3) serves the same purpose.

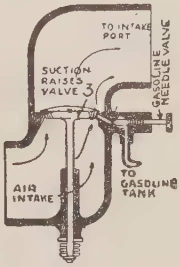


Fig. 1. Early form of a carburetor; a mixing valve.

Note the absence of any float arrangement. The gasoline is fed by gravity, and when the engine stops the gasoline needle valve must be cut off, otherwise the gasoline will drip.

Constant-Level Type of Carburetor

Fig. 2 explains the purpose, location, and parts of a simplified carburetor.

The gasoline tank is above the level of the carburetor; therefore the gasoline is fed to the carburetor float chamber by gravity.

The air goes through a passage, in which is a small pipe called a "spray nozzle," that sprays the gasoline so that it comes in contact with the air (see Fig. 2). The gasoline, being volatile, is taken up by the air, and the mixture goes to the cylinder.

The amount of air that may flow through the carburetor, and the quantity of gasoline that may flow out of the small pipe, are adjustable, so that for a certain amount of gasoline the proper proportion of air may be admitted.

When the mixture is not correct, that is, when there is too much or too little air for the gasoline flowing out of the small pipe, the running of the engine is affected, and it will not deliver its full power.

When there is too much air for the gasoline, the mixture is said to be "too poor" or "lean"; when there is too little air, the mixture is said to be "too rich."

The carburetor is connected to the inlet pipe, and no air or gas can enter the cylinder through the inlet valve without first passing through the carburetor.

The air drawn through the carburetor on the suction stroke enters it through the "air intake" and passes around the spray nozzle, drawing gasoline with it; the level of the gasoline in the float chamber then drops, and the float drops also and permits more gasoline to enter the float chamber.

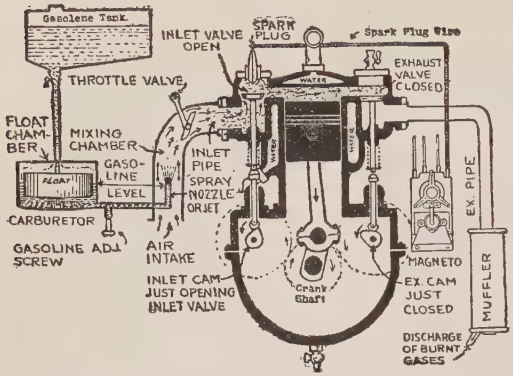


Fig. 2. Simplified illustration showing how the gasoline flows from the gasoline tank to the carburetor; how it is mixed with air and then drawn into the cylinder when the inlet valve is open.

It is in the "mixing tube," or "mixing chamber," as it is sometimes called, that the air is brought into contact with the gasoline. The "spray nozzle" projects into the mixing tube, so that it is in the center of the current of air.

How the gasoline is drawn into cylinder with the air: When the air is not passing through the mixing tube, the liquid gasoline stands just below the open end of the spray nozzle, but as soon as the current of air passes through, it sucks the gasoline out. The current of air sucks up the gasoline, very much as would a child trying to draw the last few drops of soda through a straw, drawing in really more air than soda.

The piston of the engine, on its suction stroke, produces the suction effect similar to a squirt-gun drawing in water.

The inlet valve must be open to permit the gas to be drawn into the cylinder—which is the case if the piston is on the suction or intake stroke, but in no other stroke.

The **adjusting screw** or **"gasoline needle valve"** regulates the amount of gasoline to be admitted into the mixing tube through the spray nozzle or jet. The regulation of this needle valve is very important, and after once being properly adjusted, a very slight turn one way or the other will affect the running of the engine.

The throttle valve, usually placed in the mixing tube, above the spray nozzle, governs the amount of gas which enters the cylinder on the suction stroke.

The throttle-valve lever on the carburetor connects with the throttle lever on the steering wheel. Moving the throttle lever on the steering wheel, in a certain direction opens the throttle valve on the carburetor, which increases the speed of the engine.

The more gas admitted by the throttle lever through the throttle valve, the more gas will enter the cylinder; hence more power or greater force on the power stroke results, thereby giving more speed to the piston of the engine.

Moving the lever in the opposite direction closes the throttle valve on the carburetor, reducing the amount of gas which enters the cylinder, thereby reducing the speed of the engine. The throttle valve is never entirely closed, but is set so that the engine will idle when the throttle lever on the steering wheel or accelerator is closed.

The float in the carburetor is provided merely to prevent the gasoline overflowing and running out of the spray nozzle, when the engine is not running. The float is adjusted so that the level of the gasoline will not quite reach the top of the spray nozzle or jet. Thus, as the float automatically governs the level of the gasoline in the float chamber and automatically cuts off the supply from the gasoline tank when the engine stops, it is termed a "constant-level type" of carburetor.

The floats are usually made of cork or hollow metal balls, which float in the gasoline inside of the mixing chamber. A needle point arrangement is connected with the float, which cuts off the gasoline flow when the engine stops.

The reason why engines must first be cranked, when starting a gasoline engine, is due to the fact that a charge of gas must be drawn into the cylinder and then compressed. Compressed gas is ignited by the electric spark; this produces the power stroke, and the power from this combustion of compressed gas, together with the momentum of the fly wheel, will keep the engine in motion until the next power stroke. The cycle operation of suction, compression, power, and exhaust is repeated over and over again.

An Early Constant-Level Type of Carburetor

Maybach conceived the idea of using **a float** to maintain a constant level of gasoline just below the spray-nozzle head, with a **main air inlet** below the nozzle, as shown in Fig. 3.

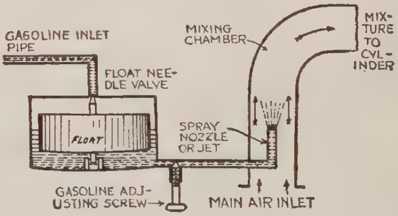


Fig. 3. Early type of carburetor with float mechanism. A "main air inlet" is provided.

The gasoline is drawn from the spray nozzle by a vacuum or suction effect produced by the piston. It is thus drawn through the mixing chamber and through the open inlet valve into the cylinder. At the same time, air is drawn into the mixing chamber at the main air inlet, but inasmuch as the greatest power of an engine is obtained by having a mixture of exact proportions of air and gasoline, it is clear that if the speed of the engine is increased, more gasoline would be drawn into the cylinder without sufficient air supply to mix with it. Thus too rich a mixture would be the result. If the air opening were enlarged to give a greater supply of air at high speeds, the result would be too great an air supply at low speeds, or too lean a mixture. This type of carburetor was evidently designed for a constant steady-speed engine.

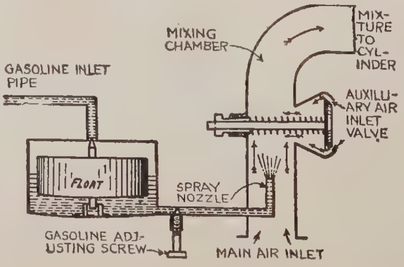


Fig. 4. In addition to a "main air inlet" an "auxiliary air inlet" is provided here.

An auxiliary air inlet was added to this type of carburetor by Krebs. Note that in addition to the main air inlet below the nozzle, an automatic auxiliary air valve was placed above the nozzle (Fig. 4).

At low speeds, the main air inlet was sufficient, but at high speeds, the suction effect being greater, the spring caused the auxiliary air valve to open, thus permitting more air to be drawn into the mixing chamber, and resulting in a better proportion of air and gasoline than the carburetor shown in Fig. 3. The greater the speed of the engine, the greater the suction effect, and consequently the greater the opening of the auxiliary air valve. At slow speeds, the air valve would remain closed and was thus automatic in action.

Another feature of the auxiliary air valve, is to break the gasoline up into as many fine particles as possible, so that the air will more readily mix with the gasoline and form a vapor. There are different methods of doing this which will be shown farther on.

Adjustable auxiliary air valve: The difficulty arising from the fact that the coil spring which held the auxiliary air valve closed at low speeds and was intended to open as the speed of the engine increased did not always function, because temperature changes would affect its sensitiveness and because the variations in the volatility of gasoline varied when cold and when warm, was overcome in a way by changing the adjustment of the tension on the auxiliary air-valve spring which was provided as shown in Fig. 5.

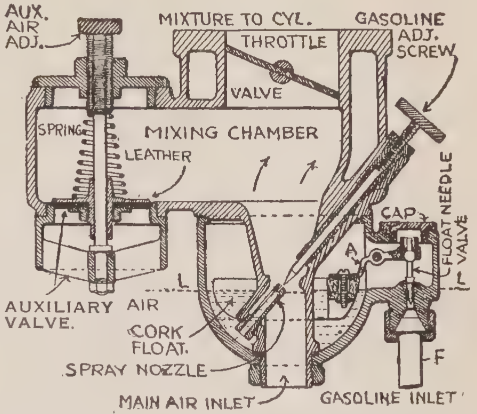


Fig. 5. Typical example of a carburetor using an auxiliary air valve.

The reader should closely observe the difference between the **main air inlet** and the **auxiliary air valve.** All carburetors have main air inlets, where air is drawn into the carburetor below the spray nozzle, thus mixing with the gasoline. This opening can be at the bottom or the side of the carburetor.

When an auxiliary air valve is used, it is usually placed so that air is drawn above the spray nozzle and thus combines with the mixture of gasoline and air. Many carburetors do not have auxiliary air valves.

PARTS OF A CARBURETOR

Before proceeding farther with the principle of different types of carburetors we will take up the subject of parts of a carburetor.

The concentric-float type of carburetor is the term applied to a carburetor where the float surrounds the mixing chamber and spray nozzle, as in Fig. 5. This makes a compact carburetor and maintains a constant gasoline level in the spray nozzle regardless of the angle at which the engine may be. On almost all concentric-type carburetors the float is made of cork.

The side-float type of carburetor is the term applied to a carburetor where the float and float chamber are placed to the side of the mixing chamber, as in Fig. 4.

Floats

Floats are usually made of light brass or copper in various hollow forms; the joints, if any, being carefully soldered or brazed, so that gasoline cannot enter the float itself. Floats are also made of cork, well shellacked, so that they will not absorb gasoline and lose their buoyancy. (See Fig. 5.)

The sole **duty of the float** is to maintain a predetermined or constant level of the gasoline in the carburetor. This level is generally a small fraction of an inch below the jet or nozzle opening.

The float chamber is that part in which the float operates; it is sometimes placed around the spray nozzle and sometimes to the side, as previously explained.

The float level: In different makes of carburetors, the level of the gasoline in the float chamber, and the gasoline in the spray nozzle, varies from about one-sixteenth to one-eighth of an inch below the top of the spray nozzle.

As gasoline flows from the main supply tank through the gasoline pipe or line into the float chamber of the carburetor, the float rises and the needle valve shuts off the further entrance of the fluid into the carburetor.

When the engine is running and using gasoline, the float in the carburetor is continually falling and rising slightly, always maintaining the approximate gasoline level in the float chamber.

There are many types of floats and float mechanisms, as will be seen in the illustrations of various carburetors in this instruction. By referring to Figs. 6, 7, and 8, the reader will observe several floats (**T**) and float needle-valve (**V**) arrangements.

Gasoline leaking into the float would increase its weight, thereby changing the proper gasoline level in the spray nozzle and causing the carburetor to flood and would thus give too rich a mixture.

Float Needle Valve

Float needle valve: The part **V** (Figs. 6, 7, and 8) explains how the float causes the float needle valve (**V**) to close the opening at the gasoline supply pipe (**F**) when the gasoline has reached the proper level in the float chamber, and how it causes the needle valve (**V**) to open the outlet at the end of the pipe (**F**) when the gasoline level is reduced. (**C**) is the opening leading to the spray nozzle.

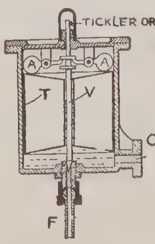


Fig. 6

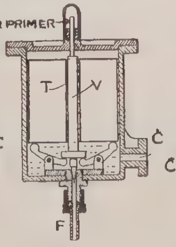


Fig. 7

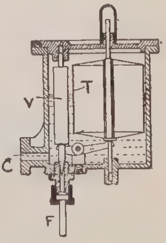


Fig. 8

Note that in Fig. 5 the float needle valve is to one side of the float. A glance will show how the float needle valve would be caused to open when the float drops below its level (L) and how it would cause the float needle valve to close when at the proper level. **Adjustment of the height of the float** can be made by slightly bending the arm (A) (Fig. 5).

A method of priming, or to supply an increased flow of gasoline at the spray nozzle when starting a cold engine, is sometimes found by what is termed "tickling" the carburetor, by raising the needle-valve rod through the float, as in Fig. 6, which projects above the carburetor and usually has a cap screwed over it to keep out dirt.

Another method is to close the main air inlet (Fig. 5), which is termed "choking" or "strangling" the carburetor, while the engine is being cranked. The fact that the air is shut off causes an increase of gasoline to be drawn in for the initial charge.

Dripping of gasoline from the bottom of a carburetor is usually due to grit or dirt getting under the float needle valve. Thus, when engine stops, instead of the needle valve seating properly and cutting off the gasoline supply from the supply pipe (F), it overflows at the spray nozzle and drips out of the main air inlet.

Remedy: By working the float needle valve up and down in its seat, which can be done by means of the rod above the carburetor float chamber (Fig. 6), or by unscrewing the cap (Fig. 5), the grit will very likely be removed. If this does not remedy the dripping, then the float should be readjusted, or possibly a new float needle valve is required.

Gasoline Needle Valve

The gasoline needle valve controls the flow of the gasoline to the spray nozzle, and the correct adjustment of it is necessary for the operation of the carburetor. It is also called the "gasoline adjusting screw" (see Fig. 5). Don't confuse this needle valve with the "float needle valve."

The regulation of this gasoline needle valve is very important and likewise very sensitive. After the carburetor is once adjusted by regulating the auxiliary air valve and the opening of this gasoline needle adjustment valve, the slightest turn one way or the other of this valve will make a difference in the running of the engine.

Types of gasoline needle valves are as follows:

1. Hand operated, as in Fig. 5.
2. Mechanically operated, by movement of a throttle through a cam arrangement by hand (treated farther on).
3. Automatically mechanically operated, by action of the auxiliary air valve, called a "metering pin" (explained farther on).

A main air inlet is on all carburetors, and, quite often, an auxiliary air valve also.

Auxiliary Air Valve

Auxiliary air inlet valve: The greatest difference in the air type of carburetor is in the construction, position, and action of the auxiliary air inlet, discussed farther on.

The auxiliary air valve is controlled automatically by the vacuum created by the engine piston, which draws air through the auxiliary air intake against a spring tension; for instance, see the auxiliary air intake in the carburetor shown in Fig. 5, page 97, the opening being controlled by the tension of a spring.

The air-valve spring: The weaker the spring the less vacuum it will take to draw the valve open, and it may be adjusted by means of a threaded sleeve (as in Fig. 5 and in various other ways).

The stronger the spring, the less air, hence a "richer" mixture. The weaker the spring, the more air, and hence a "leaner" mixture.

Another method for automatically opening and closing the auxiliary air intake is shown in Fig. 9. Note the action of the ball (L). Instead of a valve and a spring, balls are utilized instead. This carburetor is the **Kingston** air-valve type, with an auxiliary air inlet. Instead of using a spring to control the amount of air drawn into and through the auxiliary air valve, balls are used.

The **gasoline needle valve** is adjusted by hand. The float is concentric. Note the Venturi mixing tube. Another air-valve type of carburetor, with an auxiliary air valve controlled by one large ball placed in the main air inlet pipe of the carburetor is shown farther on.

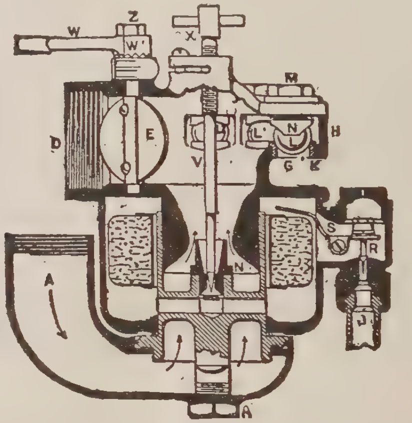


Fig. 9. Kingston air-valve type of carburetor. Note the balls in the auxiliary air valve which control the quantity of air entering the auxiliary air valve. Parts: **A**, main air inlet; **D**, outlet of mixture to engine; **E**, butterfly throttle valve; **G**, auxiliary air inlet; **L**, balls which rise as the suction increases or as the speed of the engine increases, thus admitting more air; **V**, gasoline needle valve; **X**, hand adjustment of needle valve; **W**, butterfly throttle lever connects with steering-wheel throttle lever; **N**, Venturi mixing tube.

The float is a cork float and concentric to the mixing chamber. S is an arm connected with the float needle valve, **R**. As the float rises, the arm forces the needle (R) to seat.

Explanation of the Venturi Action

If two buckets are placed side by side, both filled with water, with a one-inch opening cut in the bottom of each, one with a plain opening (A), as in Fig. 10, and the other with a "Venturi" opening (B), as in Fig. 11, the same volume of water would flow out of the Venturi one-inch opening in Fig. 11 more quickly than through the plain one-inch opening in Fig. 10.

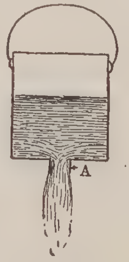


Fig. 10

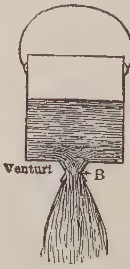


Fig. 11

Note the shape of the Venturi opening (B), in Fig. 11, then note a similar shaped tube in the mixing chamber in Fig. 9, where the arrow-points lead from (N).

The Venturi tube around the spray nozzle in the mixing chamber, is used in almost all makes of carburetors. The principle and purpose of the Venturi tube around the spray nozzle is to obtain a greater volume of air through a predetermined sized opening in quicker time. Another purpose of the Venturi tube is that the lowest pressure of the inrushing air will be at a point where it will cause the greatest suction in the spray nozzle.

Spray Nozzles or Jets

Spray nozzle: The fuel is discharged into the mixing chamber through the spray nozzle (also called **"jet tube"**). As its name implies, it is intended to deliver the liquid in the form of a fine spray, which is: (1) vaporized more or less; (2) mixed with the entering air, and (3) carried by the suction into the engine cylinder. The simplest form of spray nozzle is one having a single opening, as shown in Fig. 5 (page 97).

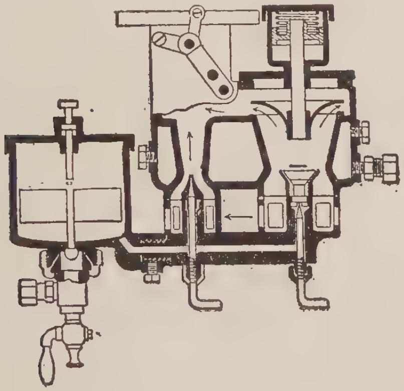


Fig. 12

Some carburetors have two spray nozzles or jet tubes, as shown in Fig. 12. Another type has what is called a "multiple jet" spray nozzle.

When a carburetor has more than one jet, it is particularly adapted to a multiple of cylinders of large size, and especially to six-cylinder engines.

The mixing chamber consists of an enclosure or passageway containing the nozzle. The gasoline and air are mixed within this tube in proper proportions and then drawn through the throttle into the engine.

Throttle Valves

There are three types of throttle valves: the butterfly, the rotary and the sliding.

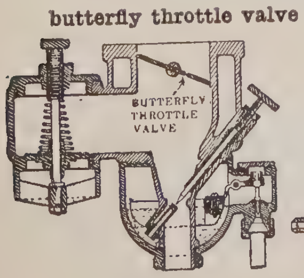


Fig. 13

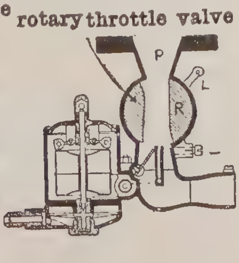


Fig. 14

Fig. 13. The throttle is placed in the mixture outlet, and the form that is shown is called a "butterfly valve." It is a disk of metal turning on pivots, so that it acts like the damper of a stove pipe. When wide open, the butterfly valve is edgeways to the flow of the mixture, but even in this position it presents resistance to the flow, which is something that should be avoided.

Fig. 14. The rotary type of valve. The passage of gas from jet to intake manifold through passage (P) is controlled by a rotary cylinder (R). It is now shown full open, but by moving throttle lever (L), it can be closed or partially opened as desired.

The butterfly throttle valve is the type of throttle used on almost all makes of carburetors. This type of throttle is shown in Figs. 13 and 9. The mechanism and method for controlling the throttle is shown in Fig. 11, page 33 and in Fig. 16, this page.

The "rotary" or "barrel" throttle valve (Fig.14), presents no resistance whatever.

The sliding throttle valve is another type which presents no resistance to the flow of gas. This type is now practically obsolete, although it was formerly used quite extensively when governors were used.

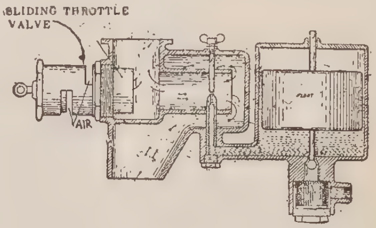


Fig. 15. The sliding throttle valve consists of a cylinder-type of throttle, but instead of being rotated, it is moved in or out of its passage, which controls the amount of gas passing to the intake manifold. As it is moved out, additional air is admitted through port holes. This type was the type formerly used with a governor.

Engine Speed; How Controlled

The method for controlling the speed of an automobile engine is by opening and closing the throttle valve on the carburetor by the hand throttle lever or foot accelerator.

A rod leading from the throttle lever on the throttle valve connects with a hand lever on the steering wheel. The driver then has the speed of the engine under his control at all times.

When running on a level and if more speed is desired, the throttle is opened by the throttle lever until the required speed is obtained. By closing the throttle, the speed is decreased.

Idling

The throttle valve is never entirely closed; the lock screw prevents the throttle from closing entirely. Therefore the engine will run slow, or "idle," as it is called, when the throttle valve lever on the steering wheel is closed and the car standing. To stop the engine entirely, throw off the ignition switch.

The Accelerator

This is the usual means for controlling the speed of the engine.

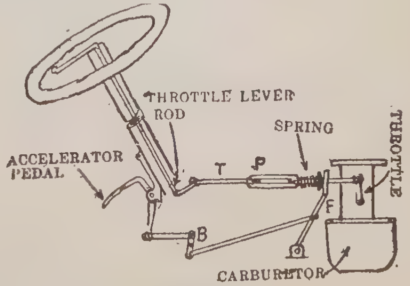
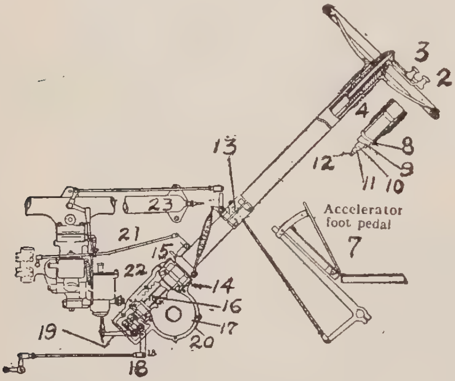


Fig. 16

The accelerator consists of a foot pedal which opens and closes the carburetor throttle valve independently of the hand-throttle lever. By referring to the illustration (Fig. 16), it will be noted that the accelerator will operate the throttle of the carburetor without moving the hand-throttle lever, by an arrangement as shown. When the foot-accelerator pedal is depressed, the rod (**F**) moves against a shoulder which is fastened to the throttle shaft. The end of the shaft (**T**) works free in a turnbuckle (**P**). Thus the throttle can be opened without disturbing the hand lever, or the hand lever can be operated without moving the foot pedal. The accelerator is used more than the hand-throttle lever. Its purpose is the same as the hand-throttle lever on the steering wheel: to open and close the throttle valve.



1—Steering wheel
2—Spark advance lever
3—Hand throttle lever
4—Air adjusting collar
7—Accelerator pedal
8—Outer casing
9—Steering shaft
10—Quadrant bracket tube
11—Throttle tube
12—Spark advance tube
13—Steering column bracket
14—Adjusting ring for roller bearings
15—Lock ring for No. 14.
16—Steering worm
17—Worm wheel
18—Spark advance mechanism
19—Hand throttle mechanism
20—Steering worm housing
21—Carburetor air adjusting rod
22—Grease plug worm gear housing
23—Inlet pipe to cylinders

Fig. 17 illustrates the relation of the accelerator connections to the spark lever and its controls on the steering device. The Locomobile is shown as an example.

When pressed downward for increase, or released for decrease of speed, its action is instantaneous. When the accelerator is released, the engine immediately resumes the speed determined by the positions of the hand lever on the steering wheel. Although either the hand-throttle lever or the accelerator may be used to control the speed of the car, the use of the hand lever is advised for beginners. After confidence in driving has been gained, the more delicate action of the accelerator will be preferred.

The word "accelerate" means "to hasten." The term, therefore, is applicable here because it is quicker to operate throttling.

The Governor

There are no pleasure cars using the governor. Nearly all truck, tractor, marine and stationary engines use governors. See Index under "Governors." One governor, which is a "throttling" type, is the centrifugal ball type illustrated in Fig. 18**A**, the principle of which, is, no doubt, familiar to all. The "sliding" throttle in the carburetor is actuated by the movement of the sleeve controlled by the balls (**B**). The balls fly out as the speed increases, causing the throttle to close. Another principle is that of the "hit and miss type."

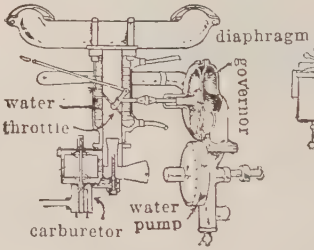


Fig. 18

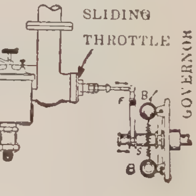


Fig. 18A

The governor formerly used on the **Packard** was termed a "hydraulic" governor of the diaphragm type, located directly above the water pump. It was operated by the pressure of the water in the water circulation system and consisted of a circular chamber divided by a flexible diaphragm of leather and rubber. On one side of the diaphragm was a water space through which the water of the circulating system passed. On the other side was an air space and a plunger head against which the diaphragm pressed. The plunger was directly connected with the throttle valve (Fig. 18).

CARBURETOR PRINCIPLES

Despite tremendous advancement made in internal-combustion engines during recent years, original methods of carburetion are still—broadly speaking—in practice.

The carburetor is still a comparatively primitive instrument, depending upon the suction of the piston during its descent on the inlet stroke to draw from a jet (spray nozzle) or jets—variable or otherwise—the necessary gasoline to mix with the air.

This jet can be of a fixed size or it can be variable in size. This spray of gasoline is at the mercy of the temperature, valve timing, exhaust, inlet, and combustion-head design.

Carburetors, as we know them at the present time, are divided into five classes:

(1) **Air-valve type.** In this the fuel issues through a fixed orifice and the additional air required when the throttle is opened is admitted through an auxiliary air valve.

(2) **Compensating-jet type.** In this an auxiliary fuel jet comes into action as the throttle is opened.

(3) **Metering-pin type.** In this the size of the gasoline orifice (jet) is increased automatically to increase the flow of fuel as the throttle is opened.

(4) **Expanding type.** In this there are a number of fixed orifices which come into action one after the other as the throttle is opened.

(5) **The "plain tube" or "pitot" principle.** A modern principle now being adopted extensively. The metering pins, dash pots, and auxiliary air valves are dispensed with. It derives its name, "plain tube," from the fact that both the air passage and the gasoline jet are of fixed size for all engine speeds. The action is to supply an increased supply of gasoline or rich mixture for acceleration and then to thin down to an economic mixture for normal engine speed.

Air-Valve Principle

The air-valve principle of the carburetor is the type previously shown in Fig. 3, page 96. In this type (see also Fig. 19), it is only possible to adjust the amount of gasoline flowing to the spray nozzle. It is therefore only suitable for engines which run at a steady, constant speed, as previously explained.

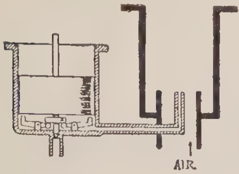


Fig. 19

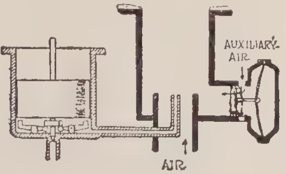


Fig. 20

The engine of an automobile, however, does not run at a steady speed; sometimes it is running fast and sometimes slow.

The speed of the air current passing through the carburetor depends on the speed of the engine; when the engine is running fast the speed of the air current through the carburetor is much greater than when the engine is running slow.

The greater the speed of the air current, the more gasoline it will suck out of the spray nozzle, and the adjustment of the gasoline flow that will give a correct mixture at a low speed will give a rich mixture when the air current moves at a higher speed. For this reason the air supply must also be varied in order to give a more combustible mixture.

Auxiliary Air Valve

To vary the air supply, different methods are used, but the one used most is the auxiliary air valve, and this is where the "air-valve type" carburetor derives its name (see Fig. 20).

The auxiliary air valve was designed for engines which run at changing speeds, so that an extra supply of air is admitted when the air current flows so fast that it would result in too rich a mixture.

The disadvantage of this type is that owing to the relieving action of the spring valve, it does not increase the proportion in proper ratio, and is hardly suitable for the present-day high-speed flexible engine.

There are several different models now manufactured, based on the principle of the auxiliary air valve only. In these, the problem is worked out in different ways; one manufacturer uses a "spring-controlled valve"; another hopes to get better results by regulating the movement of the valve by "two springs," instead of one; still another maker adds an "air dashpot" with the hope of getting finer regulation and a better functioning of the auxiliary air valve; another uses a "dashpot filled with gasoline"; and there are others who use metal "balls" to serve as the auxiliary valve, while others use what are known as "weighted air valves," in which the suction lifts balls, thus admitting the air which sweeps over the spray nozzle. While they all differ in the details of working out the design, all are, nevertheless, based on the basic principle of the auxiliary air valve as originally worked out, and shown in Fig. 4, and in Fig. 20 above. For simplicity in nomenclature we shall refer to this type as the auxiliary air valve type.

Relation of Acceleration to Gasoline Consumption

The rapid advance of high-speed and multiple-cylinder engines demands "quicker acceleration," meaning quicker "get away" or "pick up" of the engine.

Flexibility of control means practically the same thing, i.e., the capabilities of the engine to "pick up" from low to high speed and vice-versa. Rapid "acceleration" and "flexibility," both call for a sudden greater amount or percentage of gasoline to air. Quick acceleration therefore demands a surplus of gasoline for but a brief period, after which the normal supply will care for the engine. It may be but a matter of a few seconds, yet it is of importance that this additional supply be ready and in available form for that brief period.

To meet the sudden demand for gasoline, the added nozzle, or **multiple jet** has been introduced by some makers, so that when the suddenly opened throttle brings the auxiliary air valve into use, the valve in turn brings more gasoline into the mixture by opening the gasoline needle valve wider. This is termed the **"metering pin"** method. One maker does this by a "dashpot" on the auxiliary valve stem, the dash pot performing a regular pump stroke and forcing gasoline into the mixing chamber by way of a separate nozzle as the auxiliary air valve opens. Once open, the pumping action ceases, but the nozzle remains open for a more even demand for more fuel.

Proportion of air and gas: All of these methods of providing "acceleration" are based on the accepted belief that in carburetion, different mixtures of air and gasoline vapor are needed for different engine requirements. The days are past when the uniform-mixture argument dominated, the argument that the ideal carburetor was one that would give, say, a mixture of fifteen proportions of air to one of gasoline vapor for all speeds, "acceleration," "hard pulling" with open throttle, and high-speed work with open throttle, etc., etc. **The new rule** is that the amount of gasoline fed into the air volume must be changed according to demands. Thus a twelve-to-one or "rich" mixture might be best for quick acceleration; a fifteen-to-one or "leaner" mixture may be best for pulling with the throttle wide open; and a seventeen-to-one, or still "leaner" mixture may be desirable for particularly high-speed work. Therefore a "varying mixture" must be supplied.

The Compensating-Jet Principle

The compensating jet type of carburetor is where an **auxiliary fuel jet** comes into action, as the throttle is opened. Types of carburetors coming under this heading would be the Zenith; the Stromberg model "H" and the Marvel (see Index).

The Metering-Pin Principle

In the metering-pin type the size of the gasoline orifice, or jet, is increased automatically to increase the flow of fuel as the throttle is opened. In other words, as the throttle is opened, the metering pin (P, Figs. 21, 22, 23), which is similar to a gasoline needle valve, is moved so as to permit more gasoline to flow throught the spray nozzle or jet (J). Thus, instead of the gasoline needle valve (metering pin), being adjusted by hand, it is automatically adjusted by the speed of the engine, thereby permitting more or less gasoline to flow as the speed increases or decreases. This principle is called the "metering pin" principle, also the "pneumatic" principle, when operation is by air control.

Various methods are employed to operate this needle valve or metering pin as follows:

On the Schebler model "L" (Fig. 21), the metering pin (P) is connected with the carburetor **throttle lever** in such a manner that the metering pin (gaso-

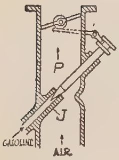


Fig. 21

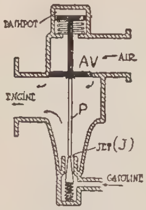


Fig. 22

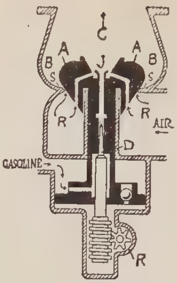


Fig. 23

Fig. 21. Schebler model "L." Metering pin controlled mechanically.

Fig. 22. Schebler model "T." Metering pin controlled by auxiliary air valve.

Fig. 23. Stewart model metering pin controlled by air suction.

line needle valve) is raised as the throttle is opened. See Index under "Schebler carburetors."

On the Schebler model "T" (Fig. 22), the metering pin (**P**) is connected to and controlled by the **auxiliary air valve.** As the throttle is opened, the speed of the engine increases, the suction becomes greater, and the air valve (**AV**) is sucked downwards, causing the metering pin (**P**) to give a greater opening at jet (**J**), thus admitting more gasoline.

On the Stewart carburetor (Fig. 23), the metering pin (**D**) is controlled by **air suction.** As the throttle is opened the suction becoming greater, the metering valve (**A**) (part in black) rises, enlarging the opening at the metering pin (**D**) and drawing more gasoline through jet (**J**). At the same time more air is drawn around the valve seat (**B**). A ratchet (**R**) is connected with a control on the dash for the purpose of enlarging the opening at the metering pin, so as to obtain a rich mixture when starting.

Example of a Carburetor with Both a Metering Pin and Dash Pot

The Rayfield uses a "metering pin," which is lifted as the throttle opens in the main jet (**N**) (Fig. 24), through a link arrangement, which establishes a right for it to be classified as a metering pin type. But it goes farther. It incorporates an auxiliary nozzle (**AN**) which also has a metering pin that is depressed when the auxiliary air valve opens. Thus, by having two distinct nozzles it establishes its right also to be classified as an expanding type of instrument.

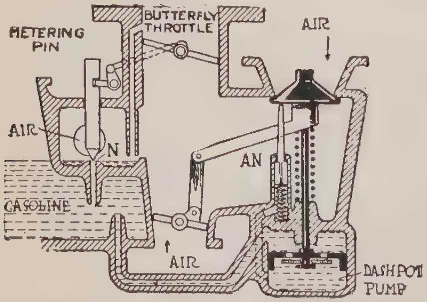


Fig. 24. The Rayfield carburetor principle with "metering pin" connected with the throttle and "dash pot," with auxiliary air intake.

But the Rayfield goes still farther, in that it combines a **pumping action** on the gasoline in the auxiliary nozzle (**AN**) whereby a very rich mixture is furnished for acceleration whenever the air valve is suddenly opened. This is accomplished by the piston on the lower end of the air-valve stem working in a "dashpot" filled with gasoline. Gasoline enters the dashpot above the piston and is admitted to the space below the piston by the disk valve in the piston. When the air valve suddenly opens, forcing the piston downward, this disk valve is automatically closed, forcing or pumping the gasoline upward through the dotted fuel passage into the nozzle (**AN**), where it is sprayed into the inrushing air. Only when the valve opens is this pumping function occurring; at other times the gasoline issues through this auxiliary nozzle according to the suction of the engine. Thus the **Rayfield is a compound** of two metering pins in conjunction with the pumping function for acceleration.

Expanding Principle

In the expanding principle, there are a number of fixed orifices which come into action, one after the other, as the throttle is opened. Types of this class of carburetors are shown in Fig. 25 and in the description of the "Master" carburetor (see Index).

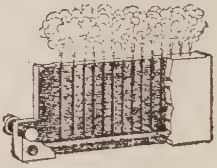
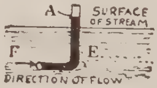


Fig. 25. The multiple jets of the Master carburetor.

The Pitot or Plain-Tube Principle

The "Pitot" or "plain tube" type of carburetor differs from other principles. It is the principle now being used to a considerable extent, and derives its action as well as its name from a Pitot tube.

A Pitot tube is a very old instrument for measuring velocities of flowing streams of water, invented by Henri Pitot in 1730. It consisted of a vertical glass tube with a right-angled bend as shown at (**E**).



The impact of the flowing water against the open end (**F**) of tube (**E**) caused a column to rise above the surface of the stream as at (**A**), and by this small difference in height, the velocity of the stream was calculated. A similar principle, but to provide air, is embodied in the carburetor using this principle.

The Pitot tube is also used for measuring pressure in moving streams of gas or liquids. It can be used facing in any direction, but, as applied to the carburetor, faces down stream.

The Pitot tube has been used for years for measuring fire streams, chimney drafts, etc. In the carburetor it is simply used to provide air at sufficient pressure to force the fuel from the well to be enclosed in the carburetor.

The Pitot function as applied to a carburetor is simply to provide air at sufficient pressure to force the fuel from a well inclosed in the carburetor. The intake of the Pitot tube is inside the carburetor where the air pressure is quite low, but, owing to the Pitot action explained above, the pressure of the air delivered to the well from (**A**) is increased so that it is about as high as the pressure of the atmosphere.

See Index for explanation of a "plain tube" carburetor.

GASOLINE: PRIMING METHODS; HEATING METHODS; VAPORIZING GASOLINE

Before taking up the subject of various constructions and adjustments of carburetors, we shall first deal with the subject of gasoline, vaporizing gasoline, and fuel-feed methods.

Gasoline

The usual fuel for automobile engines is gasoline. Gasoline is distilled from mineral oil (petroleum).

When petroleum is heated, it gives off gases, just as water, when heated, gives off steam. When these gases are cooled, they become liquids, and are called gasoline, kerosene, benzine, naptha, etc.

The chief difference between them is their **"volatility."** When a liquid turns to vapor, or gas, it is said to be **"volatile."** Gasoline should be very volatile in order to insure easy and prompt starting, and to furnish power.

Temperature makes a great difference in the volatility of liquids; for instance, thick, heavy oil is not volatile at the ordinary temperature of the atmosphere, but is volatile when heated.

Gasoline is very volatile at the ordinary temperature of the atmosphere. It is so volatile that it must be kept in air-tight tanks, for it would entirely evaporate if left exposed to the air. Because of this volatility, gasoline must be handled with care to prevent fires and explosions. It should never be handled near an open flame.

A low grade of gasoline will produce poor results in any carburetor. Difficulty in starting is the main disadvantage in its use, as it is not as volatile as a high-gravity gasoline.

Inferior, or too much gasoline is generally indicated by a **black smoky exhaust** and a disagreeable odor. When a low-gravity gasoline is used some effective method for vaporizing it must be employed.

A test by hand: To ascertain how near kerosene you are getting, pour a little gasoline in the hand. When it evaporates slowly and leaves a greasy deposit, it is of a very low grade. When it evaporates rapidly and leaves the hand dry and clean, it is of a higher grade. This furnishes a fairly reliable test.

Testing gasoline with a hydrometer was the method used a few years ago. It is used as follows: Fill the glass tube with gasoline, and insert the hydrometer, which will float. The gravity of the gasoline is determined by the depth the hydrometer sinks in it. A scale is graduated on the upper portion of the hydrometer and the level of gasoline indicates the specific gravity. The scale usually runs from 60 to 80. Gasoline under 60 test ought not be used. It averages about 64 to 68, and the better grade is 72.

Gravity is no longer an accurate test of the merits of the fluid, the only really accurate test being from a maximum and minimum boiling-point. It is, of course, not practical for the average owner to make such tests, and the best rule is to purchase from a reliable distributor, who handles gasoline manufactured by responsible distillers.

Most of the gasoline today sold for motor-car use differs from that of several years ago in that it is not all of one grade, but is a compound or blend of the different petroleum elements; some of it being very light and volatile, while about one-fourth of it may have a boiling point higher than that of water, and is correspondingly difficult to convert into a vapor.

Gasoline of 56° to 64° Baume paraffine base is used almost universally in the United States east of the Rocky Mountains. Fuels of lighter gravity are also produced from asphalt base petroleum. In certain sections of the country gasolines of very low grade have recently been introduced, one-half being actual kerosene. With this fuel and the ordinary intake manifold it is almost impossible to make an engine operate properly either at closed or open throttle, unless the radiator is covered up and the cooling water is brought to a temperature of 160° to 180° F.

To use this fuel it is necessary that the whole carburetor and intake manifold system be thoroughly heated. Without this heat the carburetor setting will have to be changed and made richer than necessary, while the extra heavy part of the fuel, not vaporized, will burn slowly in the cylinder, forming carbon, and sooting up spark plugs, etc.

There is, of course, a period of time just after starting the engine cold, when the rich mixture will be necessary (and can be furnished by the dash control), but the control should be released as soon as the engine becomes warm.

It is also advisable, while the engine is cold, to avoid opening the throttle full, as the fuel vaporizes much more readily in the suction or partial vacuum which exists in the manifold while the throttle is partly or completely closed.

In very cold weather it is advisable, instead of readjusting the carburetor or using the dash control continuously, to cover part of the radiator surface, so that the normal temperature is maintained under the hood.

In some parts of the country there is so great a range in the constituents of the gasoline sold that the lighter or more volatile fractions may, in warm weather, boil in the carburetor, under normal operation of the car. In this case, the hot-air supply to the carburetor may be disconnected, while care should be taken that the gasoline supply line from the tank to the carburetor does not approach the exhaust pipe, cylinder walls, or other heating influence.

If the gasoline should catch fire, do not try to put it out with water, for as the gasoline will float on water, it will only spread the flames. Damp sand, flour, or a wet blanket will smother the fire.

Low and High-Gravity Gasoline

The proper gravity of gasoline to use is governed by conditions. In the summer a low gravity vaporizes much more easily than in the winter; therefore the engine starts easier.

A great many claim that the low gravity gives results as good as or better than high-gravity. Probably it does, as there are more heat units per gallon, but as a matter of easy starting and absence from carbon deposit, the high gravity is preferable, unless the carburetor has been properly adjusted, and priming and heating methods are provided.

With the high gravity we have a high "flame" rate (mixture burns rapidly), whereas, with the low gravity, we get a higher combustion heat, but slower "flame" rate. With a high flame rate the mixture burns rapidly—pressure rises quickly and imparts a powerful push at the commencement of the stroke, but falls away equally quickly as the stroke progresses.

With low-gravity gasoline, the reverse occurs. The explosion generates slowly and does not impart a violent shock, but with a retarded flame rate, and the pressure predominates through a much greater proportion of the stroke. The results are obvious. With high speed, as in racing, the high gravity is best. For medium speeds, where steam-engine-like power is required, combined with fuel economy, low gravity is best—providing the carburetor has been readjusted for the low-gravity fuel and proper heating arrangements are provided.

Owing to the great amount of **carbon in low-gravity gasoline** it is very necessary that the carburetor be properly adjusted.

The starting will be more difficult with low gravity, but with the use of a primer and a hot-air arrangement, this trouble can be overcome.

It is a well-known fact that **an engine,** especially an old one with loose bearings and slack pistons, **will run much more quietly on low-gravity gasoline.** This is due to the slow flame rate; the pressure is gradual on the piston head and presses rather than slams.

How Unvaporized Gasoline Thins the Lubricating Oil

Gasoline vapor that is not completely consumed in the engine does one of three things: it either passes out into the exhaust in an unburned state and is wasted, is deposited in the form of carbon within the cylinder, or condenses and runs down past the pistons into the crank case.

The first of these is the most direct loss, but the other two are equally important in the long run. A carbonized engine is of itself inefficient. Carbon makes the engine miss, makes it overheat and preignite. All of these things are sure to shorten the life of the engine.

When the unburned fuel runs down past the piston, it destroys the seal between piston rings and cylinder, removes the oil film which is to protect the surface of the cylinder, piston, cam, and crank shaft bearings from friction and wear, and, lastly, dilutes the lubricating oil in the crank case to such an extent that in time it becomes worthless.

Manufacturers are advising now that the crank case be drained even more frequently than ever before for this very reason. As cold weather approaches, the necessity for frequently refilling completely with new oil will become more imperative. Either the motorist is forced to drain out his oil and refill with fresh at an increased outlay, or he must suffer the consequences of an engine damaged by insufficient lubrication.

Starting Engine

Remember, when you start an engine by closing the air intake and thus choking off the air, that pure raw gasoline is being drawn into the cylinder. For this reason, a **heating method** of some sort should be attached to every carburetor, so that the gasoline will become heated and vaporized as quickly as possible, thus avoiding the use of the choker for any length of time.

Priming Methods

On a cold morning, **after the engine and all parts have become chilled,** we find that the ordinary grade of gasoline now in use does not vaporize readily until it is heated. Considerable cranking of the engine is sometimes necessary in order to ignite the cold, damp, unvaporized gasoline.

There are several methods of overcoming this; one being to use a higher grade of gasoline. But even with the higher grade, which is difficult to obtain, on a really cold day the starting will be somewhat difficult with some makes of carburetors. For these reasons, **priming,** by injecting raw gasoline into the cylinder, is necessary.

Examples of various priming methods are exexplained in Figs. 1–6:

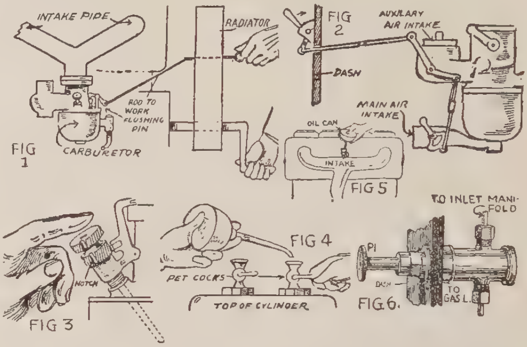


Fig. 1. Method of priming by depressing float, thus opening the float needle valve, and providing an excess of gasoline to be drawn into cylinder.

Fig. 2. A damper is provided in the main air-intake pipe. When closed, the suction provides more gasoline than air. Sometimes the tension of the spring on the auxiliary air valve is regulated from the dash or steering post.

Fig. 3. Priming the carburetor by opening the gasoline needle valve. This method is not advisable, however, because the adjustment valve is a very sensitively adjusted part of the carburetor, and will upset the proper working of the carburetor after the engine is heated up. If this method is employed, be sure to mark a notch on the head of the valve, so that it can be turned back to its original adjusted position.

Fig. 4. Priming with gasoline through priming cups.

Fig. 5. The oil-can primer, where gasoline is injected into the intake manifold. Simple and effective when other methods fail.

Fig. 6. The spray primer; a small injector pump. The suction part of the pump is connected to the gasoline supply pipe between the tank and carburetor. The other part connects to the intake manifold; one stroke of the plunger sprays a charge into the manifold. The Imperial Brass Co., of Chicago, manufactures a pump primer of this type, as also does the Bay State Pump Co., 102 Purchase St., Boston.

When an engine fails to start during cold weather and you are positive there is a good hot spark, an effective method is to pour boiling water over the carburetor and inlet pipe. A resort to the "choker" or "damper" principle, however, usually results in starting the engine.

The "damper" or "choke" method is shown in Fig. 7. Instead of lowering the float, the air intake is closed. This causes an increased suction of gasoline and is called "choking" the air supply.

Too much priming, however, will fill the float chamber so full, that gasoline will run out of the spray nozzle, giving a rich mixture, on which the engine will not start; it will then be necessary to open the switch and close the throttle, and to crank the engine a few times to draw in more air. Then close the switch and crank again, when the engine ought to start if there is a good spark.

In either method explained, remember that **a good hot spark must be provided** in order to ignite this raw gasoline, because it is harder to ignite when cold than after it is warmed up.

Note. In order to facilitate **easy starting** next time, by hand or motor, it is advisable to open the throttle just before stopping the engine, in order to draw in a good charge of gas. This is done by speeding the engine up with the clutch out, and leaves a **charge in the cylinder** for starting later.

After the engine is started, some means should be employed for heating the gasoline so it will vaporize quickly and thus prevent raw gasoline being drawn into the cylinder.

Vaporizing Gasoline

Gasoline gives off more vapor at about 170° Fahr. It is the vapor mixed with air which is most desired. With the proper mixture there is more uniform power and flexibility.

Carbureting means breaking up the gasoline into infinitesimally small particles, mechanically, without heating, which is called "spraying." This is the best method, but is very difficult to accomplish, owing to the different amounts of gasoline passing from the spray nozzle, and on account of the variation of the throttle, or of the speed.

If a low gravity of gasoline is used, it is necessary to heat and vaporize the mixture, because it is practically impossible to break it up; but if it is a high-gravity gasoline, it generates into gas or vapor more quickly. In other words, it is the vapor that we must obtain, which is possible with high-gravity gasoline. In using high-gravity gasoline, however, it must be remembered that it will not stand as much heating as low-gravity gasoline, for if too much heat is used, it makes the mixture so rare that the actual amount of gasoline that goes into the cylinder is so small and at such a low flash point, that it ignites quicker, and will burn and expand more like powder. It will do its work and cool before the piston gets well under way. Furthermore the pressure on the piston does not last as long.

Owing to the low-gravity gasoline now being used, the mixture is not a true vapor. Instead of forming a gaseous mixture, it condenses inside of combustion chamber and manifold. Therefore a plentiful supply of heat is required.

As previously stated, the use of **low-gravity gasoline** requires more heating or vaporizing than a high grade. It might be compared with the firing of a furnace with soft coal. If soft coal is properly fired and is properly mixed with air, it will produce the most heat without producing very much smoke. Just so with a low grade of gasoline. If properly vaporized, it will work fairly well, otherwise carbon deposit and smoke will be the result.

High-gravity gasoline may be compared with hard coal. It is very easy to get the proper mixture of air with the high-gravity gasoline, because it is so very "volatile"—meaning that there is more vapor, and less vaporizing is necessary, and that it will "carburet" more readily. Therefore it will work satisfactorily in most any carburetor construction. Just so with hard coal. It will burn with less smoke and produce an equal amount of heat even though you burn it in an open shovel, and makes very much less carbon.

On stationary and high-duty marine engines a low gravity fuel is used, as kerosene and oil, but before it can be used it must be "vaporized."

A correctly heated carburetor runs on less gasoline than an unheated one, therefore in such a case a closer adjustment of the gasoline needle valve or a smaller jet is necessary.

An engine requires **more gasoline in winter than in summer,** as the gasoline does not vaporize and readily mix with the air until warm.

Heating Methods

What we desire to heat is the gasoline, so that it will vaporize and enter the cylinder in the form of gas, or mixed vapor and air instead of raw gasoline mixed with air.

We might classify heating methods under four classifications as follows:

1. **Heating the air** which is drawn into the air intake of the carburetor, and which mixes with the gasoline as it is drawn into the cylinder.
2. **Heating the mixture** as it is drawn into the cylinder.
3. **Heating the air and the mixture.**
4. **Heating the carburetor.**

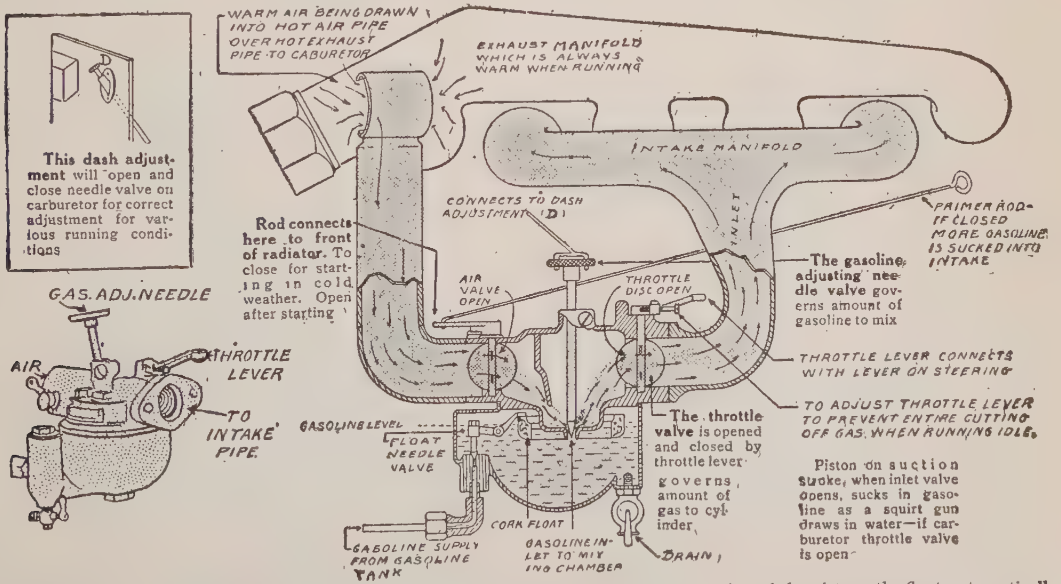

WARM AIR BEING DRAWN INTO HOT AIR PIPE OVER HOT EXHAUST PIPE TO CABURETOR
EXHAUST MANIFOLD WHICH IS ALWAYS WARM WHEN RUNNING
This dash adjustment will open and close needle valve on carburetor for correct adjustment for various running conditions
INTAKE MANIFOLD
CONNECTS TO DASH ADJUSTMENT (D)
INLET
PRIMER ROD—IF CLOSED MORE GASOLINE IS SUCKED INTO INTAKE
Rod connects here to front of radiator. To close for starting in cold weather. Open after starting
The gasoline adjusting needle valve governs amount of gasoline to mix
AIR VALVE OPEN
THROTTLE DISC OPEN
GAS. ADJ. NEEDLE
AIR
THROTTLE LEVER
TO INTAKE PIPE
THROTTLE LEVER CONNECTS WITH LEVER ON STEERING
TO ADJUST THROTTLE LEVER TO PREVENT ENTIRE CUTTING OFF GAS WHEN RUNNING IDLE.
GASOLINE LEVEL
FLOAT NEEDLE VALVE
The throttle valve is opened and closed by throttle lever governs amount of gas to cylinder
Piston on suction stroke, when inlet valve opens, sucks in gasoline as a squirt gun draws in water—if carburetor throttle valve is open
CORK FLOAT
GASOLINE SUPPLY FROM GASOLINE TANK
GASOLINE INLET TO MIXING CHAMBER
DRAIN

Fig. 7. **Float principle:** When gasoline and air are drawn into the cylinders by suction of the piston, the float automatically lowers, thereby opening the float needle valve and permitting more gasoline to enter the float chamber. When the engine is not running the float chamber fills up, causing the float to rise, thereby closing the float needle valve. This prevents more gasoline entering, which would cause overflowing and dripping. If the float happens to become loose or lowered more than intended, it would not cause the needle to cut off the gasoline supply—hence dripping would result. (Note the dotted lines indicate the gasoline level.)

Heating the Air

The illustration (Fig. 7) is that of the early model "Y" Kingston carburetor, used on the Ford. (See the Ford instruction for the later models.)

The air is taken in at the "air-valve" opening. A hot-air pipe is shown connected, which admits warm air to be drawn in from around the exhaust pipe. This is a good example of **how the air is heated** before being drawn into cylinders. It will be noted that there is no auxiliary air valve on this carburetor.

Priming method: The damper or "choker" or "primer" method (Fig. 7), for priming or feeding the engine more gasoline for starting is operated by closing the damper or "air valve." This is used principally during cold weather.

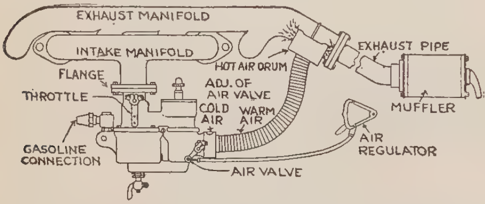


Fig. 8

Another example of **heating the air** drawn into the carburetor and also a method of admitting cool air is shown in Fig. 8. This is practically the same principle as in Fig. 7. Hot air is drawn into the main air-supply opening of the carburetor. A **hot air drum,** also called a "stove," is fitted around the exhaust pipe, not close, but placed so that air can be drawn in where the arrows indicate. A flexible tube then permits the air to flow to the air opening of the carburetor.

A valve is provided, called the **"air valve,"** also called a "damper" or "choker," which can be opened or closed by the "air regulator" lever, usually placed on the steering column or dash. This lever operates a butterfly type of valve in the air opening of the carburetor.

Choking air supply to start engine: When starting the engine, this air valve is closed, cutting off the air supply to the carburetor and causing an increased suction of gasoline to enter the cylinder (or an extremely rich mixture). This gives the initial priming for starting. Immediately the engine is started, the air valve is slightly opened to admit air. As the engine becomes warmed up, the air valve is opened more and more until fully open, or, in other words, to where the engine runs without missing or jerking which is common during cold weather. It is well known that engines will miss when first starting, due to the gasoline particles being unevaporated, which, in turn, is due to lack of heat. But after the engine is warm, the gasoline becomes vaporized and the engine runs without missing. The idea is to run on as much air as possible at all times. Therefore open the air valve to the point where missing will not occur.

By this method, warm air will be drawn into the carburetor whenever the air valve is open. But after the engine is thoroughly warm, and especially in summer, the air valve is opened more fully, thus permitting more air to be drawn in and mixed with cool air taken in at the "cold air" opening.

Temperature regulator: After the engine is well warmed up, it ought to have more air, and the more air used, the less gasoline required.

If warm air is drawn into the carburetor after the **engine is very hot,** then the mixture would be made too rare or lean.

We also know that gas expands in direct proportion to the degree to which it is heated. Therefore, when **heated too much,** the gas is unduly or prematurely expanded to such an extent that it **loses** a certain percentage of **its energy.** Furthermore, the piston will draw in a smaller amount of gas during each stroke.

The best degree for general running appears to be somewhat below the boiling point of water, i.e., between 170° and 200° Fahr.

Therefore some means of **admitting cool air** must be employed which will mix with the warm air. This would be termed a "temperature regulator."

Adjustable temperature regulator: It will be observed, in Fig. 8, that the cold-air opening is a fixed opening and the amount of cold air drawn through the air valve is not adjustable. The amount of warm air drawn in, however, is governed by the air regulator. The arrangement shown in Fig. 9 is slightly different. The cold-air opening is adjustable.

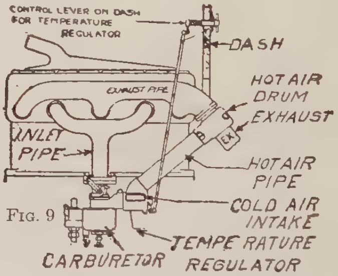


Fig. 9

The temperature of the warm air entering the carburetor can be regulated by opening the cold-air intake, thus permitting cool air to be drawn in. The use of this opening is governed more or less by the temperature. In summer, the opening is usually wide open, but closed more or less during cold weather.

Heating the Carburetor Mixture

There are various methods employed for heating the mixture, as it enters the cylinder, as follows:

1. **The hot-spot method** or heating the inlet manifold by placing it adjoining the exhaust manifold, as in Figs. 10 and 11.
2. **Passing hot exhaust gases** through a jacket surrounding the inlet manifold (Fig. 12).
3. **By circulating hot water** through a jacket around the inlet manifold (Figs. 13 and 14).
4. **By circulating hot water** through a jacket around the carburetor (Fig. 15).
5. **By passing exhaust gases** through a jacket around the carburetor (Fig. 16).
6. **By heating the mixture** with an electric resistance (Fig. 17).
7. **By a method termed a "fuelizer,"** as used on the Packard (Fig. 18).

The various methods mentioned above will now be illustrated and described. The reader should observe, however, that these examples refer to "heating the mixture" after the air has been taken into the carburetor through the main air inlet and mixed with the gasoline.

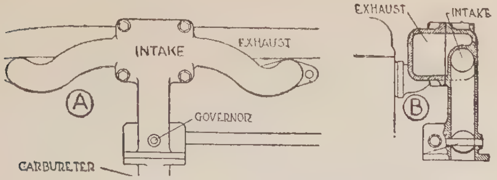


Fig. 10. "Hot-spot" heating of mixture by placing the exhaust manifold adjoining the inlet manifold. Only a part of the inlet manifold is heated: the upper part. The idea here is to prevent condensation of fuel. The liquid particles, when they reach the top of the vertical passage, do not swing to the left or right with the gas, but go straight, since they are heavier, until they strike the hot spot.

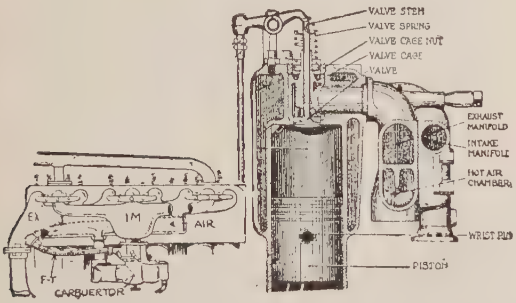


Fig. 11. Buick's exhaust heating of mixture. Note the exhaust manifold which adjoins the inlet manifold (**IM**). The lower part of the exhaust manifold (hot-air chamber) is divided from the exhaust (above). Air passes through the lower chamber which is heated. Hot air is also drawn into jacket around the upper part of the carburetor by a flexible tube connection (**FT**).

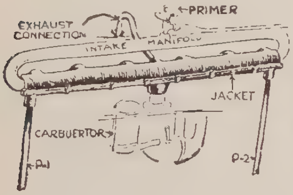


Fig. 12

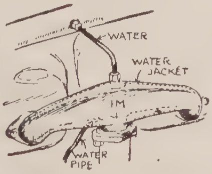


Fig. 13

Fig. 12. Franklin exhaust method of heating the mixture. Note the jacket which encloses the intake manifold through which exhaust gas passes. A cut-off is provided when the engine becomes very warm. **P1** and **P2** pipes are left open.

Fig. 13. Stutz hot-water-heated intake manifold.

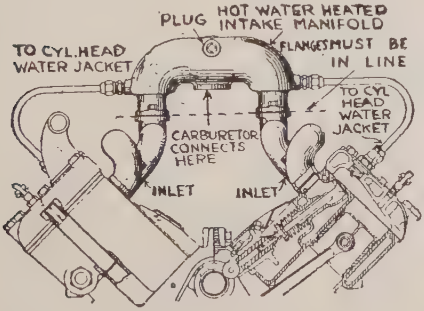


Fig. 14

Fig. 14. Hot-water heating of mixture as employed on the Oldsmobile eight-cylinder "V"-type engine. Note the hot water circulates through a jacket around the inlet manifold. This principle is more effective than heat around the carburetor. Exhaust gases can be passed through this jacket instead of hot water, which will heat the mixture quicker, and is more generally used.

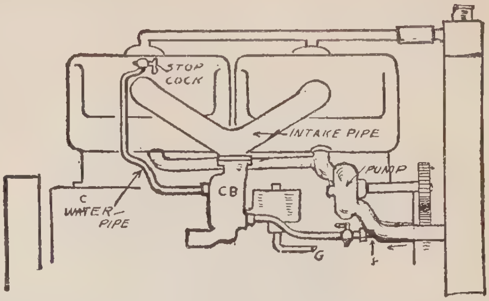


Fig. 15. Hot-water heating of carburetor. The usual method of connecting the hot water to the carburetor water jacket is to connect the upper water connection to the cylinder water jacket or pipe, and the lower one to the suction end of the pump (between radiator and pump). See that the connections are made in such a way that water will drain out of the carburetor jacket when the system is drained. Place a shut-off cock in the line for use in extremely hot weather.

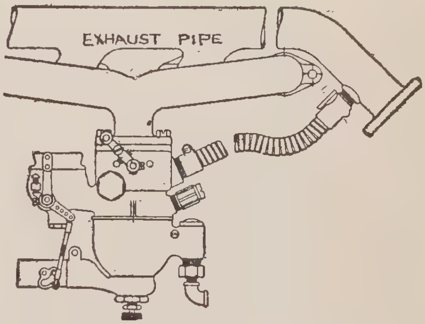


Fig. 16. Exhaust-gas heating of carburetor. The exhaust gases from the exhaust pipe can be carried to the carburetor water jacket, by tapping the exhaust pipe and connecting a flexible or copper tube to the water jacket. It is advisable to use as large a pipe as possible—say ½″, as it has a tendency to clog up. The other opening of the water jacket is left open by a ⅜″ or ½″ copper-pipe connection extending to the lower part of the engine for emission of gases.

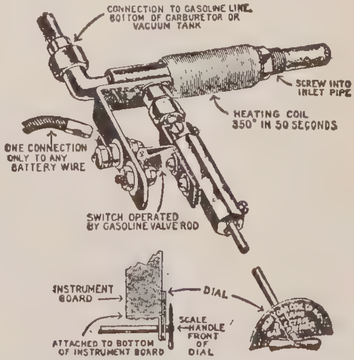

CONNECTION TO GASOLINE LINE, BOTTOM OF CARBURETOR OR VACUUM TANK
SCREW INTO INLET PIPE
HEATING COIL 350° IN 50 SECONDS
ONE CONNECTION ONLY TO ANY BATTERY WIRE
SWITCH OPERATED BY GASOLINE VALVE ROD
INSTRUMENT BOARD
DIAL
SCALE
HANDLE FRONT OF DIAL
ATTACHED TO BOTTOM OF INSTRUMENT BOARD

Fig. 17. Heating the priming mixture electrically. A pipe connects with gasoline supply. The primer is screwed into the inlet manifold. Suction of the piston draws in raw gasoline. An electric heating coil connected with the battery heats the gasoline used for priming as it passes into the manifold. There are various electrical methods for heating.

Packard "Fuelizer" for Heating Mixture

The pipe marked "By-Pass" (Fig. 18) carries a minute quantity of gas direct from the carburetor to the fuelizer, a small combustion chamber surrounding the intake manifold.

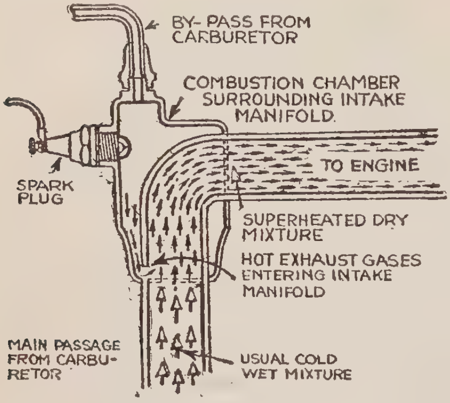

BY-PASS FROM CARBURETOR
COMBUSTION CHAMBER SURROUNDING INTAKE MANIFOLD.
TO ENGINE
SPARK PLUG
SUPERHEATED DRY MIXTURE
HOT EXHAUST GASES ENTERING INTAKE MANIFOLD
MAIN PASSAGE FROM CARBURETOR
USUAL COLD WET MIXTURE

Fig. 18. Packard fuelizer.

The gas is ignited by means of an independent spark plug in this chamber, as shown, and circulates at a very high temperature through the fuelizer chamber which surrounds the intake manifold. At the bottom of the fuelizer chamber are two small holes through which the superheated exhaust of the fuelizer enters directly into the main inlet manifold.

Thus the main inlet manifold temperature is raised by direct mixing with the fuelizer exhaust as well as from the heat developed in the fuelizer chamber.

The result is that all gas passing through the main manifold is thoroughly dried, sufficiently heated, and broken up into a completely combustible fuel. Any grade of commercial gasoline, after receiving this treatment, explodes without a trace of carbon and without depositing lower grade fuels.

The circulation of gas through the fuelizer pipe and chamber is maintained by the same cylinder suction which draws gas through the main manifold. However, the circulation of gas through the fuelizer starts below the butterfly valve of the carburetor and exhausts into the main inlet manifold.

When the butterfly valve is closed, engine suction is very heavy upon the fuelizer; it receives a maximum supply of gas and gives off a maximum heat.

On the other hand, the farther the butterfly valve is opened, the less becomes the suction of the engine by the way of the fuelizer, because it is easier for the engine to suck the gas by way of the main manifold. This automatically decreases the heat given off by the fuelizer directly in proportion to the decreasing need of the engine for heat.

When the engine is being started, or idling, the fuelizer is going at maximum. But when the engine reaches an ideal combustion heat, because of high-speed traveling, or heavy low-gear work, the fuelizer automatically shuts off until it is again needed.

The Lexi-Gasifier

The following illustration and explanation is taken from the instruction book of the Lexington series "S" model. The air is not heated, but is drawn in cold.

Incorporated in the Moore multiple exhaust system manifold is a device that converts all the heavy portions of the fuel not vaporized by the carburetor into gas, which is taken up by the air stream and carried into the engine cylinders to do useful work instead of going down the cylinder walls, destroying lubrication. All of the highly volatile portion of the fuel, in passing through the carburetor, is vaporized and is carried by the air stream into the engine cylinders. The heavy portion, or "high-end point," after passing the throttle valve, is deflected into the hot grid back of the manifold, by the bend in the pipe immediately above the carburetor.

The system is so designed that all six of the exhausts play on the back of the grid, keeping it quite hot. All heavy particles of fuel falling into this grid are instantly converted into gas, which rises and is carried by the air stream directly into the engine cylinders. Its action is similar to pouring gasoline on a hot stove.

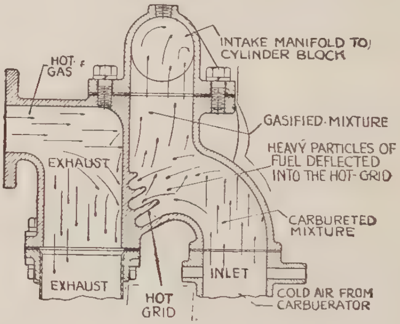

INTAKE MANIFOLD TO CYLINDER BLOCK
HOT GAS
GASIFIED MIXTURE
HEAVY PARTICLES OF FUEL DEFLECTED INTO THE HOT-GRID
EXHAUST
CARBURETED MIXTURE
INLET
EXHAUST
HOT GRID
COLD AIR FROM CARBUERATOR

Fig. 18**A**. Lexington gasifier.

This device is not to be classed with the hot-spot manifolds, which heat the carburetor mixture (both air and fuel). Heating the air expands it, and prevents the cylinders from taking in the maximum amount of oxygen units to mix with the fuel, thereby weakening the explosions.

In the Lexi-Gasifier the air passes in almost cold, taking with it the gasified fuel, providing the maximum oxygen units in a given space for this fuel. This excess of oxygen and gasified fuel produces a greater pressure in the cylinders, hence more power.

After all, the power obtained from the internal combustion engine is the difference in temperature of the incoming mixture and the temperature to which we can raise this after burning.

Cadillac "61" Carburetor Thermostatically Controlled

The carburetor on the type "61" Cadillac is provided with thermostatic control for the tension on the auxiliary air-valve spring and also for regulating the effectiveness of the accelerating pump.

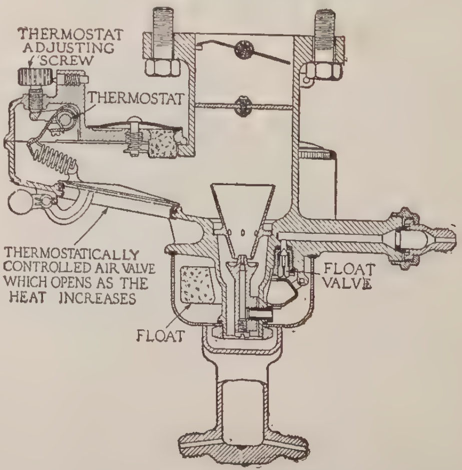

THERMOSTAT ADJUSTING SCREW
THERMOSTAT
THERMOSTATICALLY CONTROLLED AIR VALVE WHICH OPENS AS THE HEAT INCREASES
FLOAT VALVE
FLOAT

Fig. 18B. The Cadillac carburetor is provided with thermostatic control on the auxiliary air-valve spring and also for regulating the effectiveness of the accelerating pump.

Referring to Fig. 18B showing a sectional view of the carburetor, it will be noted that the manual setting for the air valve is employed as usual, but superimposed on this manual setting is a **thermostat** which alters the tension of the air-valve spring in accordance with temperature requirements.

On a cold engine the spring tension is increased, thereby causing increased resistance to the opening of the auxiliary air valve.

In warmer weather the effect is the reverse, thus tending to make the mixture leaner.

The thermostat on the accelerator pump (not shown in the illustration), which is located in the fuel chamber, operates a shutter which covers and uncovers a vent, thus increasing the effectiveness of the pump when the engine is cold, and decreasing it when the engine is warm. In other words, when the vent is open the accelerator pump has little or no effect, but when it is closed the accelerator pump or throttle pump will force gasoline through the spray nozzle, when the throttle is opened quickly for acceleration. When the throttle is opened slowly the pump has practically no effect on the gasoline. The throttle pump is interconnected with the throttle, and its function is to force compressed air into the float bowl. When the thermostat comes into effect and opens the vent, the air, of course, cannot be compressed, and consequently the pump operation is materially reduced.

It is claimed that the introduction of these two thermostats materially reduces the warming-up period of the engine. (*Motor Age.*)

Heating the Air and the Mixture

A combination of heating the mixture and heating the air is shown in Fig. 19. The exhaust manifold adjoins the inlet manifold which heats the mixture as it enters the cylinders. Warm air is drawn around the upper part of the carburetor, admission of which is controlled by a throttle which keeps the upper part of the carburetor warm. Warm air is drawn in the main air supply which heats the air. **A temperature regulator,** controlled from the dash, admits cool air into the main air supply when the engine is thoroughly warmed up.

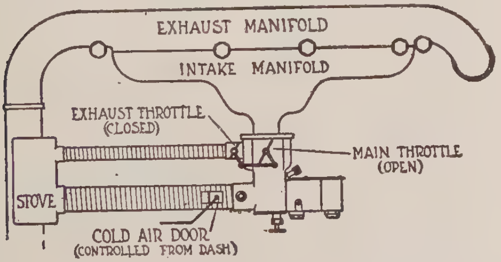

EXHAUST MANIFOLD
INTAKE MANIFOLD
EXHAUST THROTTLE (CLOSED)
MAIN THROTTLE (OPEN)
STOVE
COLD AIR DOOR (CONTROLLED FROM DASH)

Fig. 19

For starting, the lower air opening of the carburetor can be closed entirely, which "chokes" the air and causes gasoline to be drawn into the cylinder until the engine starts. This system is used on the Nash trucks and is an ideal system.

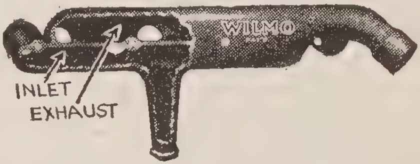


Fig. 20. Wilmo exhaust-heated intake manifold, designed for Fords and other cars. An example of method for heating the mixture just before it passes into the cylinders. The carburetor connects with the lower, or inlet part of the manifold; the exhaust is the upper part, with a plate between. By completely vaporizing the gasoline, no residue is left to seep into the crank case to thin the lubricating oil. The Whittier Co., 2415 So. Mich. Ave., Chicago, Ill., are the manufacturers, who claim for it an increase in mileage on a Ford.

Remarks on Water and Exhaust Heating

If the intake manifold is heated with water, the temperature is not so liable to cause overheating, as the temperature seldom goes above 170° to 200°, especially if a thermostatic principle is used.

When the engine is cold, after standing all night, the water does not heat as quickly as if exhaust-gas heated, but when the engine is run and warmed up and left standing, the water will remain warm for some time and will quickly heat again. The water is quite often circulated around the carburetor and inlet manifold and in connection with a temperature regulator and heated air intake. A water heating system can be used only with engines using a force or pump water-circulating system.

When the intake manifold is heated by the exhaust, the temperature is liable to increase to a high degree, if the engine is run continuously for a long period. The latter system, however, will heat the mixture more quickly than the water system, when the engine is cold. Therefore means for admitting cool air and some means for cutting off the exhaust gases from the manifold jacket ought to be provided, especially in case of the long-continued running of the engine.

HOW TO DETERMINE THE SIZE OF CARBURETOR TO USE

The size of the carburetor should be determined by the area of the valve opening on the engine, and not by the cylinder displacement, as the former is a true measure of the engine capacity. A carburetor cannot deliver more charge to a cylinder than the area of the valve opening will allow to pass.

A large carburetor with too much passage area cannot cause an engine to deliver more power than it would with one having a passage equal in area to that of the valve opening. Too large a carburetor would not only waste fuel, but would reduce the power of the engine by furnishing a weak mixture.

If the carburetor is too small the engine will not develop its rated power, as it could not deliver a full charge at high speed.

When a carburetor is small for the engine, it **becomes very cold** while in operation, as the amount of heat necessary to effect the vaporization of the gasoline is more than is available from the entering air or than could be secured through the metal carburetor by conduction. The temperature of the metal part of the carburetor becomes so low that water condenses on it, and, in some cases, is in the form of frost. These results are produced by the use of a carburetor too small for the engine. To meet these conditions, some makers provide means for heating the air supply, as previously shown.

It follows that the **carburetor of proper size** should have its passage area equal to the valve opening of the engine. In multiple-cylinder engines this area is equal to the valve opening multiplied by the number of suction strokes which take place simultaneously, determined from the sequence of cranks.

It will spell failure to fit a carburetor with a large jet and opening to an engine in which the exhaust closes very early, because the surplus gas cannot be expelled as completely as with an engine having a very late-closing exhaust valve.

Carburetor sizes are determined by the opening leading to the manifold. These openings are slightly larger than the indicated size of the carburetor.

For example: The opening on three different makes of carburetors varies as follows: **1-inch:** Schebler, 1 3/16″; Rayfield, 1¼″; Stromberg, 1 3/16″; **1¼ inch:** Schebler, 1⅜″; Rayfield, 1½″; Stromberg, 1 7/16″; **1½ inch:** Schebler, 1⅝″; Rayfield, 1¾″; Stromberg, 1 11/16″.

In fitting a carburetor to the manifold, the carburetor opening should be slightly smaller and never larger than the opening in the intake manifold.

S.A.E. flange openings are as follows: **1-inch carburetor** has 2⅜″ between bolt-hole centers; **1¼ inch carburetor** has 2 11/16″ between bolt-hole centers; **1½″ carburetor** has 2 15/16″ between bolt-hole centers.

GASOLINE TROUBLES

The tank of a fuel system is always provided with a small hole, usually drilled through the filling cap, as at (V), Fig. 1, by which air may enter to replace the gasoline as it is drawn off. If this hole becomes clogged with dirt, the gasoline in flowing out will tend to create a vacuum, and the flow will stop.

The outlet pipe should project slightly above the bottom of the tank, so that water and dirt may settle, and not be carried to the carburetor. A filter screen should also be provided.

A temporary repair for a slight leak in a gasoline tank can be made by applying ordinary soap. Such a repair may last till the defective part can be soldered. Leaks at gasoline taps can generally be cured by screwing up the nut securing the tap plug, or by grinding in the tap with crocus and oil.

If gasoline drips from the feed line, examine connections (A) and if it **drips from the carburetor** it is probably due to the float needle valve failing to seat properly. Gasoline leaks are sometimes difficult to locate.

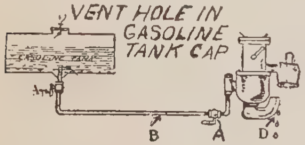


Fig. 1

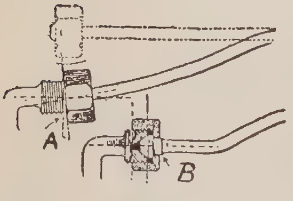


Fig. 1A

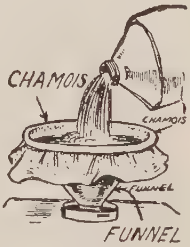


Fig. 2

If gasoline fails to flow to the carburetor, see that (V), Fig. 1, is open. If this is open, then examine the filter screen at the bottom of the tank. If this is open, then remove pipe (B) and blow it out. If this is open, then take the carburetor apart and see if it is clogged up with waste or sediment.

Gasoline feed-pipe connections should have special unions. See Index under "Pipe connections." The threads are very fine and can easily be crossed. Therefore use every precaution not to "cross-thread" when joining a gasoline pipe coupling as at (A) (Fig. 1A). In (B) the threading is straight and correct.

Gasoline rots rubber rapidly and should not be conveyed through a rubber hose, nor should joints be packed with rubber. Shellac or soap may be used when screwing joints together, as it helps to make them tight.

Draining: The lowest point of the gasoline line on a vacuum-feed system is the bottom of the gasoline tank. On a gravity feed system it is at the carburetor. A strainer made of brass wire mesh is usually at the lowest point, and should occasionally be removed and cleaned.

Water in gasoline is indicated generally when the engine runs irregularly and finally stops. This will often prevent starting of the engine. Water is frequently present in gasoline, and, particularly when the tank is low, is liable to get into the pipes and carburetor. The drain cock at the bottom should be opened occasionally to let off the water and sediment.

In cold weather, this water is liable to freeze, preventing the action of the carburetor parts. Ice in the carburetor can be melted only by the application of hot water (or some other non-flaming heat) to the outside of the float chamber.

To prevent water getting into the gasoline and freezing during cold weather, thereby clogging the flow, strain through a chamois.

Gasoline ought to be strained. Many carburetor troubles would be avoided if more care were taken to free gasoline of all dirt before its entrance into the tank, and, later, into the carburetor (Fig. 2).

It is said that **static electricity will be generated** when straining through a funnel and chamois, and a spark is liable to ignite the gasoline. If the funnel is grounded to the tank this cannot occur.

Old gasoline left in the carburetor for some time, when the car is not in use, will lose its strength. If the engine should not start easily, then drain the float chamber.

Stale gasoline: After standing for many days, even in a tight tank, gasoline will become dead and slow to ignite. This is partly due to evaporation, and partly to chemical changes that take place.

A strainer should be on all gasoline tanks or lines, as water and sediments being heavier, always settle at the bottom.

Addresses of carburetor manufacturers, classified under the type of carburetor they manufacture, are given elsewhere; see Index under "Address of carburetor manufacturers." For detailed information catalogs are of value.

Broken gasoline pipe can be temporarily repaired by wrapping with tape.

Another method of repairing a broken gasoline pipe is to scrape the tube near the break and to wind about 1″ of clean copper wire on each side and over the break, and then to solder carefully.

Air leaks cause missing. If the engine persists in missing and this is not due to faulty ignition, then look for air leaks in the inlet manifold. Examine gaskets and see if a crack is in the intake casting—providing the trouble is not in the ignition.

Leaks in the intake pipe gasket are a very common cause for missing at low speeds. This is best detected by letting the engine run at the missing speed. Take a squirt-can full of gasoline and squirt around all the intake-pipe joints. If you detect any difference whatsoever in the running of the engine, there is a leak.

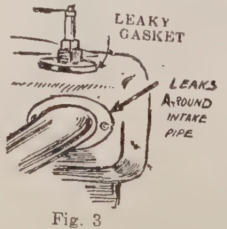


Fig. 3

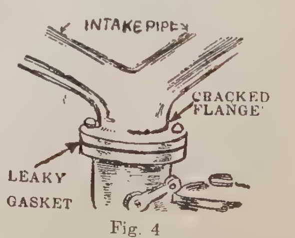


Fig. 4

Cracked flanges (Fig. 4) can be repaired by having them welded by oxy-acetylene process. See Index under "Gaskets," for the kind of gasket to use.

GASOLINE TANK AND GAUGE

The main gasoline tank used on the Studebaker six is shown in Fig. 5. Note the connection to the vacuum tank, also the **gasoline gauge** mechanism. As the tank is filled, the float rises, which causes the bevel gear on the float-rod to turn the rod connected with the gauge needle.

The words "main gasoline tank" apply to the gasoline tank which contains the greater amount of gasoline and is usually suspended at the rear of the car.

The auxiliary gasoline tank is a smaller tank placed on the inside of the dash when the vacuum system is used, as explained farther on.

Gasoline feed pipes are usually made of copper tubing or brass pipe 5/16″ outside diameter and 7/32″ inside diameter.

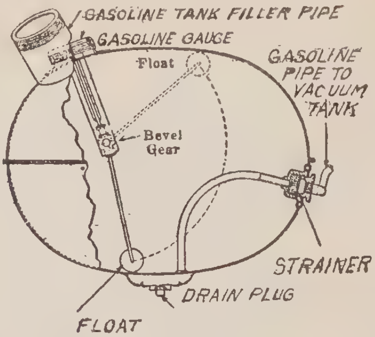


Fig. 5

GASOLINE-TANK SHUT-OFF COCKS

On many cars there is a reserve of gasoline carried in the tank. This reserve is not usually partitioned off. The shut-off cock controls the reserve. An example is the shut-off cock used on the King car.

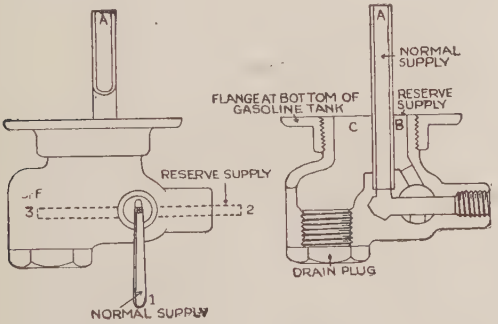


Fig. 5B

Fig. 5C

Figs. 5B, 5C. Gasoline-tank shut-off valve as used on the King car, as an example.

The capacity of the tank is 18 gallons. When the shut-off cock is turned **down** as shown in (1) (Fig. 5B), before the gasoline will flow to the vacuum tank there must be a sufficient amount of gasoline in the tank to run through tube (**A**). Therefore when the gasoline level is below the top of tube (**A**) with the shut-off cock down, the supply of gasoline will not flow to the vacuum tank, although there are two gallons in the tank.

Reserve: By turning the shut-off cock to a horizontal position, as at (2) (Fig. 5**B**), the reserve amount of gasoline is permitted to flow through pipe (**B**) (Fig. 5**C**). This reserve amount is 2 gallons.

To shut off the supply: Turn shut-off cock to position (3) (Fig. 5**B**) and the gasoline will run through opening (**C**).

To drain the tank: Unscrew the drain plug.

There are other similar methods employed on different cars; for example, see page 112 under the heading, "A three-way valve located on the top of the gasoline tank," as used on the Packard.

FUEL FEED METHODS

There are **five methods for feeding gasoline,** some of which are not in use. They are as follows:

1. By **gravity.**
2. By **exhaust pressure.**
3. By **combined gravity and exhaust pressure.**
4. By **forced air pressure.**
5. By **vacuum and gravity.**

The vacuum and gravity method is used most; the air-pressure feed is used by some of the larger cars, and the gravity feed is used on the Ford.

Gravity Feed

A tank is placed above the level of the carburetor so that the gasoline flows from tank to carburetor by gravity (Fig. 6). The tank can be placed at any point on the car, providing it is above the level of the carburetor.

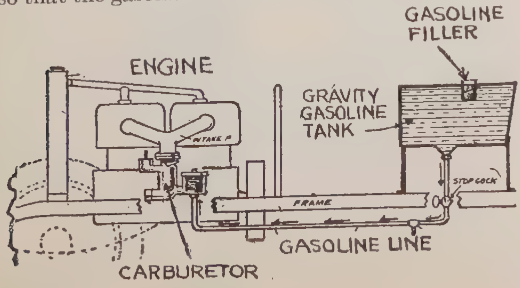


Fig. 6

The disadvantage of this where the tank is not close to the carburetor lies in the fact that when ascending hills, or on the side of an incline, the gasoline may fail to flow through the pipe.

Exhaust-Pressure Feed

With this system (Fig. 7), the tank is placed in the rear. A hand air pump is connected to obtain the initial pressure in the tank. After the engine is started the exhaust gases pass through a check valve to the tank, creating a pressure, which forces the gasoline to the carburetor.

A small pipe is used for the exhaust passage. The pipe being exposed to the air, the gases are cooled and prevent a flame. A check valve prevents the gas passing back, as it can pass in but one direction.

Disadvantage: The pressure is liable to interfere with the proper operation of the float. This system is practically obsolete.

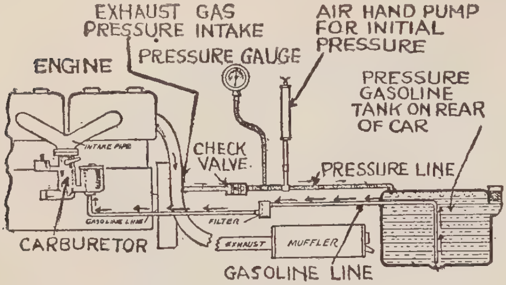


Fig. 7

Gravity and Exhaust-Pressure Feed

Gasoline is forced by exhaust pressure from the tank to an auxiliary tank, placed above the level of the carburetor. The gasoline then flows to the carburetor by gravity. The auxiliary tank is small and is placed close to the carburetor, so as to make sure that the gasoline will always feed (Fig. 8). This system was used in the early days of motoring, but not to any great extent.

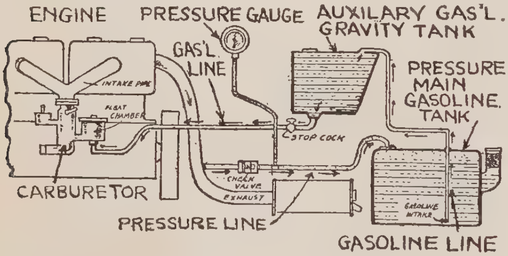


Fig. 8

Air-Pressure Feed

A modern gasoline air-pressure feed is that shown in Fig. 9, which represents the Packard system. A similar method is used on the Cadillac and on the Locomobile.

General principle: The supply of gasoline is carried in the tank at the rear of the frame. The gasoline is supplied from the tank to the carburetor by **air pressure** (at 1½ to 2½ lbs.) provided by an air pump attached to the engine front-end cover and driven by the forward extension of the generator shaft.

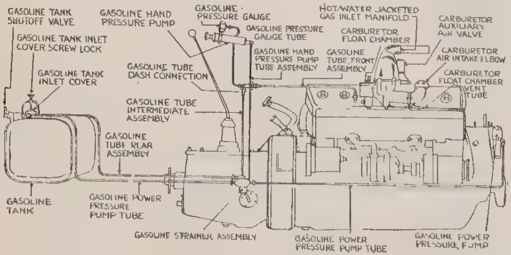

GASOLINE TANK SHUTOFF VALVE
GASOLINE HAND PRESSURE PUMP
GASOLINE PRESSURE GAUGE
HOT-WATER JACKETED GAS INLET MANIFOLD
CARBURETOR AUXILIARY AIR VALVE
GASOLINE TANK INLET COVER SCREW LOCK
GASOLINE PRESSURE GAUGE TUBE
CARBURETOR FLOAT CHAMBER
GASOLINE HAND PRESSURE PUMP TUBE ASSEMBLY
GASOLINE TUBE, FRONT ASSEMBLY
CARBURETOR AIR INTAKE ELBOW
GASOLINE TUBE DASH CONNECTION
GASOLINE TANK INLET COVER
CARBURETOR FLOAT CHAMBER VENT TUBE
GASOLINE TUBE INTERMEDIATE ASSEMBLY
GASOLINE TUBE REAR ASSEMBLY
GASOLINE TANK
GASOLINE POWER PRESSURE PUMP TUBE
GASOLINE STRAINER ASSEMBLY
GASOLINE POWER PRESSURE PUMP TUBE
GASOLINE POWER PRESSURE PUMP

Fig. 9

The carburetor is mounted above and between the cylinder blocks, and receives the heat generated by the engine, which assists in the vaporization of the gasoline.

The gasoline tank is located on the rear of the frame. The capacity of the tank on all models is twenty gallons, including about a three-gallon reserve.

A three-way valve located on the top of the gasoline tank connects with outlet pipes leading to each side of the tank. Turning the valve handle to the right permits the gasoline to be completely drained from the right side of the tank and vice versa. When gasoline has ceased to flow, turn the valve handle to its opposite extreme regardless of the previous running position, in order to obtain the reserve supply. Turning the handle straight up shuts off the gasoline.

Caution: If the gasoline tank has been completely drained and is replenished with less than a five-gallon supply, turn the valve handle to the left, which is the side of the tank which receives the first three to five gallons, otherwise, the gasoline will not flow.

Air pressure for supplying gasoline to the carburetor is furnished by an air pump attached to the crank-case front-end cover, and driven by an eccentric mounted on the generator shaft.

The air is drawn from outside the crank case and forced under pressure to the gasoline tank. To **increase** the pressure, remove the plug at the top of the pump cylinder and unscrew the smaller plug at its base. To **decrease** the pressure, the small plug should be screwed down.

The hand or auxiliary pump on the instrument board provides a means of obtaining initial air pressure before the engine is started, providing the gauge on the dash shows that there is no air pressure in the gasoline tank.

To obtain pressure by hand, unscrew the handle to the left. When the plunger is free, operate the pump until pressure shows on the gauge. Do not pump higher than 2½ lbs. pressure.

Note. When air pressure is used, if the carburetor has a small float, the pressure should not be over 2½ or 3 lbs. With a larger float, the greater area will withstand more variation in pressure.

If the gasoline gauge does not respond to the hand pressure pump, it is probably caused by the tank outlet valve being shut off.

Caution: Having finished operating the pump, push the plunger in, and be sure to lock it in place by screwing the plunger handle to the right.

The plunger leather of the pump should be oiled occasionally with neat's-foot oil. Mineral oils improve the operation of the pump only temporarily, and tend to dry up the leather.

A gasoline pressure gauge on the instrument board is connected directly with the supply line at the gasoline strainer housing. The gauge indicator should show from 1½ to 2½ lbs. pressure when the engine is running.

If the pressure gauge indicates that **the pump is not maintaining the proper pressure** in the tank, proceed as follows:

Inspect the gasoline-tank filler cap, seat, and gasket to make sure that they are in good, clean condition and free from nicks.

Be sure that the filler cap is tightly seated. If the trouble is not found by this method, examine all connections on the air pressure and gasoline supply lines to make sure that there are no leaks. A good method of locating leaks in the air line is to put pressure in the tank and go over the line carefully with soap suds.

If it is determined that all pipes and connections are absolutely air-tight, raise the air pressure by adjusting the pump as described above.

THE STEWART VACUUM GASOLINE SYSTEM[1]

It will be noted in Fig. 1 below that gasoline is fed by gravity to the carburetor in the usual manner, by an auxiliary gasoline tank, which is combined with a vacuum system of drawing the gasoline from the main gasoline tank. In other words, the same gravity principle of feeding gasoline to the carburetor is utilized with the auxiliary or gravity tank placed on the inside of the dash (usually) above and near the carburetor, so that the gasoline will feed to the carburetor at all times, regardless of the angle or position of the car.

The difference in this system is that of drawing the gasoline up to this tank, as the main gasoline tank is below the level of the gravity tank. Instead of air being applied to the gasoline in the main tank to force the gasoline to the gravity tank, it is sucked by a vacuum process through pipe (**D**) to the vacuum chamber (12); thence it flows through trap or flapper valve (6) to the gravity tank, thence to the carburetor.

This vacuum is created by suction at the intake manifold through pipe (**C**), connected at (**N**). (Although the connection of pipe (**C**) is shown in the center of the manifold at (**N**), the usual plan is to connect it near the end of the manifold, as the vacuum is greater at a point closer to one of the cylinders.) We know that a great suction takes place in the intake manifold when pistons are working; this suction is utilized to create the vacuum, as will be explained below.

Principle of Operation

There are two chambers: the upper or vacuum chamber and the lower chamber or gravity feed tank. See Fig. 2.

When there is no gasoline in either chamber, the float and levers (**E**) and (**F**), to which the float is connected, **close** the valve (**B**) which admits air

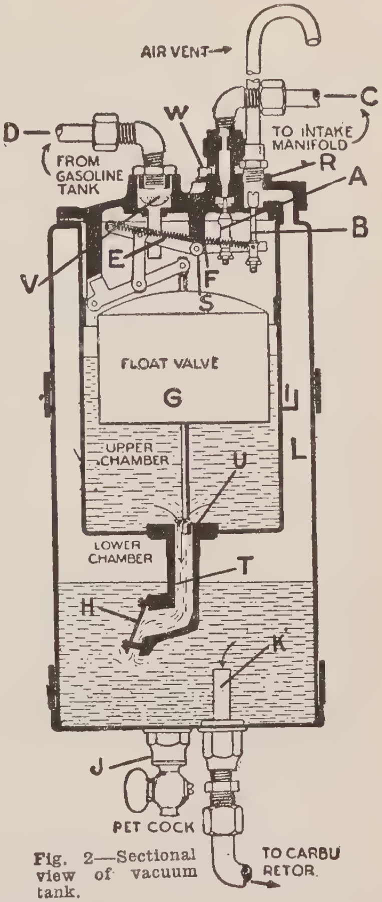


Fig. 2—Sectional view of vacuum tank.

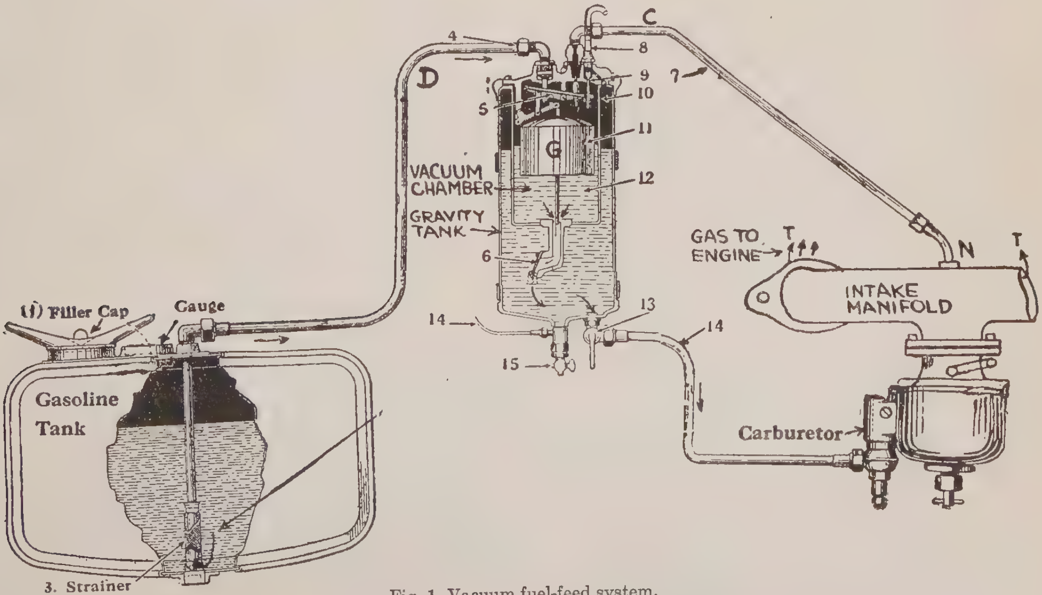


Fig. 1. Vacuum fuel-feed system.

Parts: (4) inlet from gasoline tank (**D**); (5) toggle lever operating valves; (6) flapper valve (**H**) (Fig. 2); (7) suction line to intake manifold; (8) vent for air; (9) vent valve (**B**) (Fig. 2); (10) outer supply chamber; (11) float (**G**); (12) gasoline in float chamber; (13) shut-off valve to carburetor; (14) primer supply pipe; (15) drain valve (**J**) (Fig. 2).

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[1] Another fuel system is the G. G. Fuel System, Zorzi Corporation, 1737 Broadway, New York.

into the vacuum chamber and at the same time opens the valve (A) connected with the suction pipe (C) which is connected with the intake manifold.

If the engine is working (by crank or power), a vacuum is then created in the upper chamber which closes the flapper (H) (by suction), thereby making the upper chamber absolutely air tight, which creates a vacuum and causes the gasoline to be drawn from the main gasoline tank to the vacuum or upper chamber.

As the gasoline enters the upper or vacuum chamber the float rises, and through levers (E) and (F), connected to the float, the valve (A) to the intake manifold is closed, thereby cutting off further suction and at the same time valve (B) is opened, which permits air to enter the vacuum chamber, through the air-vent tube.

Air entering the vacuum chamber causes flapper (H) to open, which permits the gasoline in the vacuum tank to flow into the lower chamber or gravity tank, thereby causing the float to lower as the gasoline flows out.

As the float lowers, the operation of levers (E) and (F) is again brought into action, and valve (A) is again opened and (B) closed, which again causes (H) to close, and the vacuum and suction take place again. It will be noted that the lower chamber is always open to air circulation through the "air-vent tube," otherwise the gasoline would not flow by gravity to the carburetor.

The primer (14) (Fig. 1) is a connection used by some of the car manufacturers for connecting with the hand pump on the dash, for priming the engine to start during cold weather.

Installation

The top of the vacuum tank must be above the level of the gasoline in the main gasoline tank when full, even when the car is going down a steep grade.

The bottom of the vacuum tank must be not less than 3″ above the carburetor; 5/16″ copper pipe is used.

Do not install the tank directly over the generator or wiring terminals, on to which gasoline could leak.

Never tap through a water jacket, if the intake manifold is provided with one. Always tap the intake manifold at a point as close to the intake of one of the cylinders as possible. Be careful in bending tubing. **The air vent** must be placed at as high a point as possible under the hood. The best location for the tank is on the engine side of the dash.

On eight- or twelve-cylinder "V"-type engines with two inlet manifolds, a "Y" connection is made at (C) on top of the tank, with both manifolds tapped.

Care and Repair of Stewart Vacuum-Feed System

Some of the various troubles which might arise and the remedy for them are explained in the following paragraphs.

Vent-Tube Overflow

The air vent allows an atmospheric condition to be maintained in the lower chamber, and also serves to prevent an overflow of gasoline in descending steep grades. If once in a long while a small amount of gasoline escapes no harm will be done, and no adjustment is needed. However, if the vent tube regularly overflows, one of the following conditions may be the cause:

(a) The air hole in the main gasoline tank-filler cap may be too small or may be stopped up. If the hole is too small or if there is no hole at all, the system will not work. Enlarge the hole to ⅛″ diameter, or clean it out.

(b) The vacuum tank may not be installed quite high enough above the carburetor. If the bottom of the tank is not 3 inches above the carburetor, raise the tank.

Gasoline Leakage

If gasoline leaks from the system, except from the vent tube, it can do so only from one of the following causes:

(a) A leak in the outer wall of the tank may exist. If so, soldering up the hole will eliminate trouble.

(b) The carburetor connection in the bottom of the tank may be loose. If so, it should be tightened.

(c) There may be a leak in the tubing leading from (D) or (C) (Fig. 2).

Failure to Feed Gasoline to Carburetor

This condition may be due to causes other than the vacuum system. To test; after flooding the carburetor, or "tickling the carburetor," as it is commonly called, if gasoline runs out of the carburetor float chamber, you may be sure that the vacuum feed is performing its work of feeding the gasoline to the carburetor.

Another test is to take out the inner vacuum tank, leaving only the outer shell. If you fill this shell with gasoline and the engine still refuses to run properly, then the fault clearly lies elsewhere and not with the vacuum system.

If the failure to feed is in the vacuum tank, one of the following may be the cause:

(a) The float (G), which should be air-tight, may have developed a leak, thus filling up the float with gasoline and making it too heavy to rise sufficiently to close the vacuum valve. This allows gasoline to be drawn into the manifold, which in turn will choke down the engine.

(b) The flapper valve may be out of commission.

(c) Manifold connections may be loose, allowing air to be drawn into the manifold.

(d) The gasoline strainer or tubing may be clogged up. Look to this first.

Remedies

(a) **To repair float:** remove top of tank (to which float is attached). Dip the float into a pan of hot water, in order to find out definitely where the leak is. Bubbles will be seen at the point where the leak occurs. Mark this spot.

Next, punch two small holes, one in the top and the other in the bottom of the float, to permit discharge of the gasoline. Then solder up these holes and the leak. Test the float by dipping in hot water. If no bubbles are seen, the float is air-tight.

In soldering the float, be careful not to use more solder than required. Any unnecessary amount of solder will make the float too heavy.

To overcome the condition of a leaky float temporarily until you can reach a garage, remove plug (W) at the top. In some cases the suction of the engine is sufficient to draw gasoline into the tank, even with this plug open, but not enough to cause it to continue to be drawn into the manifold. If, however, you are not able to do this, close up plug (W) with the engine running. This will fill the tank. After running the engine until the tank is full, remove plug (W) until gasoline gives out. Continue repeating these operations until a repair station or garage is reached, when the leaky float can be remedied.

(b) **A small particle of dirt getting under the flapper valve** (H) might prevent it from seating airtight, and thereby render the tank inoperative.

In order to determine whether or not the flapper valve is out of commission, first plug up the air vent; then detach the tubing to the carburetor from the bottom of the tank. Start the engine and apply a finger to this opening. If suction is felt continuously, then it is evident that there is a leak in the connection between the tank and the main gasoline supply, or else the flapper valve is being held off its seat and is letting air into the tank, instead of drawing gasoline.

In many cases this troublesome condition of the flapper valve can be remedied by merely tapping the side of the tank, thus shaking loose the particle of dirt or lint which has clogged the valve. If this does not prove effective, remove the tank cover, as described below. Then lift out the inner tank. The flapper valve will be found screwed into the bottom of this inner tank.

To Fill the Tank

To fill the tank, should it ever become entirely empty: With the engine **throttle closed** and the **spark off**, turn the engine over a few revolutions. This takes less than ten seconds, and will create sufficient vacuum in the tank to fill it.

If the tank has been allowed to stand empty for a considerable time and it does not easily fill when the engine is turned over, this may be caused by **dirt or sediment** being under the flapper valve (H).

Or, perhaps, **the valves are dry.** Removing the plug (W) in the top and squirting a little gasoline into the tank will wash the dirt from this valve, and also wet the valves, and cause the tank to work immediately. This flapper valve sometimes gets a black carbon pitting on it, which may tend to hold it from being sucked tight on its seat. In this case the valve should be scraped with a knife.

To Clean the Tank

Remove the top of tank and take out the inner shell or vacuum chamber. This will give access to the lower chamber from which dust or dirt may be removed. Clean the tank every three months.

To Remove the Top

After taking out screws, run the blade of a knife carefully around the top, between the cover and the body of the tank, so as to separate the gasket without damaging it. The gasket is shellacked.

Auxiliary vacuum pump: On some cars (Hudson), a small hand vacuum pump is provided on the dash. If the vacuum tank should become empty, it would not be necessary to turn the engine over, but merely to operate a pump connected by a check valve to pipe (C), which will create sufficient vacuum to draw gasoline from the main tank.

RELATION OF THE INLET MANIFOLD TO CARBURETION

Engine manufacturers endeavor to make **a manifold which will have the least number of curves,** and be as straight and as short a path for the gas to travel through as possible.

The **ideal inlet manifold** is one in which no unnecessary resistance is offered to the flow of the mixture.

An inlet manifold for a six-cylinder engine which will deliver an equal mixture to each cylinder has been a problem with manufacturers. If the distance is too great, the gas tends to condense.

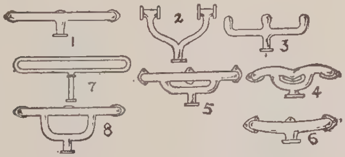

Fig. 3. Types of inlet manifolds.

The inlet manifold in use today is smaller in diameter than formerly, owing to the poor grade of gasoline in use. The fuel is harder to "break up" and will not vaporize readily. It condenses and clings to the inner walls of the manifold. By having smaller intake manifolds, the mixture is sucked through at a greater speed, which in a way prevents this condensation.

With too large an intake, using the present low-grade fuel, after a hard pull, the engine tends to "choke" and miss until it runs a short distance on a closed throttle.

Water jacketed or exhaust-heated manifolds are now the approved method. On many engines the intake manifold is cast right into the cylinder.

FITTING CARBURETOR TO MANIFOLD

Carburetors are **attached to the inlet manifolds,** either with a horizontal connection (Fig. 4) or a vertical connection (Fig. 5).

When fitting a carburetor, a gasket must be placed between the carburetor flange and the flange on the intake pipe, and it is very important that an air leak does not occur, otherwise the mixture is changed.

The best form of gasket is copper, interlined with asbestos. Multibestos or similar material can also

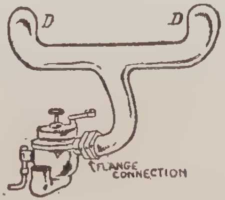

Fig. 4.—Carburetor Attached Horizontally.

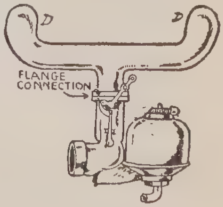

Fig. 5.—A Carburetor Attached to the Intake Manifold Vertically

be used, coated on each side with shellac. Leather could also be used here, but would not answer elsewhere, because it would get too hot. If material is used which has a rough edge, it is important to watch that none of it gets into the carburetor pipe.

At the point (**D**) where the inlet manifold covers the inlet ports, a copper gasket must be used and drawn tight to prevent air leakage. Be sure there are no air leaks where the carburetor joins the intake pipe, and where the intake pipe connects to the engine.

The air inlet of the carburetor, if exposed to dust and dirt, should be placed so that dust may not be drawn in.

The inlet manifold, connecting the carburetor to the inlet-valve port chamber, should present no resistance to the flow of the mixture. Sharp bends or turns will make it harder for the mixture to pass.

When fitting a carburetor, be sure there is no vibration. If there is, the result will probably be a broken flange connection. If there is vibration, place a small iron hanger from a nut on the engine frame to the carburetor, to steady it and also to take the strain off the intake pipe.

COMPRESSION RATIO

Compression ratio is defined as the volume of gas in a cylinder when the inlet valve has just closed, divided by the volume of gas in the cylinder after the compression stroke has been completed. Consider the engine as shown in Fig. 6: the inlet valve has just closed and there is one cubic foot of gas in the cylinder.

In Fig. 7, the compression stroke has been completed and the gas has been compressed until its volume is only ¼ of a cubic foot (the volume of the combustion space). The compression ratio is then 4, because **1 cu. ft.÷¼ cu. ft.=4.**

The final compression pressure (just before ignition takes place) in an automobile engine depends on two main things, namely, **the compression ratio and the pressure of the gas when the inlet valve has just closed,** as shown in Fig. 6. (It is obvious that the greater the pressure in Fig. 6, the greater the pressure that will result in Fig. 7.) The pressure in Fig. 6 is equal to the pressure of the atmosphere; therefore the lower the atmospheric pressure, the lower will be the compression pressure. A further consideration is that the **explosion pressure** (immediately after ignition), which gives the engine its power, depends on the **compression pressure before ignition.**

Conclusion: A low atmospheric pressure will cause a low compression pressure, which in turn will cause a low explosion pressure, and therefore the power of the engine will be reduced.

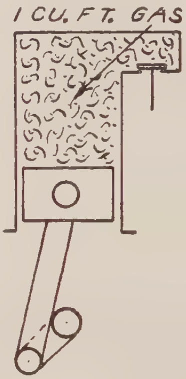

Fig. 6

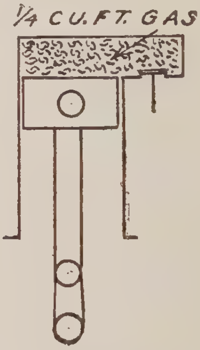

Fig. 7

Fig. 6. Inlet valve has just closed; Fig. 7. Compression stroke completed; the compression ratio is 4 to 1.

EFFECT OF ALTITUDE ON CARBURETION

Atmospheric conditions have much to do with the action of a carburetor. For example, an engine which would run satisfactorily at a low altitude, say at sea level, would lack power and would overheat at a high level, as, for instance, at Denver, Colo., where the elevation above sea level is approximately 5,280 feet, or one mile high.

This is due to the fact that at sea level, the air exerts a pressure of approximately 15 lbs. per square inch. This means that a column of air one inch square in cross-section and 50 miles high weighs approximately 15 lbs. It has been fairly well established that atmosphere blankets the earth for a depth of about 50 miles.

Therefore if we go higher, we begin to shorten this column of air responsible for this pressure; we therefore have not so much weight of air above us, and consequently the pressure corresponding to the reduced weight is also reduced.

Thus, if, at Denver, the height above sea level is 1 mile, there would be only 49 miles depth of air in the column to establish this pressure, and a column of air 49 miles high weighs less than a column 50 miles high, so that we find the atmospheric pressure at Denver is just a trifle over 12 pounds per square inch. As we go still higher, the pressure begins to fall off.

The drop in pressure amounts to approximately one half-pound per square inch for each rise of 1,000 feet. This, however, is not strictly accurate, nor is there a distinct and invariable relationship between the two, for it depends upon barometric variations, the amount of moisture in the air, etc., which, as we know, will cause the barometer to vary even though it remain in one place.

This reduction of air pressure as a result of increasing altitude has an effect on the power of the engine.

First it affects the compression, reducing it at a rate corresponding to the reduction in atmospheric pressure, as explained above. Thus at sea level, an average Ford engine would have a compression pressure of 64 lbs. per square inch, as measured by a pressure gauge, and after ignition, the explosion pressure would be 256 lbs. per square inch; while in Denver, owing to the low atmospheric pressure, the compression pressure would be only 48.5 lbs. per square inch, and after ignition, the explosion pressure would rise to only 194 lbs. per square inch. It is the latter pressure which determines the power of the engine, and since it has decreased from 256 lbs. per square inch to 194 lbs. per square inch, the engine will deliver much less power.

Second, we know that at sea level the composition of the air by weight is approximately 25 parts of oxygen to 75 parts of nitrogen, and the combination is a mechanical mixture, not a chemical one.

It is the oxygen that we rely upon to support combustion of the gasoline. Thus if the oxygen is reduced in value to that of the fuel, the mixture is affected.

The higher we go, the less the percentage of oxygen in the air. Therefore, unless the carburetor is readjusted to suit the changed conditions, we get an over-rich mixture, slow combustion, and overheating.

The point, then, is to open up the air intake, giving more air, rather than to cut down on the needle valve of the carburetor, reducing the gasoline supply.

Where carburetors are fitted with adjustable air valves, then the air-valve adjustment should be opened wider for altitude work.

Where carburetors have no air adjustment, use smaller jets for altitude work.

At the top of Pike's Peak, which rises to an altitude of 14,000 feet above sea level, the atmospheric pressure of the air is only 8.5 lbs. per square inch; therefore the compression pressure will drop to 30 lbs. per square inch (as measured by a gauge) and the explosion pressure will be only 120 lbs. per square inch, thus causing a very great loss of power.

Furthermore, water boils at a lower degree (Fahrenheit) at higher altitudes, for example at 14,000 feet above sea level water boils at 185° F., owing to less atmospheric pressure, whereas at sea level, water boils at 212° F.

Altitude	Atmospheric Pressure	Boiling Point of Water	Compression Pressure (as measured by a Gauge) on Engine with Compression Ratio of 3.6
Sea Level	15 lbs.	212° F.	64 lbs.
1,000 feet	14.1 lbs.	210° F.	59.5 lbs.
2,000 feet	13.6 lbs.	208° F.	57 lbs.
3,000 feet	13.1 lbs.	206° F.	55.4 lbs.
4,000 feet	12.5 lbs.	204° F.	51.2 lbs.
5,000 feet	12.3 lbs.	203° F.	49 lbs.
6,000 feet	11.6 lbs.	201° F.	46.5 lbs.
7,000 feet	11.2 lbs.	199° F.	44.3 lbs.
8,000 feet	10.8 lbs.	197° F.	42.1 lbs.
9,000 feet	10.4 lbs.	195° F.	40 lbs.
10,000 feet	10 lbs.	193° F.	37.9 lbs.
14,000 feet	8.5 lbs.	185° F.	30 lbs.

Note. The Ford engine has a compression ratio of 3.6.

INSTRUCTION No. 14

CARBURETOR ADJUSTMENTS: Mixture; Troubles and Remedies; Float Adjustments; Tools for Repairing Carburetors; Examples of Principle and Adjustments of Leading Carburetors

The principle of carburetion is treated in instruction No. 13. It will be advisable to start at the beginning of the subject and master the fundamental principles before taking up the subject of adjustments.

Kerosene carburetors are treated under the subject of "Tractors." See Index.

The first and most important thing to learn about any carburetor is to let it alone as long as it is working properly. Never tamper with the carburetor until you are quite sure that it is at fault.

There are two essentials necessary before an engine will run: first, gasoline; second, a spark. The gasoline must reach the inside of the cylinders and a hot spark must be there at the proper time to ignite the gas. If you have both, something is bound to happen, even though it is but a single explosion.

Next, remember that even though you have a spark and gasoline, the engine will not run properly if the gas does not enter the cylinder at the right time and if it is not in a proper gaseous form, or a correct "mixture." See "Digest of Troubles" for various reasons why an engine will not start, etc.

MIXTURE

At low speeds the mixture should be richer than at high. At low speeds more heat is lost to the cylinder walls, more compression is lost by leakage, and the combustion can therefore be slower, thus sustaining the pressure. **At high speeds** the compression is higher, due to less leakage and less loss of heat. A lean and highly compressed charge burns faster and hence gives better pressures and fuel economy than a richer one.

The quantity of mixture an engine will take, varies greatly with the speed and pull. **At slow speeds,** the volume, at carburetor pressure, is equal to the cubic content of the cylinders multiplied by the number of intake strokes.

At high speeds of one thousand revolutions or over, the quantity may drop to less than one-half the amount, depending on the design of the valves, inlet piping, and passages. This reacts upon the compression, and hence on the mixture desired for best results.

The design of the engine has a bearing on the carburetor design, which explains the well-known but seemingly mysterious fact that a carburetor giving good results on one engine sometimes fails to maintain its reputation when applied to one of different design. **The system of ignition** used also has a marked influence on the proper working of an engine, as a hot spark is most essential.

Proportions of air and gasoline. Different mixtures of air and gasoline are needed for different engine requirements. It is no longer the belief that a uniform mixture is correct for all speeds. The new rule is, that the amount of gasoline fed into the air must be changed according to demands, and that if a 12 to 1, or rich, mixture is best for quick acceleration, a 15 to 1, or leaner, mixture may be best for pulling with the throttle wide open, and a 17 to 1, or still leaner, mixture is best for particularly high speed work. Therefore, a varying mixture must be supplied.

Atmospheric conditions have much to do with the action of a carburetor. An engine seems to run better at night. Taking an engine from sea level to an altitude of 10,000 feet involves using air in the engine cylinders at atmospheric pressures ranging from 14.7 lbs. down to 10.1 lbs. to the square inch. In other words, the higher the altitude, the lighter is the air, and thus more air for the carburetor is required.

To Test the Mixture

If there are doubts in the mind of the operator as to whether the mixture is too rich, one method of ascertaining **the correct proportion of air and gasoline** is to shut off the fuel at the tank and open the throttle.

If the mixture passing into the cylinder is too rich, the engine speed will increase as the level of the gasoline in the float chamber is lowered, since this operation weakens the mixture considerably.

If the mixture is thought to be too weak, the float chamber can be flooded while the engine is running, and if this causes the engine to speed up, it may be taken as an indication that the mixture is not rich enough.

The proportionate amount of gasoline to air is essential. The novice usually gives the carburetor too much gasoline by opening the adjustment valve too wide, thereby causing "too rich a mixture." Too much gasoline will not run the engine any better than not enough. It must be remembered that only a very little gasoline is required in proportion to the air needed.

Use air. It is advisable to run the engine with as much air as possible, which means a "lean" mixture. This not only means economy of gasoline, but prevents soot deposit and pitted valves (providing good lubricating oil is used).

Of course, when first starting, or when cold, more gasoline is absolutely necessary, but as soon as the engine warms up, cut down on the gasoline and run on more air. Most carburetors, now-a-days, are fitted with air regulators and heated intake manifolds for this purpose.

An engine will run on less gasoline, and more air, the warmer it gets. This accounts for the necessity of the air adjustment.

Rich and Lean Mixture

A rich mixture is one in which the proportion of gasoline abnormally exceeds the amount of air. It may be due to faulty adjustment of the gasoline needle valve, float, or air valve. The expression, "mixture too rich" means that too much gasoline is present in proportion to air, or, technically, that there is insufficient oxygen to support its combustion.

An over-rich mixture will cause an engine to overheat and thereby give rise to a number of troubles, such as preignition, accumulations of carbon on the pistons and cylinder heads, steaming water in the radiator, and loss of power and "loping" or choking up on slow speeds.

The cause of mixture being too rich may be: Too much gasoline at needle valve; punctured float; float valve not working properly, owing to bent needle, or presence of foreign matter in valve seat; too much priming; primary air passage clogged or partially obstructed; air valve not open enough, spring too strong or air opening choked.

A mixture is poor or lean when it contains too much air and not enough gasoline, a condition often due to a faulty adjustment of the needle or air-valve, float, a leak in the inlet pipe, the spray nozzle, float valve, or feed pipe partly clogged, or water in the gasoline.

A poor mixture will make the engine miss when running idle at slow speeds, and at high speeds it will not only cause misfiring, but the missing will be accompanied by coughing and "popping" in the carburetor. Both this and explosions in the muffler may also occur.

The cause of mixture being too weak may be: Too much air, not enough gasoline; carburetor passages or jet clogged; throttle valve out of adjustment; insufficient flow of gasoline; tank valve closed; vent hole in gasoline tank cap stopped up; break in gasoline supply; bad gasoline, originally, or from standing; water in gasoline; carburetor cold; gasoline cold and unvaporized; gasoline supply exhausted. The ignition system not working properly will also act in a manner similar to too lean a carburetor mixture.

Smoke Indications of Carburetor Mixture

If the engine is fed too much gasoline, black smoke, smelling of raw gasoline, will usually be in evidence, issuing from the exhaust. Care should be taken to distinguish this from the excess of heavy blue smoke which is indicative of too much engine lubrication.

Whenever any considerable quantity of smoke of either color comes from the exhaust, the engine may miss explosions through fouled spark plugs.

If the mixture is too rich, the engine will have a tendency to slow up and "choke" or "load up" when the throttle is opened wide, and will run at a higher speed when it is partially closed.

Another indication of the mixture being too rich will be shown in its speeding up perceptibly, if the auxiliary air valve of the carburetor is held open, or additional air is admitted in any way between the carburetor and the cylinders.

Such being the case, the exhaust gases, if ignited by holding a piece of burning paper near the end of the exhaust pipe, will burn with a large red flame, similar to that of a bunsen burner when the air is mostly cut off.

Loping. Another indication of too rich a mixture is that when "idling," the engine will run in a loping manner, as if actuated by a governor; more air and less gasoline is needed.

"Loading up" when running slow or idling is due to the fact that the air comes into the carburetor so slowly that the gasoline particles are not broken up fine enough, and condensation takes place. Thus the gasoline is taken in in a more or less liquid form, and combustion is very poor. That is one reason why as much heat as possible should be applied to the air intake of the carburetor. Also, the engine should not be allowed to tick over slowly for any length of time when the car is standing idle. It not only wastes fuel, but the manifold will load up with raw fuel, and acceleration will be anything but good when you attempt to get under way.

By opening the relief cocks in the cylinder heads (if provided), while the engine is running, one can judge fairly well, by the color of the flame, when the mixture is correct. At each explosion a jet of flame will shoot out of the cylinder through this relief cock.

If the mixture is too poor (too much air for the gasoline), the flame will be light yellow.

If the mixture is too rich (not enough air for the gasoline), the flame will be red and smoky. Black smoke will also come out of the muffler, smelling of raw gasoline.

If the mixture is correct, the flame will be light blue or purple, and hardly visible.

Note. This test is not absolutely reliable, because, when the relief cock is open, air is drawn into cylinder which tends to change the mixture.

"Back Firing" or "Popping" in the Carburetor

Back firing. There seems to be much confusion in the use of the terms "back kick" and "back fire," the latter being very often used to describe what happens when, in starting an engine, it suddenly reverses its direction of rotation to give a "back kick."

Generally speaking, "back-firing" is caused by a weak mixture which burns so slowly that the flame continues until the opening of the admission valve again, when it ignites the incoming charge in the intake pipe and shoots back to the carburetor. While an over-rich mixture will also burn slowly, it rarely ever will cause back-firing.

Another cause of back-firing is, of course, the faulty timing of the valves, or, in fact, a badly leaking valve. As a general rule, back firing is due to one or more of the following causes: (1) very slow explosion or weak mixture; (2) very late explosion; (3) a spark occurring during the intake stroke; (4) the intake valve being partially open during the power stroke; (5) premature ignition.

Slow combustion is caused by a lean mixture; **late combustion** is caused by a weak or retarded spark. Nos. 1 and 2 are the usual causes, while Nos. 3 and 4 happen infrequently.

Back-kicking is usually caused by preignition in starting the engine, which is due usually, as is well known, to too much "advance" in the spark timing.

"Popping back" or "spitting" in the carburetor is quite a common occurrence with carburetors when first starting the engine on a cold day. But after the engine has been run for a brief period it will become warmed up and the gasoline will begin to vaporize properly and run without popping back.

If the "popping back" continues, then the mixture is too weak and more gasoline is required. By giving the auxiliary air-valve spring a slight increase of tension, or by opening the gasoline needle valve a notch or so, or by closing the "choker," or closing the "damper" at the air intake, more gasoline will be supplied to the carburetor until the popping stops, which it will probably do when the engine is warmed up.

Do not use the "choker" any more than absolutely necessary. It permits raw gasoline to be drawn into the engine, a part of which passes to the crank case and thins the lubricating oil.

Never run an engine in a closed garage, because carbon monoxide, a deadly poisonous gas, is present in the exhaust of gasoline engines. Too rich a mixture increases the amount of carbon monoxide given off.

Carburetion during Cool Weather

Since, at the present day, low-gravity gasoline is being used, the engine will have a tendency to miss explosion and run in jerks or uneven explosions, especially when starting.

This is due, principally, to **insufficient heat** properly to vaporize the gasoline to prevent condensation. After the engine becomes thoroughly warmed up, the "missing" usually disappears. When the weather is warm the engine starts easier, because gasoline will vaporize more readily and is easier ignited. Therefore during cool weather three things are essential: a good **hot spark,** a **quick method of heating,** and a **choker** or primer for enriching the mixture to start on.

For starting. There are different methods employed to inject a rich mixture into the cylinder in order to start the engine at all on a cold day. The common method is to close the main air intake, which causes raw gasoline to be drawn into the cylinder, which would be termed "choking" the air supply. After the engine is started, it is then only a matter of running the engine until warm enough to vaporize the gasoline, at the same time gradually opening the choke or air valve, until the regular amount of air is being used.

There is a disadvantage, however, in priming an engine, and that is, the raw gasoline drawn into a cool cylinder is not all utilized for combustion, but part of it forms carbon, due to lack of oxygen, which is not being supplied, as the air is choked. The result is a deposit of carbon on the head of the piston, in the combustion chamber, and on the spark plug. Therefore the air should be supplied as quickly as possible. The problem is, then, to heat the gasoline as quickly as possible, so that vapor and air are used instead of raw gasoline.

The "choker" or some method of supplying a richer mixture, however, is usually necessary for starting. If the choker principle is used, it is closed only until the engine starts, then gradually opened. In fact, by using an exhaust-heated intake manifold to heat the mixture, and also drawing warm air through the air passage of the carburetor, the amount of raw gasoline injected into the cylinders will be considerably less than if it is not heated. Therefore this system will provide a quicker vaporizing or heating of the mixture and a saving of fuel, with less carbon deposit in cylinders.

Additional Pointers on Cold-Weather Starting

Don't expect the engine to warm up in a minute any more than you expect a kettle to boil as soon as it is set on the stove. It takes time to heat.

Take into consideration the fact that cold solidifies the lubricant in the transmission, rear axle, and other parts of the car. Therefore it requires greater energy on the part of the self-starter to revolve the engine. If the clutch is in, when starting, and gears are in neutral, the transmission counter-shaft gears are directly in this oil and are revolved when cranking. After a car has been standing over night in a cold garage or sufficiently long at the curb to become thoroughly chilled, **throw out the clutch** when cranking. This eliminates the drag of the transmission gears plowing through the solidified grease.

A good hot spark is important, especially in winter. Be particular to see that the battery is always charged. A quick method of starting should be provided in order to save current.

CARBURETOR ADJUSTMENTS IN GENERAL

The parts to adjust in the carburetor depend upon the type of carburetor. This subject is therefore best treated by giving examples of carburetors of different types, such as the air-valve type, metering-pin type, plain-tube type, etc.

Carburetors are usually adjusted to the best advantage when the engine has been run and all parts are warmed up. If a carburetor is adjusted when the engine is cold, it will be noticed that it will need readjusting when warm, that is, in order to get a perfect adjustment.

When carburetors are adjusted when warm, sometimes, especially on a cold day, the engine will not hit just right when first starting; it will miss and not run even or smooth until it has run a few moments and is heated up; then it runs satisfactorily.

Another point to remember is to be sure the ignition is right and you have a good hot spark, and the spark plug gaps set about .025″. **If too close,** the engine will operate unevenly at idling speeds and miss at higher speeds; **if too wide,** it will miss when accelerating at very low speeds or hard pulls. A weak spark causes late combustion. (See Index for "Adjusting spark-plug gaps.") Also remember, that if trouble, lack of power, etc., develops with the engine missing, it is well to be sure that the trouble is in the carburetor and not due to other troubles. See "Digest of Troubles," for suggestions of how to diagnose troubles.

The best way to adjust a carburetor is to arrange so that the engine may be run loaded while the adjustment is being made. One way to do this is to adjust the carburetor while the car is in motion on the road.

To test the carburetor for adjustment, run throttled down for two blocks. When there is a clear space ahead, suddenly press the accelerator pedal down. The engine should pick up smoothly, to as high speed as you care to run at. If the engine chokes, stalls, misses or labors, or backfires at the carburetor or at the muffler explosions, it shows the carburetor is out of adjustment.

Adjusting the Air-Valve Type of Carburetor

The three principal parts of a carburetor used for making adjustments on the air-valve type are: the **auxiliary air valve,** the **gasoline needle valve,** and the **float needle valve.**

For the average carburetor, having an "auxiliary air valve" and a "needle-valve" adjustment, the following rule for adjusting will apply.

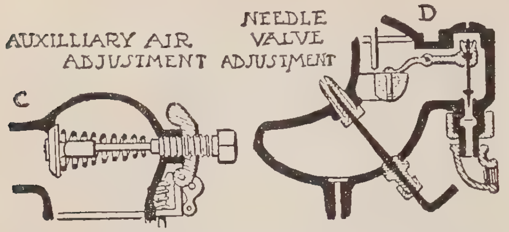

Fig. 1. Showing principal parts of an air-valve type carburetor for adjustments.

First, run the engine at what will be nearly its maximum speed in ordinary use, with the throttle open considerably and the spark rather late. This speed, of course, will be considerably less than the maximum speed of the engine when running idle.

Second, turn the main gasoline needle-valve adjustment, until the mixture is so weak that there is popping in the carburetor.

Third, note this position and then turn this adjustment until so much gas is fed that the engine chokes and threatens to stop.

Fourth, set the adjustment half-way between these two points, which will be very near the correct position. Turn the adjustment slightly in one direction and then in the other until the point is found where the engine seems to run the fastest and smoothest.

Fifth, gently and gradually cover the auxiliary air inlet of the carburetor by placing the hands partly over the valve, if necessary, in order partially to exclude the air. If the engine slows down, the spring should be weakened, since not enough air is allowed to enter the carburetor.

Sixth, next try opening the auxiliary air inlet slowly and gradually by pushing the poppet off its seat with the finger or the end of a pencil. If the engine speeds up, there was not enough air and the spring should be loosened, while if it slows down, the mixture is correct or a little too lean, according to the degree to which the speed is affected. If it is found to be too lean, the spring needs tightening.

Seventh, after the auxiliary air inlet has been adjusted, open the throttle again and adjust at high speed, as this adjustment may now require to be altered.

In the air-valve spring lies the chief difficulty in making carburetor adjustments, if the carburetor is provided with an automatic auxiliary air valve. This spring should be of such length and of such gauge wire, diameter, and number of convolutions as to provide the requisite progressively increasing resistance to opening, while at the same time exerting little or no pressure upon the valve when it is against its seat.

Adjustment: The needle valve should be set for slowest running with the air valve held lightly against its seat, and then the spring adjustment should be backed off until the slightest further increase in throttle opening causes the valve to leave its seat.

From this point on the only proper adjustment for the air valve becomes a series of tests for spring strength without alterations being made in its normal length; that is, with the adjustment backed off in accordance with the instruction just given. If the spring tension with increased throttle openings is too light, and "spitting back" in the carburetor continues in spite of the increased opening of the gasoline needle-valve adjustment, it is a pretty sure indication that the air-valve spring is too weak and that a stronger one should be obtained from the factory. These can usually be obtained in several sizes or degrees of tension to suit varying engine and climatic conditions.

Too strong a tension on the auxiliary air-valve spring will result in too much gasoline and not enough air (too rich a mixture), because the valve will be more difficult to open by suction. **Too weak a spring tension** will give too much air or too lean a mixture.

When adjusting a carburetor on a "V"-type engine, a good plan is to adjust each block of cylinders separately.

TO OBTAIN A SLOW, EVEN PULL OF ENGINE WITHOUT MISSING

Factors which, in addition to proper carburetor adjustment, assist an engine in pulling slowly and firing regularly at low speeds are:

1. **Good compression,** which includes proper clearance of pistons, good piston rings, and no air leaks at the inlet manifold, carburetor gaskets, valve caps, or spark plugs, etc. If there is an air leak in one cylinder it will affect the other cylinders.
2. **Proper valve clearance, properly seated valves, and correct valve timing** are very important.
3. **Proper ignition timing**—not too far advanced; when running slow, retard the spark.
4. **Interrupter points should be set correctly** with a clear, flat surface at the points.
5. **Be sure there is a good hot ignition spark** which will fire a charge at a wide-open throttle and also at low speed. A defective coil, condenser or resistance unit will produce a spark, but not one of sufficient volume to ignite the gas properly. See Index for these subjects, including how to test a fully charged battery.
6. **Properly set spark-plug gaps.** About .025″ is the average gap. Good spark plugs are also important.
7. **Cooling water** must be at least 90° F.; 140° F. is better.

These details are essential to secure a flexible and smooth-running engine.

Indication of Correct Carburetor Adjustment

1. Run the engine until warmed up.
2. Close the throttle with spark between half advance and fully retarded position. The engine should then run evenly.
3. The car should run 6 to 7 m. p. h. smoothly on high gear.
4. Run one-quarter to one-half mile at 12 to 13 m. p. h. The engine should run evenly.
5. With the car running 7 to 8 m. p. h., open the throttle wide suddenly. The car should accelerate smoothly.

Indications of Incorrect Adjustment

The following indicate a lean mixture:

1. The engine starts hard.
2. The engine backfires through the carburetor when opening the throttle suddenly.
3. The engine refuses to idle.

The following indicate a rich mixture:

1. Spark plugs foul quickly.
2. Exhaust gas causes one's eyes to burn.
3. Black smoke issues from the muffler.
4. Engine operation is uneven, causing "loading up" or "loping," as previously explained. On a Ford, a rich mixture will cause the rear axle to have an uneven hum which is distinctly heard at 13 m.p.h.

POINTERS ON GOOD CARBURETION[1]

Good ignition, good compression and good spark plugs are necessary for perfect carburetor performance.

Valve stem guides: When the carburetor is properly installed and the engine refuses to idle, look for defective guides. To locate these defects, squirt gasoline from an oil can at the bottom of the guides while the engine is running. The tendency of the gasoline is to travel upwards through the loose guide, and each cylinder will begin firing as the gasoline takes the place of air which was previously passing through the guide.

Remedy: New valves should be installed or the valve guides should be bushed. A great deal of imaginary carburetor trouble can be traced to valve springs being weakened and to unequal tension having developed.

Air leaks in intake manifold: When the engine refuses to idle, test for air leaks, by removing the hot-air tubing from the intake and with a squirt-can apply gasoline freely around the manifold connections. If an air leak exists the engine will either speed up or choke down entirely. Air leaks are often responsible for poor mileage, loss of power, and over-heating trouble.

The cause of an engine galloping is found in unequal explosion in the cylinders, caused by leaking valves and pistons, or by leakage past the intake guides. It may also be due to improper carburetion, allowing some of the cylinders to be fed liquid gasoline. The spark-plug points should be the same distance apart; likewise there should be no partial short circuit anywhere in the distributor wiring, and all brush segments in the distributor should be cleaned so that the brush may make equal contact with all of them.

Popping back in the carburetor usually indicates a weak mixture, not enough gas; it may also indicate a sticking valve, or possibly a leaky intake valve which might be due to lack of clearance between the stem and push rod. It could also be due to improperly timed ignition or to short circuit.

Exploding of the gases in the muffler, caused by an intermittent spark, generally is due to lack of adjustment of the breaker points, to sticking of the breaker mechanism, to a loose or badly worn distributor brush, or to loose or short-circuited wires or connections.

The proper spacing of spark plugs is very essential. There are very few motors that should have a gap set closer than .025″.

If gaps are set too close, the engine will not idle properly, as there will be a loping at low throttle. The action is something similar to too rich a mixture. Under these conditions the results will be the same with either a lean or rich mixture.

If spark-plug gaps are set too wide, the engine will have a tendency to cut out at high speed. To ascertain if it is due to the carburetor mixture, enrich the mixture by closing the damper, suddenly accelerate the engine, then open the damper for the leanest mixture, and again accelerate the engine. If the same condition exists with both the "rich mixture" and the "lean mixture" test, you will know that it is not carburetor trouble, as both rich and lean mixtures have been encountered by these operations

If spark-plug gaps are set too close, it will cause the car to jerk at low throttle. The same condition will occur if there is a weak spark, a safety gap in the magneto set too close, or an exposed wire, which will cause the spark to jump across.

If the engine runs smooth on the level but misses on a grade or under extreme pulling conditions, it is an indication of ignition trouble, which is likely to be located in the coil or magneto, due to a defective condenser, or to a punctured armature or coil winding. This could also be traced to an improper mixture.

To determine whether the trouble is ignition or carburetion, release the clutch when missing occurs, leaving the throttle wide open. If the engine speeds up instantly and does not miss, it is ignition trouble. If the engine does not speed up readily and continues to miss, it indicates an improper mixture.

Poor compression is another cause of trouble which is often blamed on the carburetor and shows up more at low engine speeds. It will cause the car to jerk at speeds below fifteen miles an hour and make it impossible to get good idling with any mixture. The cylinders with poor compression will not draw in as much mixture as those with good compression. It will force out on the compression stroke a portion of the mixture taken in on the suction stroke. This trouble is caused by valves not seating properly, valve tappets set too high, or poorly fitting pistons or rings.

To test this out, see if the engine will rock on all cylinders by using the starting crank. This should always be tested before making a carburetor installation.

To "rock" means to have a good compression, which offers resistance to the piston when it is going up on compression stroke.

If the engine heats up excessively, look for a late spark or poor water circulation. If the magneto or distributor is set late, the engine will heat and will also cause a power loss, and you will be unable to get a spark knock with spark advance on a hard pull. Overheating could also be caused by an air leak or too lean a mixture.

When the engine backfires, it is caused by too lean a mixture. If it backfires continually and you are unable to overcome it by adjustment of the carburetor, you will know that a valve is sticking open. Exhaust valves closing too early will also cause the motor to heat.

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[1] From instruction on **Master Carburetor.**

The impression is prevalent that engine knocks are caused by a poor mixture. This is in fact very rarely the cause, as in the case of overheating, caused by a very lean mixture. When the engine knocks, look for carbon deposit, the spark being too far advanced, loose pistons causing a slap, loose bearings or wrist pins. Do not lay it on the carburetor.

Lubrication: To obtain the greatest possible mileage from an engine it is particularly essential to get the full expansion forces of the gases exploding in the combustion chamber. This is possible only when the best grade of lubricating oil is used. The perfect lubrication of an engine means considerably more than the mere elimination of friction between the moving parts.

The oil should form a perfect seal between the piston and the piston rings and the cylinder walls. This seal is all important in the saving of fuel, for it is very evident that if only a small fraction of the pressure is lost, a corresponding amount of fuel must be used to enable the engine to do the same amount of work. The fuel passing by the rings into the crank case will eventually dilute the oil to such an extent that it will be entirely robbed of its lubricating value. It is therefore essential to replace this oil with a fresh supply at least every two thousand miles.

When vacuum systems are used, there are occasional instances where trouble is experienced by gasoline being drawn direct from the vacuum tank to the intake manifold, causing the engine to load badly. This is due to a leaky check valve in the vacuum system caused either by dirt or a punctured float. The result is that the vacuum tank fills, permitting gasoline to be drawn through the vacuum tube direct into the manifold. To determine if this trouble exists loosen the vacuum tube connection at the manifold; when the engine starts loading, draw the pipe out of connection about one-eighth of an inch while the engine is running. If the valve leaks, you will notice gas being drawn through the tube. If there is an air leak existing at the vacuum-tank connection, the tank will not supply enough fuel to the carburetor under heavy pulling conditions.

In making carburetor installations it is often necessary to use elbow fittings, which will necessitate tapping the flange for vacuum connections. In such cases do not tap the intake manifold too close to the outlet of the carburetor throttle, as this will reduce the vacuum in the manifold when the throttle is suddenly opened to such an extent as to interfere with the proper functioning of the vacuum tank. The bottom of the vacuum tank should be at least two inches higher than the gasoline level in the float chamber of the carburetor.

Vacuum tanks should be drained and cleaned at regular intervals. The carburetor is blamed quite often for vacuum-tank trouble. However, do not lay your trouble to the vacuum system until you have proved that it lies there.

When the car runs perfectly at low throttle or ordinary speeds and will accelerate quickly without backfiring, **but will backfire at high engine speeds** or on hills with wide-open throttle, look for some restriction in the flow of fuel from the tank to the bowl of the carburetor (providing you are sure the spark-plug gaps and ignition are all right). If the line is free from restriction, remove the screen and wash with gasoline. If there is no restriction up to this point, see that the vent hole in the main gas tank filler cap is not plugged up and trapping the flow of gasoline in the line.

FLOAT TROUBLES AND ADJUSTMENTS

When a carburetor drips, it usually indicates that the float or float-valve mechanism is out of adjustment. This prevents the float needle valve from properly closing. For instance, the float may be loose at the float screw; the gasoline then reaches a higher level than the spray nozzle or jet, with the result of an overflowing at the spray nozzle.

There are several causes for a dripping carburetor: either the float needle valve does not seat, due to sediment under it, or perhaps it is worn.

If sediment is the cause, the needle valve can be turned a few times on its seat and will probably clear the obstruction. On some carburetors, the float needle valve is in the form of a rod running through the float.

If the leak is not in the float needle valve, then it is probably due to the float being set so that it does not cut off in time to prevent overflowing at the jet. Or, in the case of a metal float, there may be a small hole in it, preventing it from floating; another cause may be that the mechanism is loose.

A simple method of testing a carburetor float mechanism is shown in Fig. 1.

In making this test, unscrew that part of the carburetor which will permit access to the float and float mechanism. Then prepare a device consisting of a can with a wire handle, a piece of copper tubing soldered to the bottom of the can to form an inlet, a piece of rubber tubing, and a nipple or short piece of metal tubing with a coupling adapted for attachment to the carburetor. The gasoline flows to the carburetor from the can, when it is held above the carburetor. By watching the float chamber fill with gasoline, the height the gasoline reaches at the time the float valve cuts off can be ascertained. If the height of gasoline in the carburetor is not sufficient, then the float must be raised slightly so that it will cut off later; if the height is too great, which can be determined by the gasoline flowing out of the jet, then the float must be slightly lowered, so that it will cut off earlier.

Owing to the variation in the suction of different engines on a carburetor, it is often found that a slight variation of the fuel level or a slight change in the size of the spraying nozzle will add greatly to the efficiency of the engine. The first thing to do, then, before attempting the adjustment of a float is to learn whether or not the float needs adjustment, by seeing if the gasoline is at the proper height in the jet when the float cuts off the gasoline.

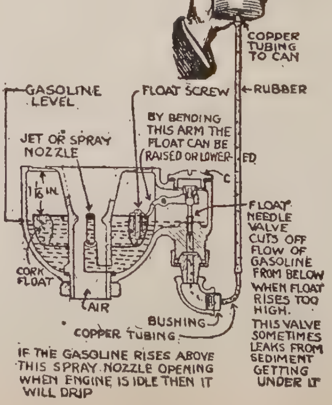

CAN FOR TESTING
COPPER TUBING TO CAN
GASOLINE LEVEL
FLOAT SCREW
RUBBER
BY BENDING THIS ARM THE FLOAT CAN BE RAISED OR LOWERED
JET OR SPRAY NOZZLE
C
$1\frac{1}{16}$ IN.
FLOAT NEEDLE VALVE CUTS OFF FLOW OF GASOLINE FROM BELOW WHEN FLOAT RISES TOO HIGH.
THIS VALVE SOMETIMES LEAKS FROM SEDIMENT GETTING UNDER IT
CORK FLOAT
AIR
BUSHING
COPPER TUBING
IF THE GASOLINE RISES ABOVE THIS SPRAY NOZZLE OPENING WHEN ENGINE IS IDLE THEN IT WILL DRIP

Fig. 1

To locate a suspected leak in a float of the hollow metal type: If the float is immersed in very hot water, the gasoline will be vaporized sufficiently to force its way out through a puncture and the spot may be located by watching the bubbles. The float should, of course, be removed from the water the instant bubbles cease appearing. The remedy is to solder the hole.

Testing the Float Height

On most makes of carburetors, the float needle valve is intended to cut off the gasoline when the level of gasoline in the float chamber reaches a level of about ⅛″ below the top of the nozzle or jet tube. Therefore this height, or the height recommended by the manufacturer, ought to be maintained.

Float adjustment: There is usually an adjustment provided directly above the gasoline float needle valve, which will regulate the height of the float. If not, then on some makes of carburetors (see Fig. 1) the float arm can be bent up or down, which will regulate the height of the float, and this in turn governs the float needle valve cut-off.

If the leak is due to a faulty seating of the float needle valve, then it will be necessary to put in a new needle valve or to reseat it.

Gasoline Level in the Jet

It is advisable to not tamper with the float unless you know positively that it is out of adjustment. This can be determined, if continually leaking, by making the test suggested above. Carburetors with floats similar to the Stromberg type "H" are provided with float adjustments. A Zenith carburetor is used as an example.

Zenith (Fig. 2): The level of the gasoline is maintained in the float chamber so that the gasoline stands 3 millimeters below the top of the jet, or about 7/64″. To regulate the level, note the washers (L), Fig. 2.

Master: The float weights are set about 1/32″ from the bottom of the float lid.

Schebler: In model "L," the top of the cork should stand 1 1/16″ from the top of the bowl in the 1-inch, 1¼-inch, 1½-inch and 1¾-inch. In the 2-inch model "L" carburetors this measurement is 1⅛″ and in the 2½-inch model "L," 1⅝″. These measurements should be made when the float valve is seated. In the Model R, the height of the cork float should be 23/32″ from the top of the bowl when the float valve is seated. In models D and E, the cork float should be level and rest 1/16″ above the top of the nozzle in the ½-inch, ¾-inch, and 2-inch sizes, and 1/32″ on the 1-inch, 1¼-inch, and 1½-inch sizes. Model H is 19/32″.

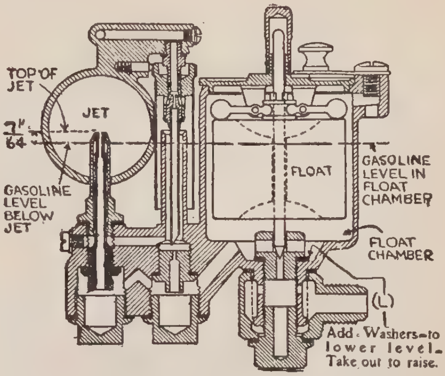

TOP OF JET
JET
7/64″
GASOLINE LEVEL BELOW JET
FLOAT
GASOLINE LEVEL IN FLOAT CHAMBER
FLOAT CHAMBER
(L)
Add Washers to lower level. Take out to raise.

Fig. 2. This illustration shows the level of gasoline in the float chamber and in the jet of the Zenith carburetor. If the float level was above the jet, the gasoline would run out of the jet.

Note: When changing the float level, great care must be taken to bend the arm in such a manner that the float will be at the proper height, yet perfectly level.

Stromberg: Note the level of gasoline in the float chamber in the Zenith (Fig. 2). This illustration will give the reader an idea as to the relation of the level of the gasoline in the float chamber to that in the jet. On the Stromberg Model "H," it should be about one inch from the lower edge of the glass. This can be adjusted by removing the dust cap and loosening the nut; if the gasoline is too low, screw adjustment up; if the gasoline is too high, screw adjustment down.

On Stromberg carburetors models "L" and "M" the height of gasoline should be 1″ below the top of the float chamber.

The adjustment on the Stromberg "K" type can be adjusted only by "bending the arm," as previously explained, which governs the float level.

Rayfield: The float level is correctly set at the factory and does not ordinarily require adjustment; but if it should, then the correct gasoline level should be maintained in the middle of the window in the side of the float chamber.

Cork floats are coated with varnish, but after long periods of time this coating may come off and the cork may become gasoline soaked, making it heavy and thus causing the float needle valve to fail to cut off properly. A mixture for coating is as follows: 1 lb. of glue, 1 teaspoon glycerine, 1 quart water. Let this come to a boil and add formaldehyde for quick drying. When coated, suspend the float by a string until dry.

Ford carburetor (Kingston and Holley): See Instruction on the Ford car.

TOOLS REQUIRED FOR REPAIRING CARBURETORS

Tools for repairing the Ford carburetor are given below as an example. Many of these tools can be used for repairing other carburetors. Special tools and wrenches can be obtained of the various carburetor manufacturers.

2 oz. hammer; ¼″ screw driver; ½″ screw driver; No. 52 drill; hand drill; adjustable wrench; pair pliers; flexible 6″ scale; 8″ mill file; wrench for inserting spray nozzle (H.), 3Z 4675; wrench for inserting float-valve seat (H. and K.), 3Z 4120; seating tool for inlet needle (H. & K.), 3Z 4114; float-setting tool and low-speed-tube nut wrench (H. & K.), 3Z 3223; low-speed-tube clearance gauge (H.), 24Z 2390; gauge for gasoline level (H.), 24Z 2393; float gauge and adjusting tool (H. & K.), 24Z 3990.

Tools with a "Z" number may be purchased from the nearest Ford branch.

Note: "H" means Holley carburetor; "K" means Kingston, as used on the Ford. Other numbers and letters are Ford stock numbers.

Carburetor Repair Bench

A space should be set aside for testing and repairing the carburetor, and no greasy or dirty tools should be used, as it is important that no dirt gets into the assembly.

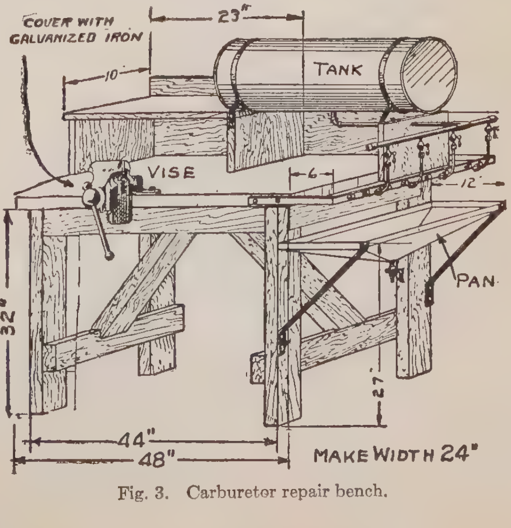


Fig. 3. Carburetor repair bench.

A suggestion for a repair bench is shown in Fig. 3. A bracket is provided to hold the carburetor in a level position. A tank 6″ above the level of the bracket is connected to the carburetor by means of a series of standard Ford feed pipes. Note the four gasoline pet cocks and connections which permit four carburetors to be tested at one time. Below the bracket a pan is provided to catch any drippings.

To guard against fire due to static electricity, the bracket should be connected to the drip pan by some metallic connector.

The carburetor is secured to the bracket and the feed pipe is attached to the carburetor from the connections (shown on the right) in the regular way. Here the gasoline level may be checked and the carburetor may be watched to see that it does not leak at the float valve.

A 4″ machine vise with jaws opening 5¼″ should be provided to hold the carburetor during the repair operations.

LEADING CARBURETORS—PRINCIPLE AND ADJUSTMENT

Owing to the fact that innumerable improvements are constantly being made in carburetor construction, it is impossible in this instruction to describe all the actual adjustments of all carburetors.

Repairmen are advised to secure instructions for adjustment of all the leading makes of carburetors from the manufacturers and to keep them on file (see Index for "Addresses of carburetor manufacturers").

Schebler Model "R" Carburetor

This carburetor may be termed an air-valve type of carburetor, with an automatically operated gasoline needle valve controlled by the auxiliary air valve.

Note that the gasoline needle valve (metering pin I) is operated automatically by movement of the auxiliary air valve. A concentric-type cork float is used.

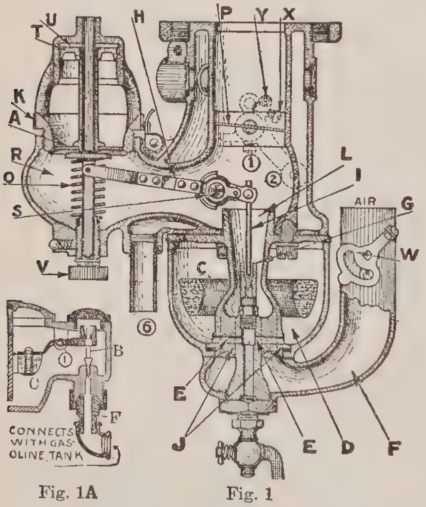


Fig. 1A Fig. 1

Fig. 1. Schebler model "R" carburetor.

Fig. 1A. Showing how the float gasoline needle-valve (B) cuts off and opens the gasoline passage (F) by the rise and fall of the float (C).

The parts consist of a float chamber (D), the cork float (C), and a float needle valve (B). These three parts control all flow of gasoline into the carburetor as it is needed by the engine.

That part of the carburetor where the gasoline and air are mixed consists of a mixing chamber (L), a spray-nozzle (G), and a needle valve (I).

The parts which automatically regulate the amount of gasoline required from the float chamber to provide the proper mixture consist of an auxiliary air valve (A) and lever (H), connected with needle valve (I).

Principle of operation: Gasoline flows from the tank through the gasoline pipe into the float chamber (**D**).

As the gasoline rises in the float chamber (**D**) it raises the cork float (**C**) with it, which, through a lever connection, automatically closes the needle valve (**B**) and shuts off the flow of gasoline from the tank to the carburetor. Of course, as the gasoline is drawn from float chamber (**D**), the float (**C**) drops and raises valve (**B**), admitting more gasoline.

The suction of the pistons draws the gasoline from the float chamber (**D**) through the passages (**E**) into the nozzle well (**G**), and past the needle valve (**I**) into the mixing chamber (**L**). As the needle valve (**I**) is raised and lowered, more or less gasoline is allowed to spray into the mixing chamber (**L**). At the same time the suction of the pistons draws from the warm-air intake (**F**) and the passages (**J**) warm air into the mixing chamber (**L**). As the suction of the swiftly moving pistons is very strong, the air is drawn through the mixing chamber (**L**) with great velocity, and there, coming into contact with the gasoline spray from the nozzle well (**G**), it vaporizes the gasoline.

This vaporized mixture is then drawn by the suction of the pistons past the throttle valve (**P**) into the cylinders. The quantity of combustive vapor flowing past the throttle valve (**P**) is regulated by the position of this throttle valve, and the position of this throttle valve is regulated by the driver either from a pedal called the "accelerator" or a throttle lever on the steering post. Opening the valve (**P**) admits more combustive vapor to the cylinders, and consequently increases the speed and power of the motor. Closing it has the reverse effect.

At high speed it is obvious that the suction through the mixing chamber (**L**) and the warm air passages (**J**) greatly increases, and as it increases beyond the capacity of these passages to supply air, a strong suction is brought to bear upon the auxiliary air valve (**A**). At a certain speed this suction is sufficient to draw this valve down against the coil spring (**O**). As the valve is drawn down, air rushes into the auxiliary air passage (**R**), and thence past the mixing chamber (**L**) into the cylinders.

Auxiliary air valve: To take care of this extra supply of air there must be an extra supply of gasoline automatically furnished. This is taken care of as follows: As valve (**A**) is depressed against the spring (**O**) it operates the lever (**H**), which is hinged at the point (**S**). As the lever (**H**) is depressed by the valve (**A**) it opens needle valve (**I**) admitting more gasoline to the mixture. It will be seen that this extra supply of gasoline is always directly in proportion to the air supply through the valve (**A**).

Dash-pot action: It is obvious that if means were not taken to prevent it, the valve (**A**), which is under the tension of the spring (**O**), would close very abruptly if the speed of the engine was suddenly checked. It would also tend to open very abruptly if the speed of the engine was suddenly increased, as, for instance, if the accelerator was suddenly opened. Furthermore, the suction of the cylinders is to a certain degree intermittent between the strokes of the pistons, and this intermission between the strokes would ordinarily tend to cause the valve (A) to flutter or vibrate if means were not taken to prevent it. The fluttering or vibratory action of the valve (A) would result in an unsteady flow of gasoline vapor to the cylinders, which would cause a vibratory or jarring effect in the engine. Any such action is prevented by a device (U) called a dash pot. Its function is automatically to insure a steady and stable supply of gasoline vapor to take care of varying engine speeds under all circumstances. To hold the valve (A) steady and to check its sudden closing or opening and to overcome its tendency to vibrate, it is attached directly to a plunger (T), which operates on a cushion of air in the dash pot (U).

To adjust the carburetor (Fig. 1): Turn the auxiliary air-valve cap (K) clockwise, or to the right (right means "rich") until you can turn it no farther. Then turn to the left or counter-clockwise (left means "lean") through one complete turn. Start the engine and then continue to turn (K) to the left or counter-clockwise until the engine hits perfectly on all cylinders, at the slowest speed possible. Advance the spark lever two-thirds or three-fourths ~~the~~ way on the sector and then suddenly open the throttle lever or accelerator wide. If the engine back-fires on this quick acceleration, turn the spring adjusting screw (V) up until the carburetor works perfectly.

By turning the screw (V) up or inward, it is turned against the spring (O), which increases its tension, thus preventing valve (A) from admitting air into the carburetor too freely.

Turning (K) to the right, or clockwise, lifts the needle valve (I) out of the nozzle well (G) and permits more gasoline to spray into the mixing chamber.

When (K) is turned to the left, or counter-clockwise, it lowers the needle in the nozzle and shuts off the gasoline. It should be remembered that it is desirable, from both points of economy and power, to drive the car with the leanest mixture possible.

The throttle valve should be adjusted so that when the hand throttle is closed, the engine will idle and run evenly on all cylinders. This can be ascertained by the regularity of the impulses in the exhaust when both the spark and throttle levers are set at their lowest positions. If the engine, however, should run too fast, or should stop when the throttle is at lowest position, adjustment is necessary. Directions for this are as follows:

Loosen the set screw (X) which locks the adjusting screw (Y) where the throttle shaft enters the carburetor. Place throttle in lowest position. If the engine runs too fast, unscrew adjusting screw (Y) so that the butterfly throttle valve (P) is closed a little tighter. If the engine runs too slow, screw in the adjusting screw so that the valve is held a little more open. Lock adjusting screw (Y) with set screw (X) after adjustment.

Schebler Model "L" Carburetor

This carburetor may be termed an "air-valve type" of carburetor with a mechanically operated gasoline needle valve. Note that the gasoline needle valve (B) is raised and thus opened mechanically by movement of the throttle lever which is connected with a cam arrangement (C). As the throttle lever is opened, the cam action raises the arm (J) connected with the gasoline needle valve, thus raising the needle valve from its seat (S) and admitting more gasoline at the jet.

To adjust the carburetor: First, make adjustments on the auxiliary air valve (A) so that it seats firmly, but lightly; then close the needle valve by turning the adjustment screw (B) to the right until it stops. Do not use any pressure on this adjustment screw after it meets with resistance. Then turn it to the left about a turn and a half and prime or flush the carburetor by pulling up the priming lever (C) and holding it up for about five seconds. Next, open the throttle about one-third, and start the engine; then close the throttle slightly and retard the spark and adjust the throttle-lever screw (F) and needle valve adjusting screw (B) so that the engine runs at the desired speed and hits on all cylinders.

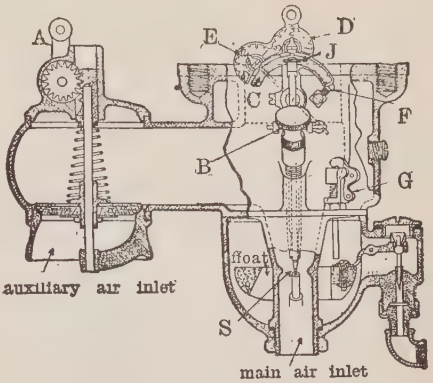


Fig. 2. Schebler model "L" carburetor.

After getting a good adjustment with the engine running idle, do not touch the needle valve adjustment again, but make intermediate and high-speed adjustment on the dials (D) and (E). Adjust pointer on the first dial (D) from figure No. 1 toward figure No. 3, about half-way between. Advance the spark and open the throttle so that the roller on the track running below the dials is in line with the first dial. If the engine back-fires with the throttle in this position and the spark advanced, turn the indicator a little more toward figure No. 3; or if the mixture is too rich, turn the indicator back or toward figure No. 1 until satisfied that the engine is running properly with the throttle in this position, or at intermediate speed. Now, open the throttle wide and make adjustment on dial (E) for high speed, the same as adjustments for intermediate speed on dial (D)

Note: In the majority of cases, in adjusting this carburetor, the tendency is to give too rich a mixture. In adjusting the carburetor, both at low, intermediate, and high speed, cut down the gasoline until the engine begins to back fire, and then increase the supply of fuel, a notch at a time, until the engine hits evenly on all cylinders. Do not increase the supply of gasoline by turning the needle valve adjusting screw more than a notch at a time, in low-speed adjustment, and do not turn it after the engine hits regularly on all cylinders.

In making the adjustments on the intermediate and high-speed dials, do not turn the pointers more than half-way at a time between the graduated divisions or marks shown on the dials.

Stromberg Model "H"

This carburetor would be termed a compensating-type carburetor, because, as previously stated, an auxiliary full jet comes into action as the throttle is opened.

For low speeds the gasoline is taken from the spray nozzle (C), in a venturi tube, through which hot air passes. Regulation of amount of gasoline is by needle valve (A) (Figs. 3 and 4).

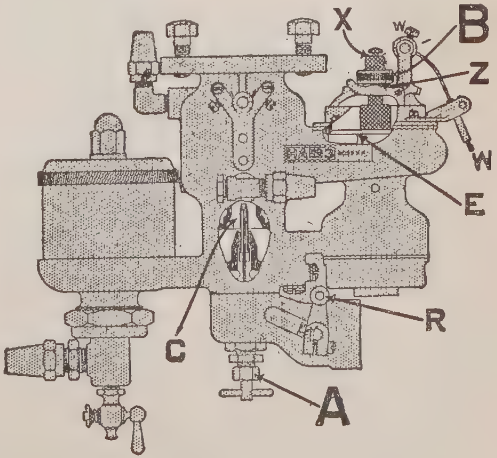


Fig. 3. Stromberg model "H" carburetor.

For high speeds, the nozzle in the center of the air valve is automatically regulated by opening of the air valve thus supplying the necessary volume of gasoline for high speed.

Adjustment for high speed is by (**B**), which controls the amount of flow of gasoline on high speed by regulating the time when the needle valve begins to open. The needle valve opens only when (**B**) comes in contact with (**X**). (**B**) is raised by a throttle opening at high speed. There is usually about 1/32″ clearance between (**B**) and (**X**).

Low-speed adjustment is controlled by the needle valve (**A**). If too rich, as indicated by the engine "rolling" or "loading," turn (**A**) up, thus admitting less gasoline and making the mixture leaner. If the mixture is too lean, turn (**A**) down, thus admitting more gasoline and a richer mixture.

High-speed adjustment: Advance the spark, open the throttle. If the mixture is too lean on high speed, screw (**B**) up until desired results are obtained. If the mixture is too rich, screw (**B**) down.

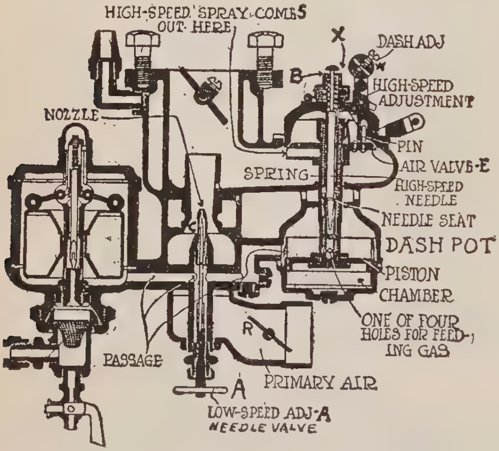


Fig. 4. Sectional view of Stromberg model "H" carburetor.

Nozzle: Before changing a nozzle, check up closely on the ignition system, and examine all manifold and valve-head connections for air leaks, as it is absolutely impossible to make a carburetor operate properly if the ignition is not in good condition or if there are air leaks in the engine.

If, however, with the engine in normal condition, it is necessary to turn the needle valve (A) down more than two and a half turns, and still the engine will not idle, it indicates that the primary nozzle is too small and that a larger one should be used.

If it is impossible to get enough gas on high speed except when nut (B) is so high that there is no clearance at (X) on idle, a higher number needle valve should be used.

If there is too much gas on high speed when nut (B) is turned down as far as it will go, a lower number needle valve should be used.

To change the primary nozzle (C), take out the needle valve (A) and remove nozzle with a regular screw driver. To remove the taper valve on high speed, pull up the steering post control, unscrew nut (B) all the way, and lift valve out. This valve and nut (B) are assembled together and should be ordered in that way. Do not attempt to take these apart or to change the taper.

Never change the nozzle more than one size at a time. The nozzle opening gets smaller as the number gets larger; thus a No. 59 is smaller than a No. 58.

High-speed needle valves deliver more gas as the number gets larger; thus a No. 7 will give more gas than No. 6.

Always install the carburetor with the float chamber towards the radiator.

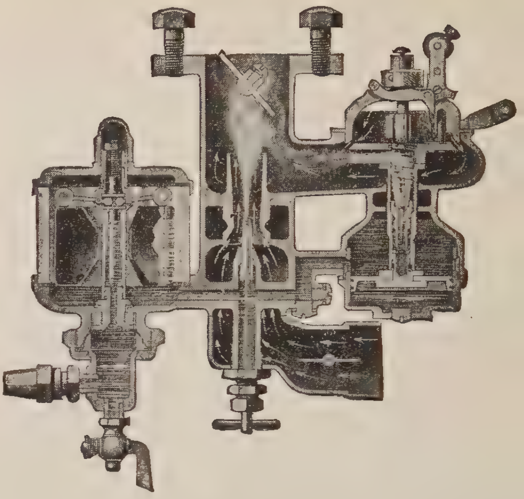


Fig. 5. Phantom sectional view of model "H" Stromberg carburetor, showing high-speed needle and primary nozzle in action. Note the path of the gas.

Marvel Model "E" Carburetor

The Marvel model "E" is a double jet, "compensating type" of carburetor, with the application of exhaust heat to a jacket surrounding the throttle chamber and venturi tube, the amount of heat being automatically controlled by the throttle opening. Outside the float mechanism this carburetor has but one moving part, the auxiliary air valve. (See Figs. 6 and 7.)

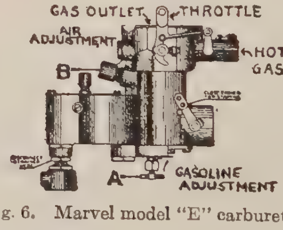


Fig. 6. Marvel model "E" carburetor.

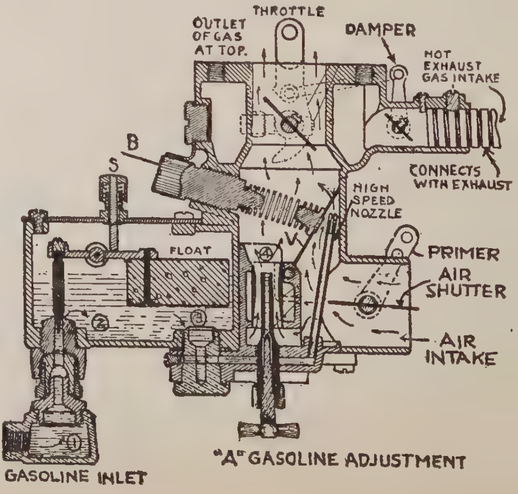


Fig. 7. Sectional view of Marvel model "E" carburetor.

Two jets are used, a primary low-speed jet and a secondary high-speed jet which is brought into action by the opening of the auxiliary air valve.

When the engine is idling, the hinged auxiliary air valve (V) (Fig. 7) rides on its seat against the bore of the mixing chamber, thus closing off the air passage past the tall high-speed nozzle jet, rendering it ineffective. At this time the air passes up through the small venturi surrounding the low-speed jet.

As the suction of the engine increases the auxiliary air valve is opened against the spring pressure, and the second jet (high speed), comes into action.

A choker valve (see air shutter) in the main air intake allows a rich mixture to be obtained for starting. This device may be controlled from the dash, so that when the engine is cold it may be closed to prevent back-fires, and may be gradually opened up as the engine warms up.

The feature of this carburetor, previously mentioned, is the **exhaust-heated jacket.** The heat is controlled by a damper connected to the throttle lever, which damper can be set to give any degree of heat desired. This is of particular importance, as the quality of gasoline is yearly becoming heavier and heavier. This heat damper, therefore, can be set to admit sufficient heat to secure good vaporization of heavy fuel on low throttle, and then, as the throttle is opened, the heat is automatically cut off, thus insuring maximum power at the higher speeds where heat is not necessary to good carburetion. By such an application of heat the entering air is not preheated, and this naturally results in greater thermal efficiency and power due to a maximum cylinder filling at each stroke of the pistons.

Adjustment: start by turning needle valve (A) to the right until it is completely closed. Then adjust the air adjustment (B) until the end of the screw is even with the end of the ratchet set spring above it.

Next, open (A) (gasoline needle) one turn, start the engine as usual, using the strangler button (S) to get a rich mixture at first. Allow the engine to settle and warm up; then gradually cut down on (A) until the engine runs smoothly.

Next, turn air screw (B) to the left, a little at a time, until the engine begins to slow down. This indicates that the air-valve spring is too loose. Turn it back to the right just enough to make the engine run well.

To test the adjustment, advance the spark and open the throttle quickly. The engine should "take hold" instantly and speed up at once. If it misses, or "pops back" in the carburetor, open needle valve (A) slightly, turning to the left. If this does not give results, the air screw (B) may be tightened a little by turning slightly to the right. It should be borne in mind that the air valve should be carried as loosely as possible, and that the adjustment for "pick-up" may be obtained by carrying more gas with needle valve (A), rather than to tighten up the air valve too much.

The best possible adjustment is secured when air adjustment (B) is turned as far as possible to the left and needle valve (A) to the right, providing the engine runs smoothly and picks up quickly when the throttle is open. The speed of the engine is governed by the small set screw in the throttle stop. If the engine runs too fast, turn the screw to the left; if too slow, turn the screw to the right.

Marvel Carburetor Connected to a Buick

The illustration (Fig. 8) is that of the gasoline system of the Buick six-cylinder, enclosed-model car. Note the vacuum gasoline feed system connected with the intake manifold and carburetor.

The Buick exhaust heating method of the mixture, by means of the exhaust manifold surrounding the intake manifold is shown.

A gasoline gauge is shown on the dash, the purpose and explanation of which is as follows:

A visual gasoline gauge is located on the dash of the closed models only and is a mechanically operating device which registers at all times the quantity of gasoline remaining in the main gasoline tank attached to the rear of the car.

It consists of a cork float, a piano wire, and a graduated registering dial. The cork float (F) is fastened to the tank base extension by means of an arm bent at the proper angle, which rises and lowers as the gasoline level changes.

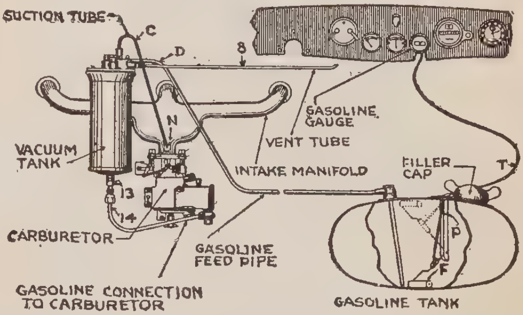


Fig. 8. Fuel system of the Buick in which the Marvel carburetor is used.

The piano wire (P) is attached to the float arm by means of a clip, and as the float rises and lowers it forces the wire to oscillate in and out of the tank through an aperture in the tank base which is fastened to the tank, from which a flexible tubing or casing (T) extends to the gauge on the dash inside of which the piano wire oscillates.

The graduated dial or drum is enclosed in a housing which fastens to the instrument plate, and the gasoline level is registered by the longitudinal motion of the wire. The drum is supported by pivot pins, and a constant tension is maintained with a hair-spring adjustment, set in such a manner as to permit the drum to rotate. The registering figures are placed on the outside of the drum and show through a small aperture in the face of the instrument conveniently located on the dash.

Rayfield Models "G" and "L" Carburetor

Rayfield carburetors are made in two types: model "G" and "L," the difference being that model "G" has a water-jacket.

In both models the **air-valve adjustment has been eliminated,** high and low-speed adjustments being made through the control of the fuel.

Both models are of the **two-jet type,** one jet feeding at low speed and both at high speed. The principle of this carburetor is explained in Fig. 24 and on page 102.

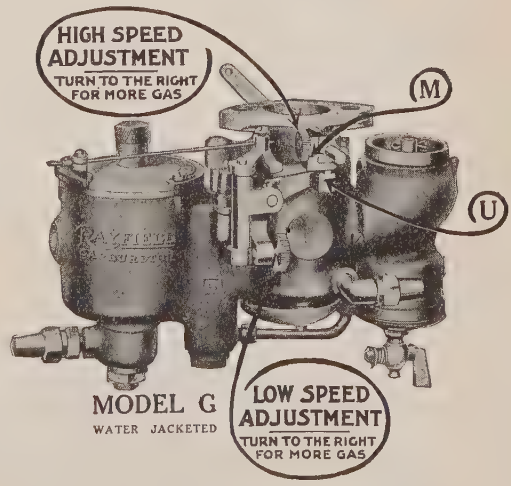


Fig. 9. Side view of Rayfield model "G" carburetor.

There are three air openings, one fixed and operating in conjunction with the low-speed nozzle and the other two having automatic valves linked together and operating simultaneously.

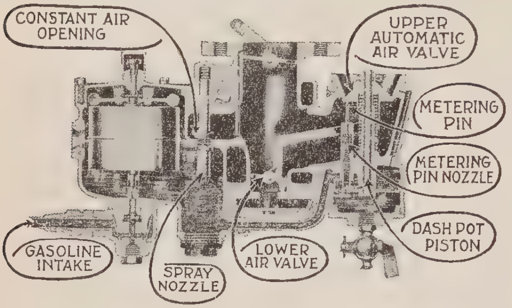


Fig. 10. Sectional side view of Rayfield model "G" carburetor.

The high-speed nozzle is controlled by a metering pin actuated by the upper automatic air valve. The stem of the valve is connected to a piston working in the dash pot, from which a passage communicates with the float chamber; the dash-pot chamber has direct connection with the high-speed nozzle.

When the throttle is opened, the tendency of the air valve to open suddenly and excessively, and to flutter, is checked by the dash-pot piston, which at the same time forces an extra supply of fuel into the nozzle and enriches the mixture for acceleration; the slow opening of the air valve increases acceleration by causing strong suction on the nozzles.

When adjusting a Rayfield, bear in mind that **both adjustments are turned to the right for a richer mixture,** as indicated on the adjustment screw heads.

The Rayfield dash control connects with the carburetor by a wire. When properly used, this will render starting easy, furnish a richer mixture when the engine is cold, and maintain a correct mixture under extreme atmospheric changes.

Raising the dash control lifts the spray needle and supplies a richer mixture. When it is raised full distance, a direct passage is opened, permitting raw gasoline to be drawn from the fuel chamber of the carburetor to the engine. The control button (or lever) should be down for running, except when a richer mixture is desired.

The automatic air valve should be closed when the engine is not running, or when throttled down.

The low-speed adjustment is to be used only when the engine is running idle and positively must not be used in adjusting high speed. Never adjust a carburetor unless the engine is hot and the water jacket of the carburetor warm.

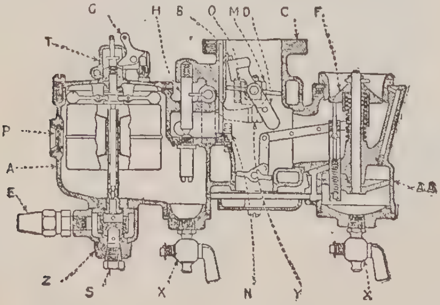


Fig. 11. Simplified illustration of the Rayfield. Note that two air valves, with a dash pot for acceleration, are used. (**A**), float chamber; (**AA**), dash pot; (**B**), stop screw; (**F**), automatic air valve; (**H**), nozzle needle; (**N**), low-speed adjustment; (**M**), cam; (**O**), high-speed adjustment; (**S**), drain cock; (**Y**), block.

Adjusting low speed: With the throttle closed and the dash control down, close the nozzle needle by turning low-speed adjustment to the left until block (**U**) (Fig. 9), slightly leaves contact with the cam (**M**). Then turn to the right about three complete turns. Start the engine and allow it to run until warmed up. Then with retarded spark, close the throttle until the engine runs slowly without stopping. Now, with engine thoroughly warm, make final low-speed adjustment by turning low-speed screw to the left until the engine slows down and then turn to the right a notch at a time until the engine idles smoothly. If the engine does not throttle low enough, turn stop arm screw (**A**) (Fig. 12) to the left until it runs at the lowest number of revolutions desired.

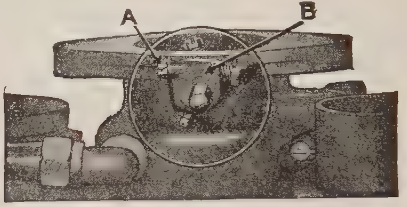


Fig. 12. (**A**) stop arm screw; (**B**) stop arm; turn screw (**A**) to left to throttle engine lower.

Adjusting high speed: Advance spark about one-quarter. Open the throttle rather quickly. Should the engine back-fire, it indicates a lean mixture. Correct this by turning the high-speed adjusting screw to the right about one notch at a time, until the throttle can be opened quickly without back-firing. If "loading" or choking is experienced when running under heavy load with throttle wide open, it indicates too rich a mixture. This can be overcome by turning the high-speed adjustment to the left.

To start the engine when cold: First close the throttle and pull the dash control all the way up. Second, when the engine starts, open the throttle slightly and push the dash control one-quarter of the way down. Third, as the engine warms up, push the control down gradually; when thoroughly warm, push the control all the way down. When the engine is warm it is necessary to pull the dash control only part way up for starting.

Hot-water connection is connected with the suction end of the pump (between radiator and pump). The connection on the other side connects with the water jacket of the engine or upper water pipe. A shut-off cock is provided for hot weather. See that these connections are made so that water will be drained out of the carburetor jacket when the system is drained.

Attach a hot-air stove to the exhaust pipe and connect to the constant air elbow of carburetor by a flexible tube. Connections are 5/16″ outside diameter tubing for gasoline and water connections.

Rayfield Model "M" Carburetor

The model "M" Rayfield (Fig. 13) is a smaller type, incorporating the features of the Rayfield model "G" without the dash pot. Fig. 14 shows the principle of the primer incorporated within the carburetor.

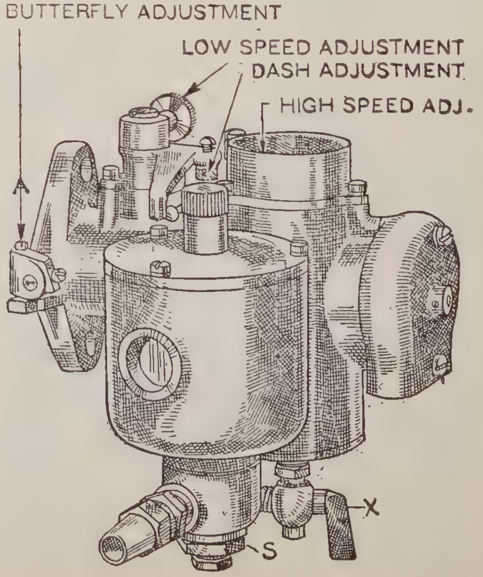


Fig. 13. Rayfield model "M" carburetor.

To adjust this carburetor, bearing in mind all the precautions cited previously, proceed as follows: The **low-speed adjustment** is turned to the right for a rich mixture, to the left for a lean.

With the engine running idle and the dash control down, turn the low-speed screw to the left one notch at a time. Between each movement of the thumb screw, the engine should be accelerated and allowed to come back to its idling speed. In this way a very exact adjustment can be obtained. If the slow-speed adjustment is obtained by turning the screw down all at once, a very accurate setting will not be obtained. When this screw has been turned down until the engine manifests a marked falling off in speed, it is a sign that the correct position has just been passed a notch or two. During the accelerating periods, the engine will commence to miss and spit back when the lean mixture is reached.

The intermediate and high speed is made accessible by removing the hot-air elbow from over the main air valve. It is well to observe a little precaution at this point. The high-speed screw should not be moved more than one-eighth turn at a time. This screw produces very effective results in the action of the carburetor, and its movement should therefore be correspondingly regulated. The economy of the engine is affected in a very pronounced manner by turning this screw.

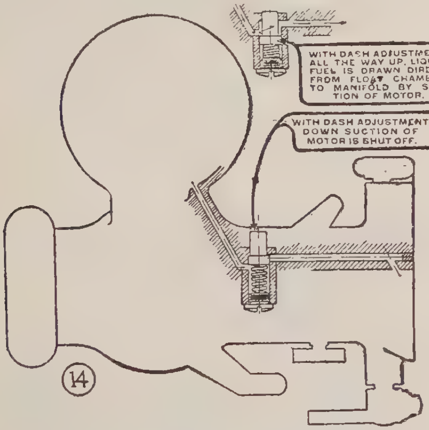

WITH DASH ADJUSTMENT ALL THE WAY UP, LIQUID FUEL IS DRAWN DIRECT FROM FLOAT CHAMBER TO MANIFOLD BY SUCTION OF MOTOR.
WITH DASH ADJUSTMENT DOWN SUCTION OF MOTOR IS SHUT OFF.
⑭

Fig. 14. Internal primer on the Rayfield model "M."

Johnson Carburetor

The Johnson is a "gravity air-valve type," with a single concentric jet, in which an air valve is made up of a sleeve rising and falling by suction and gravity in a cylindrical passage above the jet.

There are **three stages of vacuum:** one is the space between the throttle and strangle tube; the second, in the strangle tube itself; the third, in the space below the plate on the bottom of the air-valve sleeve. By removing the location of the idling adjustment (in Fig. 15) the gasoline flow (for idling) is brought in a zone of greater vacuum and hence better idling.

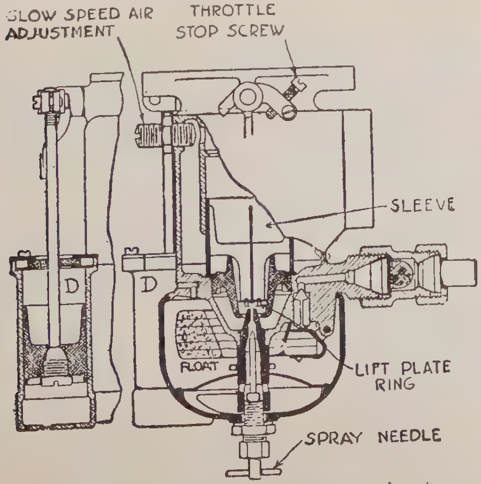


Fig. 15. Adjusting, old style Johnson carburetor.

Indications of incorrect adjustment: (A), lean mixture; (B), engine difficult to start; (C), "popping back" on quickly opening throttle; (D), engine knocks when throttle is opened quickly; (E), engine will not idle.

Many mechanics can adjust this carburetor for high speeds, but sometimes find difficulty in adjusting for low speeds or idling. The correct procedure of **adjustment is as follows:** (1) retard spark; (2) close the slow-speed air-adjustment screw (Fig. 15); (3) warm engine; (4) see that the intake pipe manifold, where it connects to the carburetor flange, does not leak air; (sometimes a water-jacketed intake manifold will become "air-locked" and water will not circulate, depriving it of heat; open "plug"); (5) accelerate the engine by opening and closing the throttle rapidly; if the mixture is too rich, acceleration will be sluggish; if too lean, it will "pop back" considerably; the spray needle adjustment should be set between these two points; (6) retard the spark and close the hand throttle; adjust the throttle stop screw until the engine runs very slowly, regardless of whether it operates evenly or not; (7) open the slow-speed air adjustment until the engine idles evenly, if possible; if it runs too fast, close down the throttle stop-screw; the adjustments on the stop-screw and the low-speed screw should be made simultaneously; (8) it may be found that the low-speed air adjustment cannot be opened at all; in this case the low-speed mixture is too lean; possibly the low-speed air adjustment can be opened more than 3½ turns, when the mixture is too rich; do not touch the spray-needle setting, but **proceed as follows:**

Disassemble the carburetor: A small ring, shown in Fig. 15, is attached by two lugs to what is known as the lift plate. This ring is somewhat curved, and if the slow-speed air adjustment can be opened more than 3½ turns without obtaining good idling, the curve is excessive and the ring should be slightly flattened. If on the other hand the air adjustment cannot be opened, the ring is too flat and should be slightly curved. The standard setting is 3/32″ from the edge of the ring to the lift plate to which it is attached.

Adjusting (Model "A"): (1) Turn both idle screw and high-speed needle (Fig. 16) to their seats, and set the throttle stop in approximately the correct position for closed throttle; (2) open the high-speed needle 1½ turns. This permits the engine to be started. Warm the engine up by running a few minutes; (3) place the spark lever in full retard position, and open the throttle until the engine turns at a speed equivalent to about 20 to 25 miles per hour; (4) turn high-speed spray needle to the right until the engine speed decreases; (5) then turn the spray needle to the left until the engine speed increases and then decreases from a rich mixture; (6) turn again to the right to a point midway between the extremes; this is the correct mixture and will give the best results for all throttle positions; (7) adjust the throttle stop screw to the desired idling position; (8) if uneven firing occurs, correct either by unscrewing the idling jet to enrich the mixture or by screwing up the idling jet to give a leaner mixture. The average setting is one-half turn from the seat. This adjustment must be made with the spark and throttle levers fully retarded.

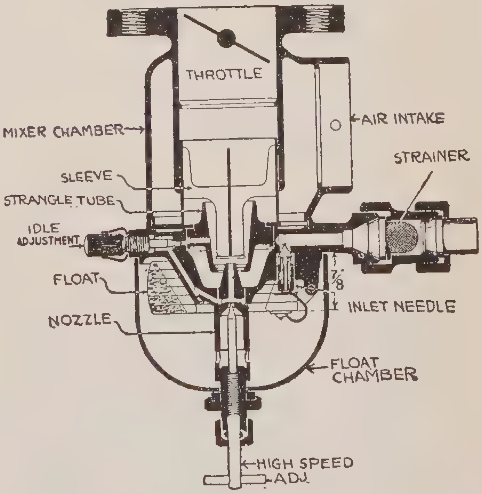


Fig. 16. Johnson model "A" carburetor.

The float should set evenly all around, the bottom being ⅞″ from the float-chamber seat, as shown in Fig. 16.

Principle of the Zenith Carburetor

We shall first consider a simple type of carburetor or mixing valve as an example, to lead up to the principle of the Zenith. This consists of a single jet (G), placed in the path of the incoming air, and fed from the usual float chamber (F) (see Fig. 17).

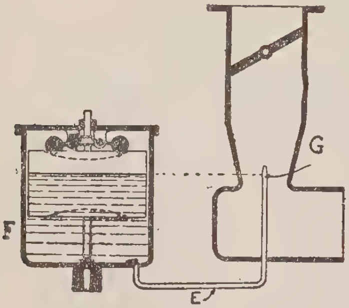


Fig. 17. A simple type of carburetor; jet (G), fed from float chamber.

As the speed of the engine increases, the flow of the air increases, but the flow of gasoline from the jet increases faster, causing the mixture to become richer and richer. The mixture is practically constant only between narrow limits and at very high speed.

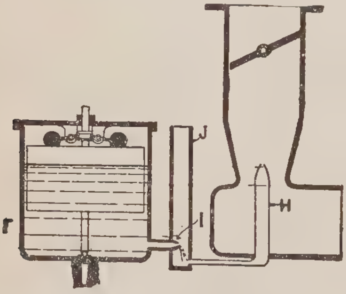


Fig. 18. Spray nozzle (H), receives gasoline from well (J), instead of from float chamber.

A second type of carburetor (Fig. 18) is shown in which the spray nozzle receives its gasoline from the well (J).

The gasoline in the well is fed by gravity only through compensating jet (I), and is not affected by the suction, as the well is open to atmospheric pressure. The flow of gasoline is therefore constant at all engine speeds. While the flow of air increases with the engine speeds, the mixture also becomes poorer and poorer as the speed increases.

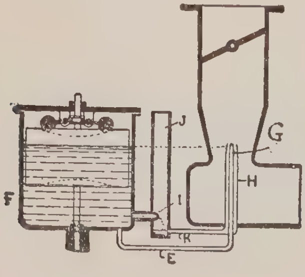


Fig. 19. A combination of Figs. 1 and 2.

It will readily be seen that the second type produces the opposite effect from the first, while a combination of the two, as shown in Fig. 19, will result in a constant mixture, when jets are properly chosen.

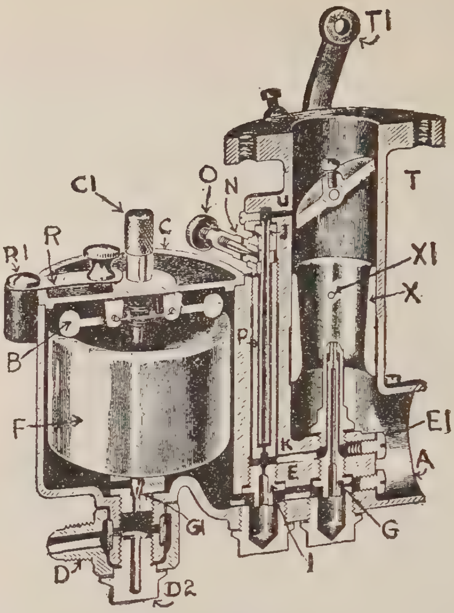


Fig. 20. The standard Zenith carburetor model "L" for 4 or 6-cylinder engines, made in five sizes ranging from 1″ to 2″ size of opening to the intake manifold. This type is used extensively abroad.

This construction, further illustrated in Fig. 20, admits of the addition of the priming tube (J) (Fig. 20) extending into the secondary well (P) and opening at the point (U) (Fig. 20) of the closing butterfly (T). With the butterfly partially open, the suction at this point (U) is powerful and draws the well full of gasoline into the cylinders, effectively priming the engine. Also, by the introduction of this secondary well, which measures the gasoline used in running idle, a perfect mixture is obtained at very low engine speeds.

The level of the gasoline in the float chamber is set at the factory and need not be changed. In case this becomes necessary, the gasoline level is as shown in Fig. 19.

The setting or adjusting of the Zenith carburetor is the choosing of the proper size of choke tube or venturi, and gasoline jets and secondary well.

The choke tube or "air nozzle" (X) is held in place by a screw and can be easily changed when the butterfly throttle has been removed. Its object is to obtain a correct gas velocity around the jets. A choke too small will restrict the flow of air and prevents the motor from receiving enough mixture for high speed. A choke too large will cause irregularities when running fully open, and when slowing down.

The main jet (G) is easily removed after unscrewing the lower plug. This jet is of the ordinary type and has a predominating influence at high speeds.

The compensating jet (I), corrects the action of the main jet, and has a predominating influence at low speeds, as when climbing a hill.

The throttle adjusting screw will regulate the opening of the throttle for slow speed and the position of the screw (O) will regulate the quality of the mixture at that speed; in screwing in this piece the mixture will get richer, and in unscrewing it, the mixture will get leaner.

Adjustments: If the engine does not slow down or idle, or if it "lopes," that is, speeding up and slowing down as if fitted with a governor, it is evidently getting too much gasoline. (1) adjust air screw (O); (2) look for air leaks at manifold and other joints; see that jets are tight on seat; (3) look for water accumulation in the passages; remove plugs under the carburetor and clean (I) and (G).

If engine does not pull properly going up hill: (1) the engine may be cold or insufficiently heated; (2) the mixture may be too lean or too rich (irregular running results in the latter case); try a larger or a smaller compensating jet (I), using the one which gives best results; try this also with jet (G) and adjust the choke tube to a corresponding size.

If the car does not attain its proper speed: (1) mixture may be too lean; try adjusting slow speed (O); if the trouble is chronic, try larger main jet (G); (2) if the mixture is too rich, try regulating air intake at (Z) (Fig. 24); if the trouble is still chronic, try a smaller-size main jet (G).

When trying a new jet, the choke tube (X) must also be changed. The choke can be removed from the upper part of the barrel by removing screw (X1) and the throttle valve. If it is stuck, remove the cap and jet at the lower part of the carburetor and use a brass rod to drive it out.

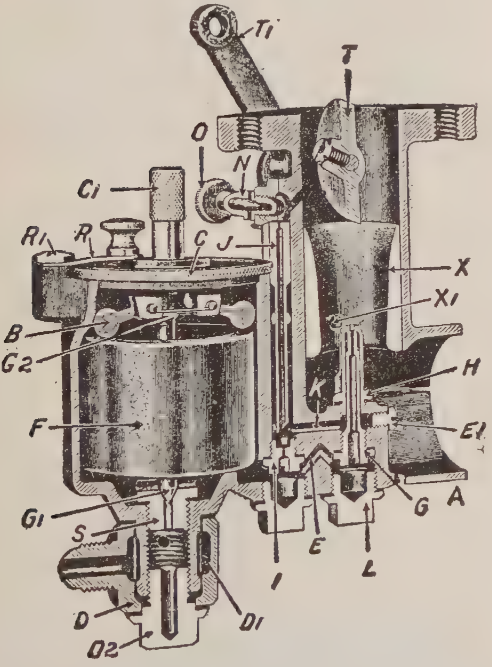


Fig. 21. Zenith model "O," a modified "L" type designed with shorter jets and simpler idling well. It is an Americanized Zenith, not intended for export, and sells for a less price than model "L". Not designed for high-pressure feeds.

A—Main air intake, connected by flexible tubing to take air from around the hot exhaust pipe.
C—Float cover.
C1—Needle-valve cap; by unscrewing this the float can be operated for priming if necessary.
D—Connects to gasoline supply.
D1—Filter screen.
D2—To drain.
E —High-speed gas opening.
E1 —Main jet set screw.
F —Float (metal).
G —Main jet.
G2—Needle-valve collar.
H —Cap jet.
I —Compensator.
J —Priming plug in idling well.
K —Low-speed gas opening.
L —Lower plug.
N —Seat of slow-speed adjustment screws.
O —Slow-speed adjustment screws.
R —Spring to hold float cover.
S —Needle-valve seat.
T —Butterfly throttle valve which is operated by T1, which is connected by throttle rod to accelerator or hand throttle lever on steering wheel; the opening of T, when closed for idling, is regulated by the stop and two set screws shown to the side of T1.
T1 —Lever operating throttle butterfly valve.
X —Choke tube.
X1 —Screw holding choke tube in place.

Zenith Model "HN" Carburetor

Another type of Zenith carburetor is the model "HN." It is similar to the models "O" and "L," except that it is designed for block-cast cylinder engines where the carburetor is fastened directly to the cylinder block without the use of a manifold.

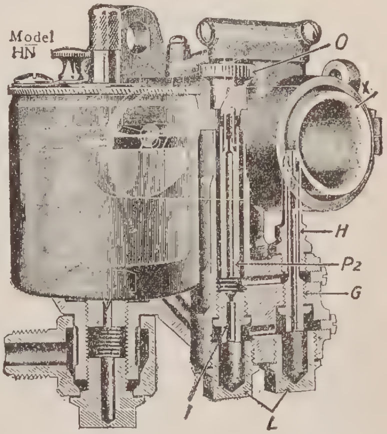


Fig. 22. Zenith model "HN" carburetor.

Zenith Duplex Carburetor

The Zenith duplex carburetor is so named, because there are two carburetors combined into one unit, both using the same float. This type of carburetor is used extensively on "V"-type engines and is a true **"compensating type,"** as is also the models shown in Figs. 20, 21 and 22.

The float is of metal and is a side-float type. The carburetor connection is vertical.

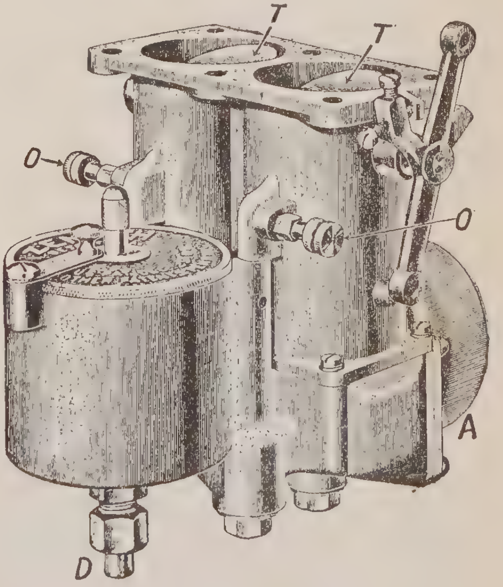


Fig. 23. Zenith Vertical "Duplex" model "OD" carburetor for eight and twelve-cylinder "V"-type engines.

Adjustments: There are but two adjustments on the Zenith and they apply to practically all models. These adjustments are provided to "idle" the engine properly. With the average carburetor, if maximum speed is desired, proper idling at slow speed is sacrificed, or vice versa. By means of admitting more or less air, however, through the small slow-speed adjusting screws (O), the Zenith carburetor will idle without "choking" and "loping," and yet the maximum speed can be obtained—providing, of course, the main jet, compensator, and choke tube are of the proper size.

By referring to the illustration (Fig. 21) it will be observed that a small amount of air is admitted over and above the mixture through the plug (J) that is fed from the idling well. After the engine is speeded up the mixture is drawn through the main jet.

There are three parts which must be of the correct size: the choke tube (X), main jet (G), compensator (I). The size is determined by the manufacturer, according to the type of engine: four, six, or eight-cylinder, bore and stroke. After once being fitted to the carburetor, there are no other adjustments except the slow-speed valve (O), as mentioned above.

If the choke tube is too large the pick-up will be defective and cannot be improved by the use of a larger compensator. Slow-speed running will not be very smooth.

If the choke tube is too small, the effect is to prevent the engine from taking a full charge with the throttle opened fully. The pick-up will be very good, but it will not be possible to get all the speed of which the car is capable.

If the main jet is too large, at high speed on a level road it will give the usual indications of a rich mixture: irregular running, characteristic smell from the exhaust, firing in the muffler, sooting up at the spark plugs, low mileage. The influence of the main jet is mostly felt at high speeds.

If the main jet is too small, the mixture will be too lean at high speed and the car will not attain its maximum. There may be back-firing at high speed, but this is not probable, especially if the choke and main jet are according to the factory setting. This back-firing is more often due to large air leaks in the intake or valves, or to defect in the gasoline line.

The compensator (I): From the explanation of the Zenith principle given on page 130, it will be readily noted that the influence of the compensator is most marked at low speeds. The compensator size is best tried out on a hill, as regular and as long as possible, and of such a slope that the engine will labor rather hard to make it on high gear. A long, even, hard pull of this sort taxes the efficiency of the compensator to the utmost, and will indicate readily the correctness of its adjustment.

If the compensator is too large, too rich a mixture will result on a hard pull. It will give the same indication as for rich mixture at high speed on the level.

If the compensator is too small, too lean a mixture will result. The engine is liable to miss and give a jerky action in the car, on a hard pull.

Note. When trying out or fitting new jets, etc., tests should be made systematically, first starting the main jet, then the compensator, then the choke. Bear in mind that when the choke is increased the main jet should be increased. Water in the gasoline will sometimes lodge in tube (J) and prevent proper idling. Remove and clean. This is a common trouble unless a strainer is used.

A temperature regulator as used on the Zenith carburetor is shown in Fig. 24. It is placed on the air opening of the carburetor. The air-control lever or air regulator operates the "air lever" or "choke" valve (Y), admitting more or less warm air.

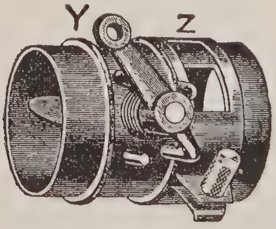


Fig. 24. Zenith temperature regulator.

The temperature of this warm air entering the carburetor can be regulated by a band (Z) placed around the opening. The opening permits cool air to be drawn in, and the use of this opening is governed more or less by the temperature. In summer, the opening (Z) is usually wide open, but closed more or less during cold weather.

Stromberg Carburetor Models "L" and "M"

The Stromberg models "L," "LB," "M," and "MB" are all called the **"plain-tube carburetor,"** the principle of which is explained on page 134.

The "L" and "M" models are the same carburetor, except that model "L" has an "economizer" action. The "L" and "M" are made for vertical connections to the intake manifold.

The "LB" and "MB" models are of the same principle as "L" and "M," except that they are made for horizontal connections to the intake manifold. The "LB" has the economizer action, the same as "L."

Instructions for Stromberg "L" and "LB" Carburetor

This carburetor differs from older styles in that it is a plain-tube type, having the air passages fixed in size, while the gasoline is automatically and accurately measured by the air flow itself, at all speeds and loads. The mixture proportion is maintained constant by the "air-bled nozzle" construction, in which a small amount of air is mixed with the gasoline before it reaches the jets.

There are three adjustments, the high speed, the extremely low speed or idle, and the "economizer."

The high speed is controlled by the knurled nut (A) (Fig. 25) which locates the position of the needle past whose point is taken all the gasoline at all speeds. Turning nut (A) to the right (clockwise) raises the needle and gives more gasoline; to the left, or counter-clockwise, less.

If an entirely new adjustment is necessary, put economizer pointer (L) in 5th notch (or nearest to float chamber) as an indicator; turn nut (A) to the left, counter-clockwise, till the needle reaches its seat, as shown by nut (A) not moving when the throttle is opened and closed. When the needle is in its seat it can be felt to stick slightly when nut (A) is lifted with the fingers. Find adjustment of (A) where it just begins to move with the throttle opening, then give 24 notches to the right or clockwise (the notches can be felt). Then move the economizer pointer (L) back to (O) notch (away from float chamber). This will give a rich adjustment. After starting and warming up the engine, thin out the mixture by turning (A) counter-clockwise, and find the point where the engine responds best to quick opening of the throttle, and shows the best power.

Low speed or idle adjustment: The gasoline for low speed is taken in above the throttle through a jet at (K), and is regulated by dilution with air as controlled by the low-speed adjusting screw (B). Screwing (B) in clockwise gives more gasoline; outward, less. The best adjustment is usually ½ to 3 turns outward from a seating position. Note that this is only an idling adjustment and does not affect the mixture above 8 miles per hour. When the engine is idling properly there should be a steady hiss in the carburetor; if there is a weak cylinder or a manifold leak, or if the idle adjustment is very much too rich, the hiss will be unsteady.

Economizer action and adjustment: The economizer device operates to lean out the mixture, by lowering the high-speed needle and nut (A) a slight but definitely regulated amount, at throttle positions corresponding to speeds from 5 to 40 miles per hour. The amount of drop and consequent leaning is regulated by the pointer (L).

After making the high-speed adjustment for best power, with pointer (L) in (O) notch, as above described, place the throttle lever on the steering wheel in a position giving about 20 miles per hour road speed. Then move pointer (L) clockwise (toward the float chamber), one notch at a time, till the motor begins to slow down; then come back one notch.

The amount of economizer action needed depends upon the grade of gasoline and upon the temperature. In the Mid-West, the best economizer adjustment will usually be the third or fourth notch. With Pennsylvania gasolines and in the South, the second notch; while on the Pacific Coast no economizer action is necessary unless Distillate (which should not be below 50° Baume) is used. Also fewer notches of economizer action will be necessary in summer than in winter.

Note. All Stromberg carburetors are supplied with hot-air attachments and a temperature regulator. When adjusting type "L," the dash control lever should be all the way down and the air-horn cam plunger (H) (Fig. 25), should clear the economizer lever so that this works freely as the throttle is opened and closed.

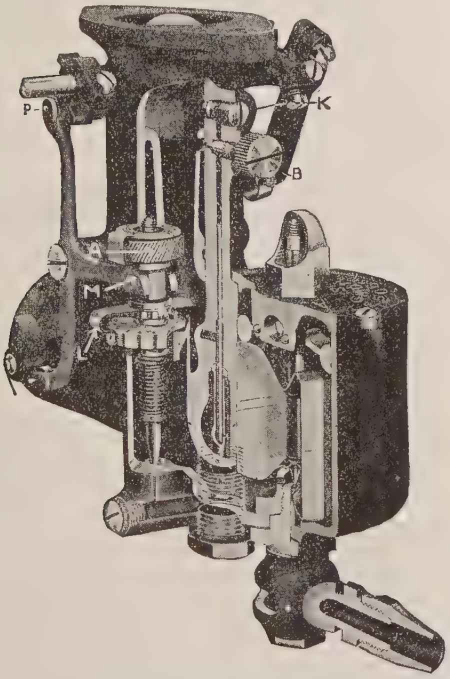


Fig. 25. Stromberg type "L." Note the vertical connection and economizer (the lever with roller P on it). This carburetor is adapted for high-speed multi-cylinder engines.

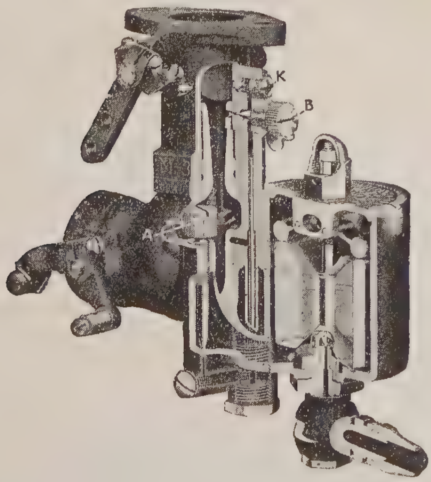


Fig. 26. Stromberg type "M," without economizer. Used on small 4-cylinder engines, trucks, tractors, etc.

Adjustment of "M" and "MB"

The only difference between the types "L" and "M," is in the "economizer" action, or the lifting of the high-speed needle valve (A) automatically. This needle valve (A) on type "M" is hand regulated.

(1) Open throttle about one-quarter of the way, which will give about 20 miles per hour on a pleasure car (or one-third governor speed on a motor truck).

(2) Open idling screw (B) from its seat two turns, so that this cannot affect the high-speed adjustment.

(3) Adjust high-speed needle (A) to the leanest adjustment which will give the best engine speed for this throttle position. Inward for less and out for more gasoline.

(4) Close the throttle gradually and screw the idling screw (B) in as far as necessary to give adjustment for low speed and idle. Screwing inward, right hand, gives more gasoline; outward gives less.

This "plain tube" and "Pitot" principle is further explained on page 102.

Note. Never adjust the carburetor to a cold engine. Start the engine and allow it to run a short time until it is warm. Not until then should the adjustment of the carburetor be attempted.

In starting the engine on a cold day it may begin "popping." Do not blame this on the carburetor and begin to adjust it. Wait until the engine has warmed up thoroughly, and then if the popping continues it is time to consider an adjustment.

Principle of Stromberg "Plain Tube" or "Pitot" Principle of Carburetor

This explanation also covers models "L," "LB," "M," and "MB," except that the economizer action, which is explained on page 132, is not used on the models "M" and "MB." The air passage and gasoline jet are of fixed sizes for all engine speeds.

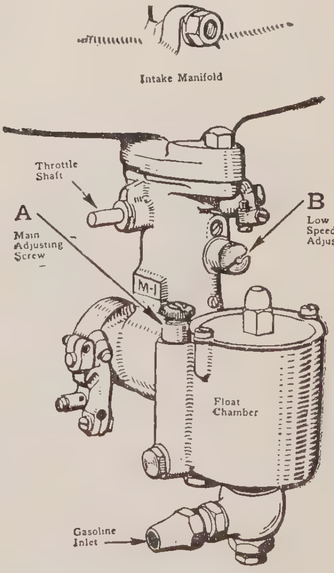


Fig. 27. Stromberg model "M," Vertical type, shown connected with the intake manifold.

This carburetor is termed a "plain tube" type, because the whole air supply is taken through a single unobstructed channel of fixed size through the jet. Air valves, metering pins, and dash pots have been dispensed with. The Pitot principle, explained on page 102, is used to provide air at sufficient pressure to force fuel from the well in the carburetor.

How the desired mixture can be maintained is answered in the principle of introducing a small amount of air into the gasoline jet at (G) before it sprays out into the main air passage, forming what is known as an "air-bled" jet or "Pitot" principle.

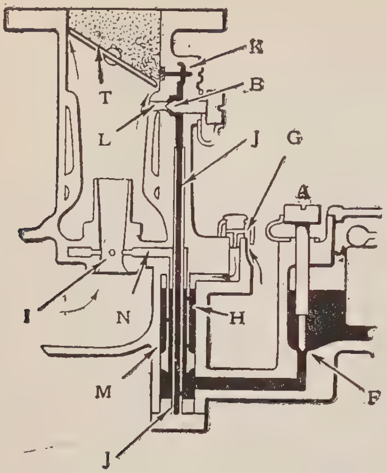


Fig. 28. Idling position. When idling, all the gasoline is drawn up the tube (J), through the idling jet (K) and sprayed above the throttle valve (T).

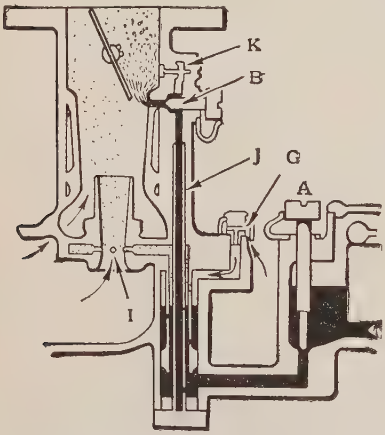


Fig. 29. Low and medium speed: At intermediate speeds the gasoline is drawn past the low-speed adjusting screw (B) from the tube (J). As the throttle is opened, more mixture is drawn through the small venturi tube (I) and augments that drawn from the opening (L) (Fig. 28).

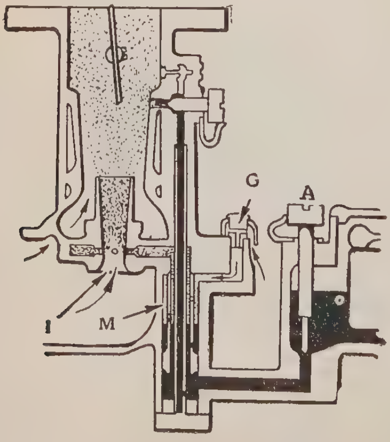


Fig. 30. High speed: At high speed practically all the gasoline is drawn through the small venturi tube (I) mixed with air, drawn through the opening (G) above the well (M).

Principle of operation: The level of the gasoline in the float chamber of the carburetor is maintained constant by the float and the valve which is operated by it. From the float chamber the gasoline flows to the accelerating well (M) through the needle valve (F) (Fig. 28) which is adjustable.

There are two tubes in the accelerating well, one a sort of standpipe (H), and the other a smaller one that is inside of the standpipe and which connects with the idling jet (K). The latter tube has a small opening in the bottom that connects with the bottom of the well (M), but otherwise has no connection with the well.

The top end of the standpipe (H) connects with a cross-passage (N) that feeds the gasoline to the eight discharge holes in the small venturi tube (I), which is located just below the main venturi tube (note that there are two venturi tubes). A rich mixture and not raw gasoline is fed through passage (N), because of the small air intake opening (G), which enters the top of the well (M), and supplies a certain amount of air with the gasoline that is drawn up the standpipe to the passage (N).

Holes in the side of the standpipe below the level of the fuel feed gasoline into the standpipe, while holes above the fuel level add air from the top of well (M), thus making a rich mixture to discharge into the small venturi passage.

At low and idling speeds, practically no fuel is drawn through the small venturi, because of the closed throttle. At this time the gasoline is through the hole in the bottom of the small tube (J), up to the idling needle valve (B), and through the passage (K), into the intake manifold above the throttle valve. This gives a rich mixture for idling and slow-speed running, but is cut out at about eight miles per hour when the throttle is opened more, and thus does not affect the running mixture at all.

Stromberg Model "OS" Carburetor

This carburetor used on the Marmon, Lincoln, Auburn, Jordan, Scripps Booth, Studebaker, and other cars, is of the **"plain tube"** type with a number of refinements which have been incorporated as follows: an improved form of accelerating well of greater capacity and of better adaptation to the great variety of fuels which must be handled today; a modified form of economizer device; a new mixture control, operating an auxiliary fuel needle. This control assists the choke valve control in starting, and gives a better control of the mixture after starting, before the engine reaches an efficient temperature.

The model "O" is suspended vertically and the "OC" and "OS," horizontally. Illustrations of the model "OS-1," are shown in Figs. 31 to 34.

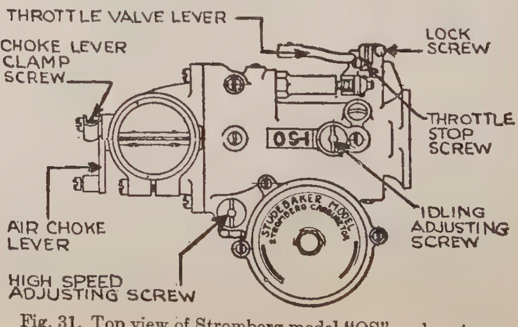


Fig. 31. Top view of Stromberg model "OS" carburetor.

Adjustment for idling mixture and closed throttle running up to about eight miles per hour is controlled by the idling adjusting screw (Fig. 31). This operates on the air, so that screwing it in gives a richer mixture and out a leaner one.

Turn the screw outward until the engine slows down, then turn in notch by notch until the proper idling mixture is reached. When the motor is idling properly there should be a steady hiss in the carburetor. If there is a weak cylinder or a manifold leak, the hiss may be unsteady. For a motor to idle steadily on present-day heavy fuel, the spark gaps must be set correctly.

If, after adjusting the low-speed needle as described above, the engine idles too fast, turn the small throttle stop screw (Fig. 31) to the left, or counter-clockwise, until the proper idling speed is reached. If the motor idles too slow and stops, turn the screw to right, or clockwise, until the proper speed is reached. Before adjusting with throttle stop screw, it will be necessary to loosen the lock screw.

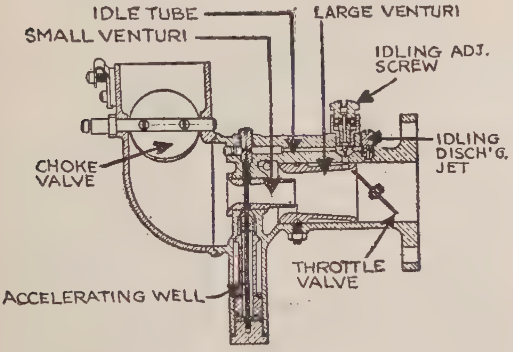


Fig. 32

Adjustment for high speed and main driving adjustment is regulated by high-speed needle (Figs. 31 and 33), which regulates the opening through which fuel flows to the jet. Turning to the left, counter-clockwise, gives more gasoline; to the right, or clockwise, less gasoline.

To make proper high-speed adjustments, advance the spark lever to normal driving position, set the throttle lever on the steering wheel at a position which will give a speed of engine corresponding to a car speed of about 15 miles an hour. Then adjust the high-speed needle to minimum opening that will give greatest engine speed for that throttle opening. This should give a good average adjustment. Two or three notches less may give best economy for continuous driving or touring, and two or three to the left may be best for short runs in cold weather when the motor does not reach normal heat.

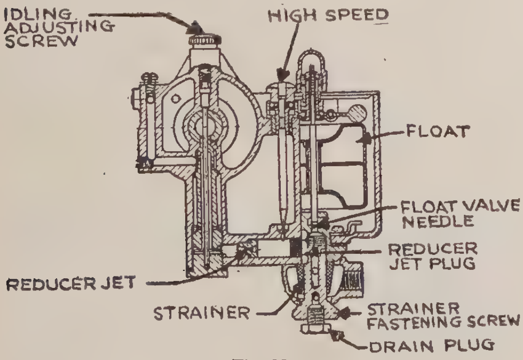


Fig. 33

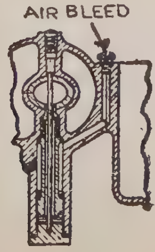


Fig 34

To prevent a wrong high-speed adjustment from giving a harmful rich mixture, a gasoline nozzle reducer is inserted beyond the high-speed needle opening, in a passage-way closed by a reducer jet plug (Fig. 33). The reducer placed in the carburetor at the factory will permit about 20 per cent more gas to pass through than is generally needed.

The economizer device operates to lean out the mixture automatically at speeds of from 10 to 45 miles per hour. The economizer needle is properly set at the time the carburetor is installed on the engine and no adjustment is needed.

When starting the engine, first open the carburetor butterfly valve slightly by means of the hand throttle lever on the steering-gear sector, then pull the choke button out all the way, turn the ignition switch to "on" position and depress the starter switch. As soon as the engine starts, push the choke button in about one-third of the way or to the point where the engine runs smoothly. Do not leave the choke button pulled out fully after the engine starts as this will flood the engine with gasoline and cause it to stop. As the engine warms up, the choke button should be pushed in gradually, the normal position for running being all the way in. It must always be remembered that the choke button should be out the shortest period of time possible, as running with an over-rich mixture tends to foul the engine, dilute lubricating oil, and use an excessive amount of fuel.

The engine should start after five or ten seconds of cranking. It it does not do so, it may be that the choke valve does not entirely close, in which case loosen the choke lever clamping screw (Fig. 31), and reset the lever on the shaft so that there is a clearance of 1/32″ between choke lever and stop on the choke-tube holder.

The normal position of the air temperature regulating sleeve is closed. Only in extremely hot weather is it desirable to have it open.

Schebler Plain Tube Carburetor

Adjustments: There are two gasoline adjustments, one for low speed, 4 to 5 m. p. h. up to the maximum without "loading" up or missing.

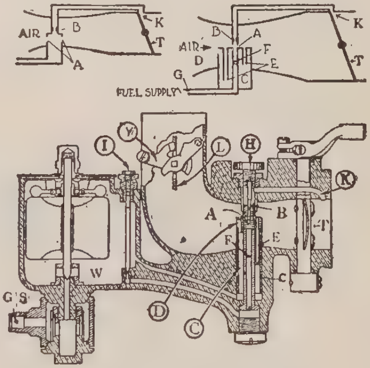


Fig. 35 (upper).
Fig. 36 (lower).

Figs. 35 and 36. (I), high-speed gasoline adjusting needle; (H), low-speed gasoline adjusting needle; (L), choker valve; (T), throttle valve; (K), idle and low-speed by-pass; (D), Pitot opening.

Operation or action: Air flows into and through the choke or venturi tube in the direction of the arrow (Fig. 35), but for idle speeds of the engine the velocity is too low to cause suction to draw gasoline through the main nozzle (A). An extension (K) is provided from the main nozzle to the space above or engine side of the throttle (T). The size of this extension or passage is controlled at (B) by screw (H).

In operation the high suction above the throttle (T) draws gasoline through the main nozzle and causes fuel to flow through the extension (K) with some air which is drawn in through the main nozzle holes (A) at (B) by (H). As the throttle is opened, the increasing suction at the main nozzle cuts down the air bleed through the holes (A) and causes more fuel to pass through the extension (K) until that suction caused by the flow of air at main nozzle (A) equals the decreasing suction above the throttle (T). Then fuel comes out of the main nozzle holes (A) into the main air stream. This also probably causes a slight reverse flow in the extension passage.

This combination produces a correct proportion of air and fuel through a very large range, if the throttle is not thrown wide open from its closed position suddenly. When this happens the engine would "lay down," or miss six or seven shots and sometimes die completely.

To overcome this trouble, an overflow well, or reserve chamber (C), is formed around the main fuel passage, whose top is integral with the main nozzle head and provided with a down-stream Pitot (D). From this head two acceleration tubes (E) extend to different depths into the overflow well (C) and discharge into the main air stream.

Pitot supplies air: With the engine idling or running slowly the well (C) will fill up by means of the hole (F) in the main nozzle passage.

On suddenly throwing the throttle wide open, the reserve supply of fuel is taken out from the acceleration tubes (E) as well as from the main jet (A). This practically makes a temporarily large jet or nozzle until one of the tubes (E) is uncovered by the lowering of the fuel level in the well. Air is then drawn out through this tube and acts in opposition to the supply of air from the Pitot (D). This opposition causes a gradually increasing suction in the well (C) and uniformly decreases the discharge of fuel from the longer tube (E). This operation fills in the time-element necessary for the main jet to resume its normal functions of delivering a thin mixture.

Tubes (E) are made of varying lengths to hold a reserve supply of fuel from some intermediate speed of, say, 15 m.p.h.

The Pitot function is simply to provide air at sufficient pressure to force fuel from well and to be inclosed in carburetor.

All the fuel passes through the main adjustment (G), which is located at the float bowl and is governed by screw (I), and therefore controls the whole range of the carburetor while still allowing the idle or low-speed adjustment to be changed with the condition of engine or variations in engines of same design.

The gasoline float level is 1" below the top of the bowl with the needle seated.

Tillotson Carburetor

This carburetor is illustrated as used on the Overland engine. It may be termed a "double-jet, compensating, variable venturi carburetor."

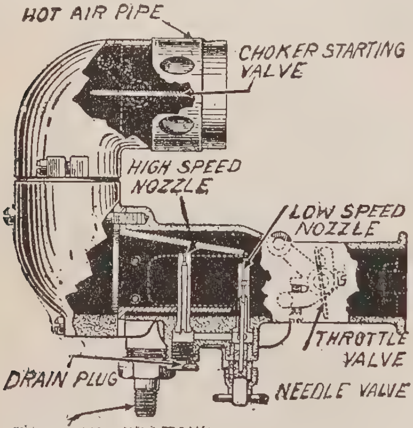


Fig. 37. The Tillotson carburetor.

A uniform partial vacuum is maintained at the fuel nozzle by two flexible reeds, which are mounted in a cage and so designed that maximum opening gives required volume for maximum speed.

When the reeds (Fig. 39) are closed, they cause the highest possible vacuum at slower engine speeds.

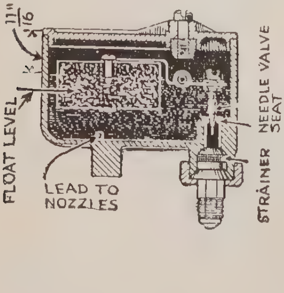


Fig. 38

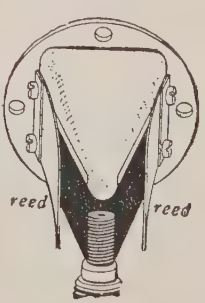


Fig. 39

Fig. 38. Float mechanism of the Tillotson carburetor, used on the Overland. Note the level of gasoline.

Fig. 39. The reeds. In Fig. 37 the reeds are placed above and on the sides of the nozzles.

The reeds open and close according to the speed of the engine. These reeds are so placed that as they move they form a virtual variable venturi. A secondary nozzle comes into operation at higher speeds and is not in use at the lower speeds.

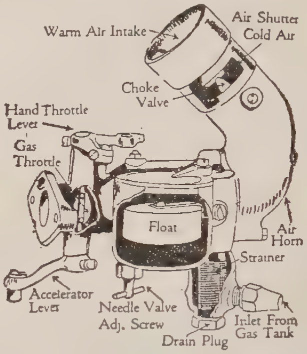


Fig. 40. Tillotson carburetor as used on Overland 4.

To adjust the carburetor, set the choke valve in full open position, after running the engine until it is warm. Push in the throttle-control button to its lowest operating point and pull out the spark lever about three notches. Slowly close the needle valve, by turning to the right, cutting down the amount of gasoline, until the engine starts to miss because of too lean a mixture. Then open the needle valve slightly, so that the engine begins to fire regularly. Push in the spark-control button and accelerate the engine either by hand or foot controls. If the engine backfires, or pops in the carburetor, increase the amount of gasoline by opening the valve slightly. Continue this until the engine fires regularly when suddenly accelerated. The engine should always be allowed to run for half a minute after it is slowed down before another attempt is made to accelerate it.

Another adjustment that is occasionally required is that of the sliding air shutter mounted on the air horn of the carburetor. In cold weather it will be found advisable to close this shutter, insuring warm air for the gas mixture. In the warm seasons this shutter should be opened.

The Hudson Carburetor

The Hudson carburetor operates upon the pneumatic principle and may also be termed the "metering-pin" type, and the "measuring-pin" type of carburetor. A glance at the sectional view of the carburetor (Fig. 41) will show clearly the operation. When the throttle is opened with the engine running, the suction is communicated to the air chamber by way of the pneumatic control passage (Fig. 42). This causes the piston to rise and with it the metering pin (A, Fig. 41).

The metering pin has a V-shaped slot cut in it, and as the pin rises or falls, according to the engine's requirements, it changes the area of the slot at the gasoline feed regulator, and consequently controls the amount of fuel passing through.

The proportioning of the mixture is automatic at all speeds, the piston giving instant response to the demands made on the engine.

Adjustments can be made entirely with the dash controls. The air-control adjustment is used only for starting the engine in cold weather, or after it has been standing for any length of time. Once the engine is running, it should be operated with the air-adjustment valve open.

The gasoline adjustment enables the driver to have the mixture as rich or lean as desired, by varying the amount of fuel allowed to pass the metering pin. This is done by raising or lowering the gasoline feed regulator which surrounds the metering pin. This regulator is actuated by the "Gas" button on the dash.

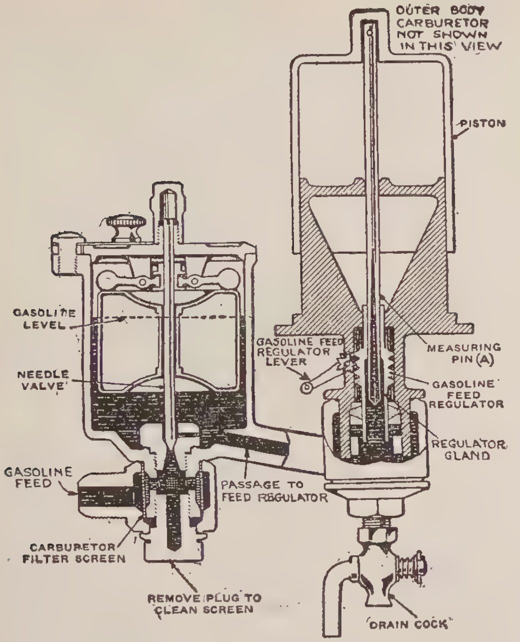


Fig. 41. View of the Hudson carburetor. Note the gasoline level.

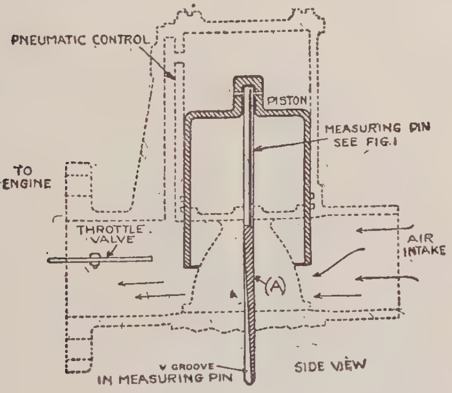


Fig. 42. Pneumatic control.

When the radiator shutter (see Index under "Radiator shutter") has been adjusted, so that the motor temperature maintains the red fluid in the motometer (see Index for meaning of "Motometer"), at the center of the circular opening, the engine will operate very economically on a lean mixture. Of course, heavier duty placed on the engine, such as hill climbing, pulling through sand, high speed, etc., places proportionate demands upon the amount of fuel, but in ordinary driving at speeds of 20 miles per hour upwards, the **carburetor should be adjusted as lean as possible.**

Too rich a mixture results in carbonization and misfiring; too lean a mixture gives less power and acceleration at low speeds. The entire range of adjustments is convenient to the driver.

Carburetor attention: Make sure, periodically, that the piston is clean and that the packing gland is tight. A sticking piston will seriously interfere with the action of the carburetor, and a loose packing gland will permit excessive gasoline consumption with its attendant troubles.

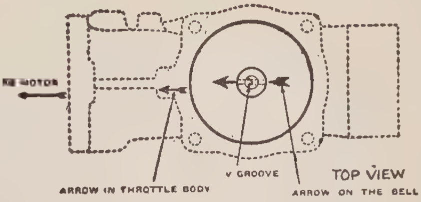


Fig. 43

Instructions for assembling measuring pin and piston: When assembling the metering pin and also the air bell to the throttle body (Fig. 43), be sure the arrow on the bell points in the same direction as the open end of the V-groove, and that the arrow on the bell also points in the same direction as the arrow in the throttle body.

Stewart Carburetor (on the Dodge)

On the Dodge the carburetor (Figs. 44, 45) is on left side of the engine, and is fed from a Stewart vacuum tank. The carburetor is supplied with a hot-air attachment which draws air from around the exhaust manifold to the air inlet.

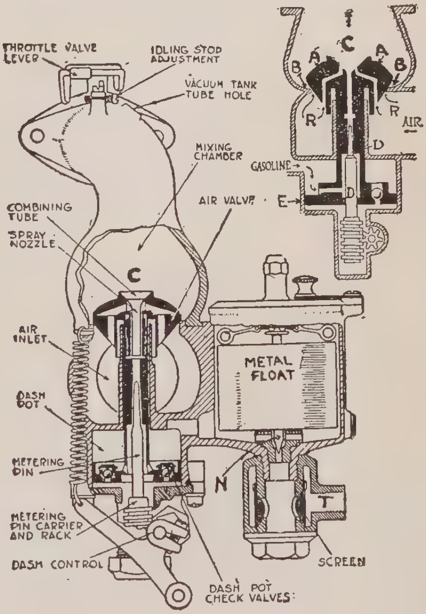


Fig. 44 (upper). How the metering pin **D** varies the mixture in the Stewart. Air passes through the passages **R** around the nozzle.

Fig 45 (lower). There is only one adjustment and that is the metering pin, which is interconnected with the dash control Ordinarily the metering pin should be two-thirds the way through.

Principle (Fig. 44): The automatic metering valve (**A**) rests on the valve seat (**B**) when the engine is not running. As the engine begins to rotate the suction of the pistons raises the valve (**A**) from the seat drawing in air (**R** to **B**) as indicated by arrows. The suction also draws gasoline up within the valve stem which mixes with incoming air in chamber (**C**).

The one adjustment of the Stewart is that of proportioning the volume of gasoline to the air admitted. The air being always a fixed factor, it is only necessary to adjust or regulate the volume of gasoline admitted which is controlled by means of the tapered metering pin (**D**).

This adjustment is made when the engine is running at idling speed. Turning the adjusting screw (on "dash control," see lower part of Fig. 45), either to the right or left, raises or lowers the position of the tapered metering pin, thereby allowing an increased or decreased supply of gasoline to be drawn up into the mixing chamber. When the proper proportion has been determined at slow speed, it will be seen that as the speed of the engine increases, the automatic metering valve (A) will rise higher from the seat (B) and away from the tapered metering pin (**D**), which will allow a greater supply of both gasoline and air, in exactly the same proportion, to be admitted to the cylinders.

On the Dodge (Fig. 45) the tapered metering pin is subject to control within fixed limits by means of the "dash control" ratchet (see lower part of Fig. 45 for connection), for the purpose of obtaining a rich mixture for starting. Should there be any reason for **changing the fixed adjustment** of the tapering metering pin (D), it can be done by turning the stop screw adjustment on the "dash control" (see lower part of Fig. 45). Turning it to the right lowers the position of the metering pin and allows more gasoline to be admitted to the spray nozzle, enriching the mixture. Turning it to the left raises the pin and decreases the supply. The **throttle valve** is in the top of the carburetor.

Ball & Ball Single Carburetor

The Ball & Ball single carburetor is used on the Studebaker "Big Six" and on many other cars (the Stromberg "LS" is also used on the Studebaker). In Fig. 47, the first and second-stage throats are plainly indicated.

Prior to making carburetor adjustment the following points should be thoroughly covered: (1) See that the spacing of the points in the spark plugs are set properly, or to .025". (2) See that the breaker points on the interrupter are set to .020". (3) See that the cylinders have good compression. It may be that some of the tappets are holding the valves partly open.

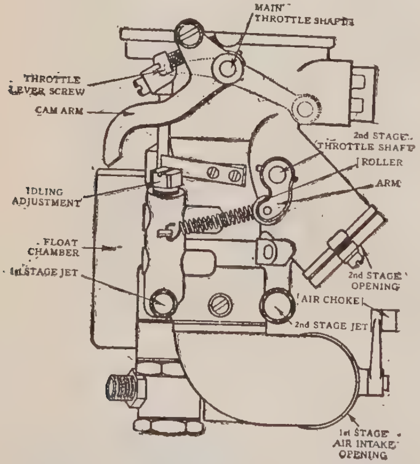


Fig. 46. Ball & Ball single carburetor designed for 4 and 6-cylinder engines.

Operation: Through a given range of throttle-opening all the gas is drawn through the **first stage** throat. The capacity of the first stage is sufficient to take care of all level road speeds up to approximately 40 or 45 miles per hour.

Fig. 46 shows clearly how the **second stage** is brought into action by opening the main throttle to its extreme position. The cam arm, integral with the main throttle shaft, coming into contact with the roller on the arm of the second stage throttle shaft causes the second stage throttle to open under additional pressure. The resultant action is to draw an additional or secondary supply of gas mixture through the second stage throat, as shown in Fig. 47.

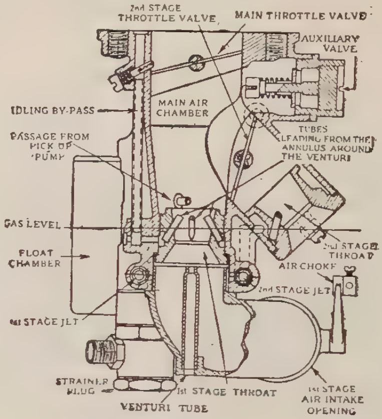


Fig. 47

Briefly speaking, the first stage furnishes all that is desired in what might be called the touring range, giving ideal economy and ample power for all ordinary purposes up to 40 or 45 miles per hour. The secondary stage supplies everything desired over and above the first stage in the form of added acceleration, power, and speed.

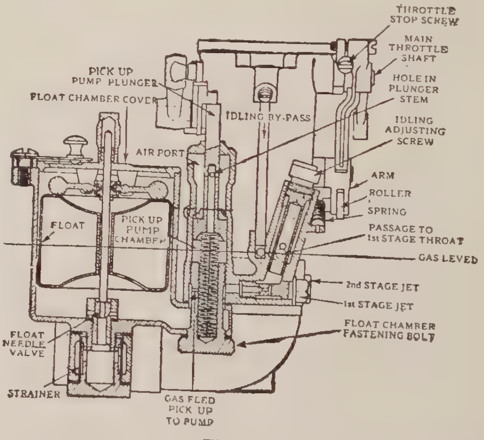


Fig. 48

In detail, the gasoline is fed into the float chamber through a removable cylindrical strainer (Fig. 48). From the float chamber the gasoline is fed separately to both first and second stage jets of the fixed orifice type (Fig. 47). In Fig. 48, the gasoline feeding to the first stage throat after leaving the first stage jet, passes through a tube, adjustable in height, known as the "idling adjustment screw." By raising this screw the idling mixture becomes leaner; by lowering the screw, the mixture is made richer. **This is the only adjustment on the carburetor,** aside from the throttle stop.

The pick-up device consists of a spring-operated plunger pump (Fig. 48) which receives a supply of gasoline directly from the float chamber through a small hole in the float-chamber fastening bolt. The gasoline fills the pump chamber to the level of that in the float chamber. In opening the main throttle, the "pick-up plunger" is depressed, which results in gasoline being forced out through holes in the plunger stem and carried into the main air chamber of the carburetor along with the air drawn through ports at the top and side wall of the pump chamber. The resultant action is to supply additional gasoline required for "quick get-away." This construction, on account of the time required to fill the pump, is such that the engine cannot be flooded by excessive repeated opening and closing of the throttle.

The idling by-pass consists of a tube through which a sufficient amount of gas mixture is taken in above the throttle valve to keep the motor running when the throttle is closed.

The choke valve is located below the first stage throat for the purpose of starting, and also may be used in a partially closed position to enrich the gas mixture until the motor warms up.

The only adjustment that can be made is the idling adjustment previously explained. This produces no effect whatever on the running of the car except when the throttle is closed to the idling position. The richness of mixture at all speeds above idling, is determined by calibrated orifices in the first and second stage jets respectively.

The possible troubles that might interfere with carburetion are insufficient gasoline supply or obstructions lodging in the carburetor passages.

To test for insufficient gasoline supply, remove the float chamber cover (see Fig. 48) and float, and note if gasoline flows freely. The gasoline strainer at the bottom of the float chamber may have become clogged.

In looking for obstructed passages in the carburetor, remove the first and second stage jets and carefully examine the jet orifices, keeping in mind that an almost imperceptible obstruction will reduce the jet capacity. Blowing through the orifice is generally effective, or, in addition, the opening may be cleaned out by means of a small wire.

For starting in cold weather, first, pull the choke button all the way out; second, open the throttle slightly and start the engine; third, as soon as the engine starts, push the choke button in part way; fourth, when the engine is warm, push the choke in all the way.

Ball & Ball Double Carburetor

The Ball & Ball double carburetor is used on 8 and 12-cylinder "V"-type engines.

First or primary stage, when starting and under usual running conditions: (1) is the hot-air passage of the primary carburetor containing the choke valve (2). (3) is the primary venturi throat connecting the hot-air passage with the mixing chamber (6), and containing the gasoline jet (4). (5) is another fixed air regulating orifice connecting the hot-air passage (1) with the mixing chamber (6) and provided with a spring-opposed idling valve (7) arranged to control the air when small quantities only are being used. (8) is a throttle valve of the usual type. The parts so far described constitute the first stage.

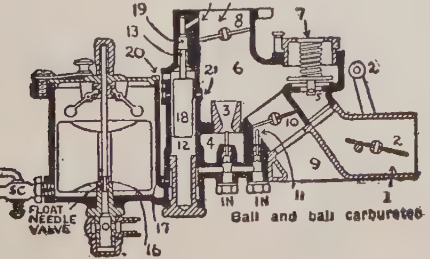


Fig. 49. Ball & Ball double carburetor, as used on the Peerless, King, Oldsmobile, and other "V"-type engines.

Second stage, or when throttle is wide open for full power: (9) is an air passage leading from the external air to the mixing chamber (6), and it contains the butterfly valve (10), arranged to control the flow of air through this passage. (11) is a gasoline jet arranged to discharge gasoline into the passage (9), when the valve (10) is opened, causing the gasoline jet (11) to be acted on by the suction of the mixing chamber (6). The air passage (9), with the gasoline jet (11), constitutes the second stage which is brought into action by opening the butterfly valve (10). A connection between the butterfly valve (10) and the throttle valve (8) (not shown) is so arranged that when the throttle valve (8) is nearly wide open, the further opening of this valve throws the valve (10) wide open. At all other times, the valve (10) is held closed by a spring (not shown).

From the foregoing description, it will be seen that under all the usual running conditions of the engine, the primary carburetor, or first stage only, is in service, and the second stage comes into service only when the throttle is thrown wide open for full power. The effect of this arrangement will be described farther on.

Pick-up device: Continuing the description (12) is a cylindrical chamber with an extension (13) of reduced diameter connected by the passage (14) with the chamber (15), above the throttle valve. The chamber (12) is connected with the float chamber (16) by means of the restricted passage (17), so that the gasoline at all times in this chamber (12) stands on a level with the level in the float chamber. (18) is a loosely fitting plunger with an extension (19) on its upper end, forming a piston in the chamber (13). An atmospheric opening (20) is located in the wall of chamber (12), and a passage (21) leads from chamber (12) to the mixing chamber (6) through which passage air is constantly drawn into the mixing chamber.

Operation of the pick-up device: It will be seen that in the operation of the engine, when the throttle is closed, the vacuum of the manifold acting on the piston (19) causes the plunger (18) to rise to its upper position, thus closing the passage to the chamber (15). The space below the plunger (18) is now filled with gasoline from the float chamber, and the mechanism is ready for action.

The opening of the throttle (8) breaks the vacuum in chamber (15) and releases the plunger (18), which falls and displaces the gasoline underneath the plunger, causing it to flow into the space above the plunger, where it is quickly discharged through the passage (21) to the mixing chamber, thus augmenting the normal supply of gasoline and causing a rich mixture to momentarily enter the cylinder. This develops a strong pick-up.

Adjustments: There are no adjustments after the size of jets is determined.

Air regulation: The amount of air is controlled by valve (2) which is operated by the choke-rod handle on the dash or steering post. For cold weather this valve (2) should be closed to draw in a rich mixture. Immediately the engine starts, push it down part of way until engine is warm, then close entirely. Don't open the throttle at all when (2) is closed, and don't run with (2) closed any more than possible.

Troubles: Dirt under the float valve will cause dripping; unscrew the cap over the float-needle valve and give it a few turns. Water or dirt may lodge in small openings and this is indicated by popping and missing. Close the valve on the gravity tank, remove four nuts at bottom, and clean jets.

Packard Carburetor

The primary air intake elbow (30, Fig. 50) is at the front end of the carburetor. The elbow contains a shutter (28) which is normally open and not in use when running. This shutter is operated by the "carburetor control" on the instrument board, which also operates the auxiliary air valve (34).

By pulling the control all the way out, the primary air intake is completely closed, allowing a very rich mixture to be drawn into the cylinders. The control should be pushed in, at least part way as soon as the engine has started firing.

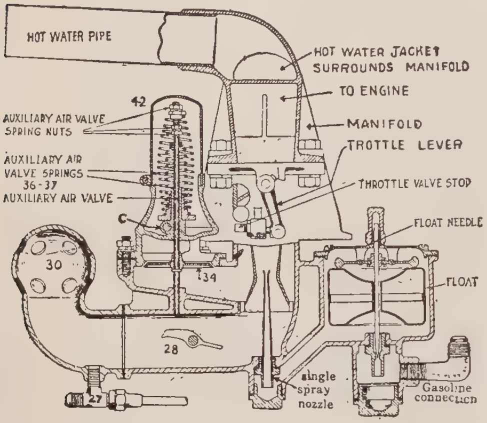


Fig. 50. Packard carburetor.

The auxiliary air valve (34) is in a housing (42) forward of the mixing chamber, and is controlled by the tension of two springs, one of which is within the other.

At low engine speed most of the air is admitted through the primary air intake (30) around the spray nozzle.

To prevent too rich a mixture at a greater throttle opening, the auxiliary air valve (34) is opened by the increase in the vacuum, admitting the right proportion of air to meet all conditions.

Carburetor adjustment: There is only one carburetor adjustment which directly affects the mixture, and this is the auxiliary air-valve adjustment. This adjustment is made by changing the tension of the air-valve springs (36, 37). This is changed by either of two methods, the first being through the operation of cams (C) at the lower ends of the springs. Raising the cams increases the pressure of the springs, and lowering the cam decreases the pressure. Increasing the pressure produces a richer mixture, and decreasing the pressure makes a leaner mixture.

These cams are controlled and operated by the air-valve control on the instrument board.

The large outer spring is at all times under tension, but the smaller inside spring is not normally under pressure until the valve opens up a little.

The other adjustment of the springs is made by changing the position of the nuts on the stem of the valve. There are two sets of nuts, one for each spring, and they allow individual adjustment of the springs.

Under ordinary conditions, and with the engine warm, the control on the instrument board should be set at the No. 4 notch. Pulling the rod out makes a richer mixture and pushing it in makes a leaner mixture.

Caution: In warm weather, or if the engine is warm, the mixture may be so rich, if the knob is pulled out, that the charge will not ignite and the surplus of unburned gasoline may interfere with the proper lubrication of the cylinder walls.

For idling, the throttle valve is held very slightly open to allow a very small amount of mixture to go to the cylinders. If the engine races or stalls when the throttle is closed all the way, the stop screw needs adjusting.

The float chamber vent tube (27) is for two purposes: (1) to give air to the float chamber to prevent a vacuum being formed; (2) to drain surplus gasoline from the chamber around the spray nozzle when the engine is suddenly throttled down.

The latest Packard carburetor is equipped with a fuelizer. With the present-day gasoline, which is heavy and slow to vaporize, when first starting and until the engine is thoroughly heated, raw gasoline often passes into the cylinders which not only produces carbon, but thins the lubricating oil on the cylinder walls and passes to the crank case and dilutes the oil. The engine also frequently misses when cold.

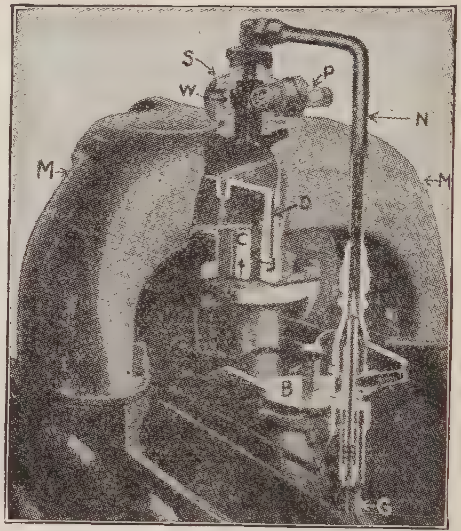


Fig. 51. The later Packard carburetor (**B**) is the same as in Fig. 50, except that the Fuelizer is attached to the intake manifold and a gasoline connection (**N**) is provided for the Fuelizer.

To heat the mixture and provide complete combustion within 20 seconds after starting on the coldest day, the Packard Co. has developed a device to heat the mixture, called a "Fuelizer."

The "Fuelizer" consists of a small supplementary carburetor (S) and a burning chamber where the gas from the little carburetor is burned. This chamber is situated in the intake manifold (**M**). When the gas enters, it is ignited by a regulation spark plug (**P**), and passes into the fresh charge going from the carburetor to the cylinders through wall (**D**) to (**C**). The heat of the burned gas changes the wet, poorly carbureted mixture to a dry vapor, which combusts with full efficiency when it is ignited by the spark in the cylinder.

The action of the Fuelizer is entirely automatic, without involving a single moving part. When the engine is starting, the Fuelizer is in full operation, and the heat supplied to the charge becomes less as the throttle is opened. This regulation is provided by an air valve similar in operation to the air valve of the main carburetor.

Through a small Pyrex glass window (**W**) the operation of the Fuelizer may be seen. A perfect mixture produces a purple flame, a fairly rich mixture produces a bluish-green flame, and an exceedingly rich mixture is indicated by yellow streaks in the flame.

(**B**) is the regular carburetor and (**G**) is the gasoline pipe connection to it from the gasoline tank, which feeds the carburetor in the usual manner. (**N**) is a pipe which is also connected with the gasoline pipe line at the gasoline connection on the carburetor and which feeds the Fuelizer. See page 108 for a detailed description of the Fuelizer.

Dave Buick Carburetor

Note. This carburetor is not the carburetor used on the Buick car. For the carburetor that is used, see the Marvel, page 126. The Buick carburetor is used on the Briscoe and some other makes of cars.

Construction: In the Buick carburetor, the float chamber surrounds the aspirator, which is in the form of a hollow tube with very small holes in the side toward the intake pipe of the motor.

The air coming into the carburetor strikes a hinged plane, which is raised or lowered as the amount of air is increased or decreased. This hinged plane is connected with the hollow aspirator tube, which rises and falls with it as the quantity of air changes. As the aspirator tube rises in its guide, more of the holes are uncovered, and more gasoline is drawn into the intake pipe. This construction assures the correct proportion of air and gasoline under all conditions.

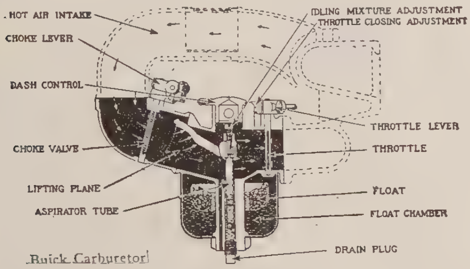


Fig. 52. Dave Buick carburetor.

At the top of the carburetor, the **auxiliary dash control** is fitted. This is simply a damper which admits additional air to the mixture. It can be used when coasting. By opening this control as far as possible, the leanest running mixture can always be secured.

The choke, which is also operated from the dash, reduces the air supply by closing a damper in the air intake, and at the same time raises the aspirator tube and allows additional gasoline to be taken into the motor. The choke may be used in starting when the engine is cold, and, if necessary, held partly out until warmed up.

The float chamber may be drained by removing the plug in the bottom. This can be done for flushing out dirt which may lodge in the float valve, causing dripping.

Adjustment: The idling mixture may be regulated by removing the auxiliary air cap from the top of the carburetor and slightly turning the screw directly below. Turning the screw to the left richens the idling mixture; turning to the right makes it leaner.

The Carter Model "N" Carburetor

This model is used on the Dort. The models "H" and "L" are similar. This carburetor is a "multiple-jet" type of carburetor.

A choker button is provided on the dash to enable the operator to obtain a correct mixture under all climatic conditions. To secure maximum economy run the car with the choker button pushed in as far as possible. When the engine is cold it will be found necessary to pull the button out as far as possible to aid in starting. It must be pushed in gradually as the engine warms up till, when thoroughly warm, it will be clear in or at regular running position.

An air-control band (Fig. 53) is provided on the hot-air sleeve for admitting additional cool air in hot weather. In cold weather the band should entirely cover the ports. It may be set at any point between full open and full closed positions at the option of the driver, according to temperature.

The throttle lever on the carburetor is provided with adjusting screws (Figs. 53 and 54). The purpose of these screws is to hold the throttle open far enough to keep the engine running when the throttle lever on the steering wheel is closed all the way and the engine is idling. If the engine runs too fast at idle speed the adjusting screw should be turned very slightly to the left, to bring the throttle nearer to closed position.

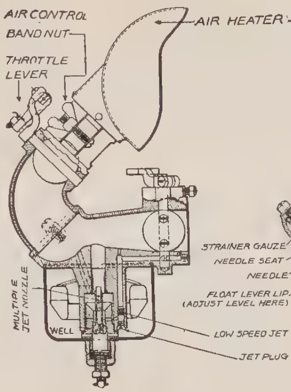


Fig. 53

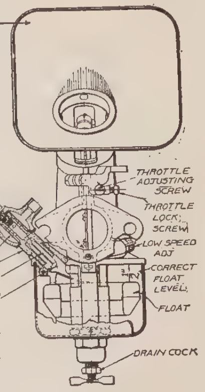


Fig. 54

A low-speed adjustment is provided to regulate the strength of the mixture at idle engine speed (Figs. 53 and 54). Turning the screw in makes the mixture richer; turning the screw out makes it poorer.

To properly adjust, close the throttle lever, retard the spark lever, turn this screw out till the motor misses on account of the mixture being too lean, then turn the screw in just enough to get the engine hitting properly. This will give the most economical setting at low speed and helps to secure proper acceleration. This adjustment should be made when the engine is thoroughly warm.

The float level: When the needle valve is closed, the top of the float should be exactly ½″ from the carburetor body. If the float has been moved from this position, it can be restored by bending the float lever lip where it touches the needle. Only a very slight bend is necessary. This is a delicate mechanism. Handle it with care.

The strainer will, as a rule, keep all dirt from getting into the needle seat, but some small particles may get through from time to time and cause the carburetor to leak or flood. When this occurs it is necessary to take out the needle and seat and to clean them thoroughly. To do this, first, take off the strainer, then unscrew the needle seat. Both needle and seat will then come out and may be wiped clean and tested. If the needle does not seat tight, it may be reseated by giving it one light tap. Never try to grind the needle to a seat.

Dirt may also cause a loss of power or uneven running by lodging in the jets, and it is often possible to clean these jets by choking the carburetor and in that way drawing the dirt on through. It is best to do this when the car is running in high gear at 25 miles per hour. Open the throttle wide and at the same time pull the carburetor choke-rod button out as far as possible, holding it in this way for two or three seconds and keeping the throttle open; then push the choke-rod button and gradually close the throttle as the engine commences firing again.

Miller Carburetor

The Miller "H" is a "multiple-jet expanding carburetor" of the rotary or barrel throttle type.

Four to six main jet tubes are used depending on the size of the carburetor, and these tubes, having

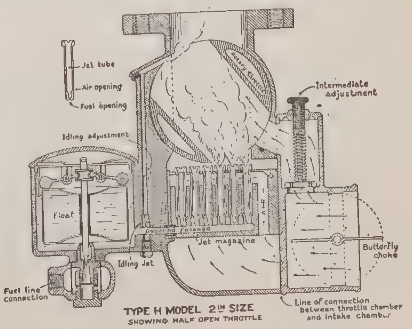


Fig. 55

each the fuel jet in the bottom and four small air holes a little above, are placed in a row in a removable magazine. This magazine has a fuel passage which supplies the jet in the bottom of the tubes and provides an air jacket which surrounds the main portion of each tube; these jacket spaces have a passageway near the top of the magazine above the float level that connects them with each other and with the outside air.

When not in action the tubes and surrounding air-jacket spaces are filled with fuel which provides a succession of puddles as the throttle is opened and the tubes brought into action one after another. Each tube, when the puddle has been drained, begins to function as a miniature carburetor with fuel entering at the jet in the bottom and air being supplied through the four small air holes just above.

By this design the fuel goes through a "two-stage" atomization process; the first in the bottom of the tubes, where a heavy spray is formed, and the second in the venturi of the carburetor, where the spray unites with the main air column. The main feature of this construction is the fact that the fuel flows through the jets by gravity from the float chamber and combines with the air of the first stage at a point below the float level. This brings the partially atomized fuel out of the tube and into the venturi for the second stage without the choke restriction necessary to create a depression at this point.

Two exterior adjustments are provided. The first is for **idling** and is a control of the idling speed air by means of a screw in the passage. The second adjustment is for **intermediate speeds** and has its principal effect on the first third of the throttle range. It amounts to a control of the spring tension on a poppet valve which admits a certain amount of air during the first part of the throttle opening when the vacuum is at a relatively high point. This adjustment has its greatest effect as a control for pick-up, and consequently is also an adjustment for economy.

The air intake is made in two sections, with an adjustable clamping ring at the joint. The second section can be supplied as a vertical elbow which can be set at any angle required for the hot-air tubing. At the intake connection a butterfly valve is provided as a choker or strangler for starting; this is operated by a flexible wire control from the dash.

The carburetor here described is the same in all respects except for the two exterior adjustments as the instrument which the Miller company has been making in large sizes only for marine and aeronautical engines in past years.

The Claudel Carburetor

The Claudel carburetor, widely used in Europe for a number of years, is now being manufactured in the United States by the Claudel Carburetor Co., Long Island City, New York.

This carburetor was used on the Sunbeam engines of the British dirigible R-34 which made the first round trip across the Atlantic. It was also used on the Rolls-Royce engines of the Vickers-Vimy aeroplane, which was the first plane to make a non-stop trip across the Atlantic. It was also used by Sadi Lecointe, the French aviator, who set a world's record of 232 miles per hour.

The design of the European model has been changed somewhat to meet the particular requirements of American cars, and such features as quick starting and rapid acceleration when cold have been provided for.

The carburetor itself is a "plain-tube" automatic compensating unit which has no moving point.

The principle used is that of breaking up the gasoline by a swift current of air which makes an emulsion inside the jet itself before delivering it to the carburetor proper.

The Claudel is really a combination of two types of jet, one, the main jet, of constant flow per unit of time; the other, shown as a series of nozzle holes, of suction-controlled flow.

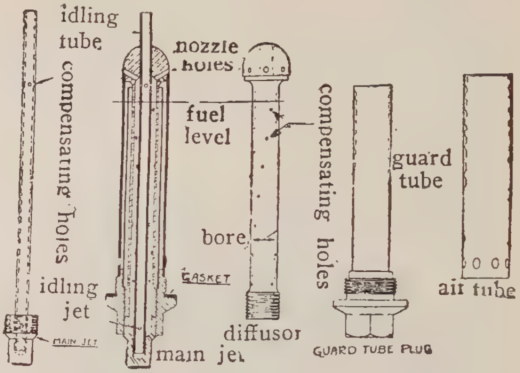


Fig. 56. Diffusor of the Claudel carburetor in section, and in its components.

Fuel from the float chamber flows through the main jet into the diffusor, then through the compensating holes into the reservoir of diffusor bore. It also flows through the idling jet into the idling tube, the level in the three tubes being the same as that in the float chamber.

Air at atmospheric pressure enters the outside base or air tube of the diffusor column, passes up this outer sleeve and over the top of the gasoline guard tube which prevents the fuel from overflowing.

As the throttle is opened gradually and the suction in the diffusor increases, thereby lowering the liquid level in the diffusor bore, a series of air-bleed or compensating holes are progressively uncovered. Through these holes the air rushes into the ascending column of gas vapor and out of the nozzle holes at the top of the diffusor in a finely broken-up gasoline emulsion. The higher the suction acting upon the diffusor, the lower will be the level of gasoline within it, and therefore, more of the compensating holes will be uncovered, permitting a greater dilution of the mixture.

At the higher speeds, the diffusor is practically emptied and twenty-one spirally arranged air-bleed holes are in action. As the gasoline globules are lifted by the suction, they must pass through a barrage of twenty-one air guns shooting at right angles into the ascending fuel. This turbulent mixing effect produces a finely divided fuel emulsion, ideal for rapid-flame propagation, extreme economy, and high power. The diffusor discharge is in approximately the ratio of fifteen parts of air to one part of gasoline by volume. This thorough intermixture of air and gasoline before it enters the carburetor barrel is the Claudel method of breaking up the heavy fuel of today for extreme economy.

The idling device is incorporated in a central tube projecting up into the depression of the barrel throttle where a strong pull is exerted on the idling jet for low-speed action. The barrel throttle is slotted to pass around the idling jet for low-speed action. The rotary or barrel throttle is slotted to pass around the idling jet, and **the only adjustment on the carburetor** is a screw extending into the air space to partially block off the area of this slot as desired. Screwing it in lessens the air area and enriches the idling mixture. Screwing it out makes the mixture leaner.

In the American type of Claudel shown in Fig. 57 a decided improvement has been incorporated for strangling the air by means of a sliding air cone (**A**), which, when in strangling position, fits snugly into the venturi entry (**V**). This cone is controlled from the dash. This device assures quick starting and warming up in cold weather. The streamline air cone, concentric with the diffusor, may be raised into contact with the venturi, shutting off the air supply and putting the full suction on the diffusor. In this position it is only necessary

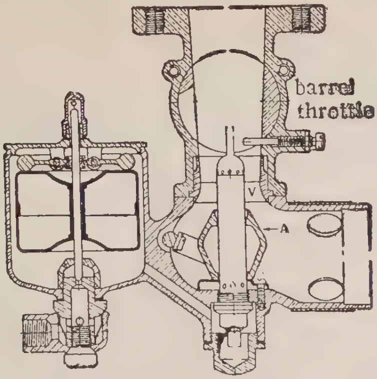


Fig. 57. Section through the standard American design of Claudel carburetor.

for the cylinders to exhaust the air in the top of the carburetor before the diffusor discharge must commence. This action is instantaneous, as the volume is small.

Master Carburetor

A sectional side view of this carburetor is shown in Fig. 58.

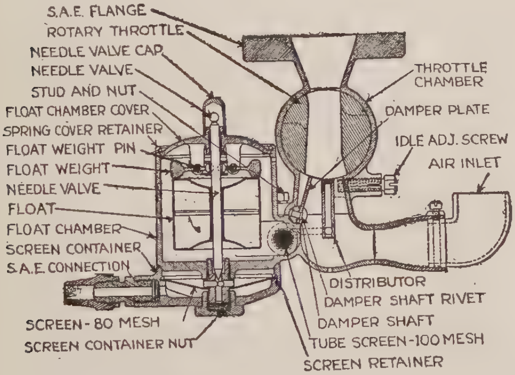


Fig. 58. Sectional view of the Master carburetor.

The fuel distributor (Fig. 59) is placed across the mixing chamber, the number of its jets varying from 11 to 19, according to its size. Each of these tiny jets occupies a different position in the path of the inrushing air, thus forming a perfectly atomized fuel that is instantly and thoroughly mixed with the air, the two elements being merged into one.

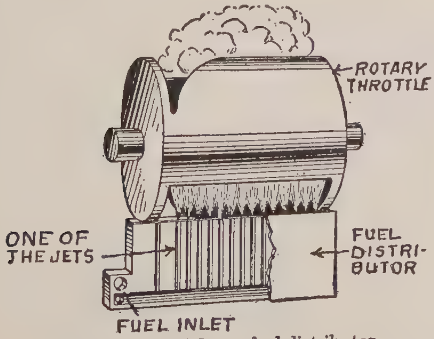


Fig. 59. The Master fuel distributor.

When the throttle is closed, a single hole remains uncovered to admit a supply of fuel that is ample for idling or for slow running. As the throttle is opened the additional holes are uncovered, one by one, and the fuel supply increased.

The rotary throttle eliminates the butterfly throttle which is extensively used in other makes.

As stated above, the fuel openings are fixed, but the air opening can be varied through the use of the positive control which operates the **damper** in the carburetor. The changing of the damper position, which increases or decreases the volume of air passing the distributor, increasing or decreasing suction on the jets, gives the widest possible mixture range.

The air supply is constricted by the damper at the outlet, like a variable venturi. When the lever on the steering-post control (which is connected to the damper), is pulled to "rich" position, the venturi (or opening) paralleling the row of 11 to 19 jets is very small and the pure gas rushes to the engine under tremendous suction, thus enriching the mixture so that quick starting, even with a cold engine, is easy and certain. As the engine picks up speed, the mixture may be modified by decrease to any mixture required.

Rapid acceleration. Do not open the throttle suddenly. A gradual opening will give quicker get-away and save wear and tear on the motor.

Idle adjust-screw. For perfect idling of the engine set the control lever in center position. If the engine rolls or gallops at idling speed, back out on idle adjust-screw. If the engine seems not to have sufficient gas at idling, screw the idle adjust-screw in. Turning it to the right enriches the mixture coming from the idle hole only.

Fuel distributors of various capacities are available for each size carburetor. Should the engine run and pull best with control in rich position at ordinary speeds, you should have a distributor of greater fuel capacity. Should the engine take all the air possible to give it at idle speeds, you should then have a distributor of less fuel capacity. The letter on the end of distributor designates its fuel capacity. See below for sizes.

Control centers are numbered at the base of the lever and care should be taken to see that the proper control center is used with the different sizes of carburetors.

Those stamped No. 1 are for 1" and 1¼" JR carburetors. Those stamped No. 2 are for 1¼" STD and 1½" JR carburetors. Those stamped No. 3 are for 1½" and all larger sizes. Manufacturers are the Master Carburetor Company, Box 444 Sta. C., Los Angeles, Cal.

Carburetor on the Maxwell

The Eagle carburetor used on the Maxwell engine is an "air-valve" type of carburetor.

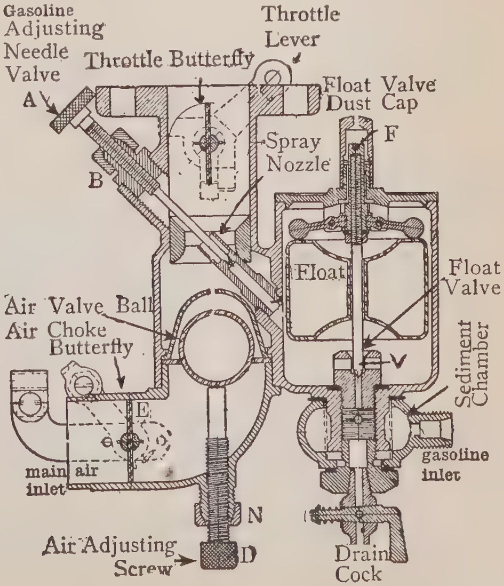


Fig. 60. Sectional view of the Eagle carburetor.

An air-ball valve is placed in the main air inlet, which thus controls all air passing the spray nozzle.

At low speeds the ball permits only a small quantity of air to pass. **At high speeds** the ball is raised by the greater suction of the piston, and thus more air is admitted.

Adjustment: Loosen lock nut (B) and turn the gasoline adjusting needle valve (A) to its seat and set the stop screw on the throttle valve to approximately the correct position for idling. Then open adjusting needle valve by turning to the left three-quarters of a turn. With this adjustment the engine can be started.

The engine should be run long enough to be warmed up to service condition. Be sure that the choker butterfly valve (E) is open when making adjustment.

Then retard the spark control, open the throttle until the engine is running at average driving speed. Next turn gasoline adjusting needle (A) to the right until the engine speed decreases from lean mixture. Then turn to left until the speed increases and again starts slowing up, which is as rich a mixture as engine can be run on. By turning again to the right to a point half-way between the two, when the engine speed is highest, the correct mixture for general driving will be obtained. Tighten lock nut (B), and the adjustment is complete.

The air-adjusting screw (D) is provided only for the purpose of controlling the air supply to the carburetor when running at low speeds. It may be possible that the adjustment on the gasoline adjusting needle is slightly too rich for idling purposes and will cause the carburetor to choke. By loosening lock nut (N) and turning the air adjusting screw (D) to the right, admitting more air, this condition will be eliminated. Tighten the lock nut, and the adjustment is complete.

Adjust the throttle-lever stop screw until the desired idling speed is secured. Adjustments should be made with spark and throttle fully retarded.

When starting with a cool engine, it is absolutely necessary to have choker butterfly (E) closed. This is operated from the dash and should be opened gradually as the engine warms up to conditions.

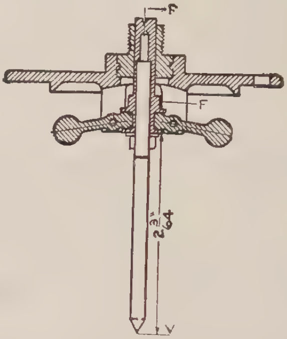


Fig. 61. If carburetor drips, it is usually due to dirt under the float needle valve (V). Remove the float dust cap, place a screw driver in the end of float collar (F) and turn gently back and forth, thus seating the float needle valve. Eagle Carburetor Co., Cleveland, Ohio.

ADDRESS OF CARBURETOR MANUFACTURERS

"Air Friction": The Air Friction Carburetor Co., Dayton, Ohio.
"Ball and Ball": Penberthy Injector Co., 1242 Holden Ave., Detroit, Mich.
"Breeze": Breeze Manufacturing Co., 254 South St., Newark, N.J.
"Buick": Buick, David Carburetor Corp., Wyandotte, Mich.
"Carter": Carter Carburetor Co., 2838 N. Spring Ave., St. Louis, Mo.
"Eagle": Eagle Carburetor Co., 11502 Madison Ave., N.W., Cleveland, Ohio.
"Holley": Holley Carburetor Co., Detroit, Mich.
"Johnson": Johnson Co., 1909 Forrest Ave. E., Detroit, Mich.
"Kingston": Byrne, Kingston Co., Kokomo, Ind.
"Master": Master Carburetor Co., 30th & Main Sts., Los Angeles, Cal.
"Marvel": Marvel Carburetor Co., Flint, Mich.
"Newcomb": Holtzer-Cabot Electric Co., Boston, Mass.
"Rayfield": Beneke & Kropf Mfg. Co., 2559 W. 21st St., Chicago, Ill.
"Schebler": Wheeler & Schebler, Indianapolis, Ind.
"Stewart": Detroit Lubricator Co., 5842 Trumbull Ave., Detroit, Mich.
"Stromberg": Stromberg Motor Devices Co., 58-68 E. 25th St., Chicago, Ill.
"Shakespeare": Shakespeare Co., Kalamazoo, Mich.
"Sunderman": The Sunderman Corporation, Newburgh, N.Y.
"Tillotson": Tillotson Manufacturing Co., Toledo, Ohio.
"Zenith": Zenith Carburetor Co., Foot of Hart Ave., Detroit, Mich.

For make of carburetor used on various cars, see Index under "Specifications of leading cars."

INSTRUCTION No. 15

COOLING THE GASOLINE ENGINE: Cooling Methods; Water Circulating Pumps; Fans; Radiators; Water Thermostats; Water Temperature; Water Cooling Troubles; Overheating of Engine; Non-Freezing Solutions; Air-Cooling Methods; Heating a Car.

WATER COOLING

If no provision is made for **cooling the cylinder of a gasoline engine,** the intense heat of the explosions would heat it to a point that would cause the lubricating oil to burn and become useless. At the same time, the cylinder must not be kept too cool, for that would prevent development of full power; the cylinder must therefore be permitted to get as hot as is possible without burning the lubricating oil. About 170° Fahr. or below the boiling point, appears to give the best results.

The cylinder may be cooled either by water or air, and while the greater number of engines are water cooled, air cooling has been developed to a point where successful results are attained.

The water-cooling system consists of jackets around the part of the cylinder that is to be cooled, through which water may flow; a **radiator** for cooling the heated water; and some method of keeping the water in circulation, together with the necessary connections (see Fig. 4). **The cylinder water-jackets** are usually cast in one piece with the cylinder. When heated, the water passes to the radiator tank, thence through the radiator tubes, where the rush of air to which it is exposed absorbs the heat, cooling the water, which then passes back to the lower water connections on cylinders.

The radiator system is always fixed in the forward part of the car, to obtain the full benefit of the draught of air. The same water is used over and over again, so that it is only necessary to replace the loss caused by evaporation and leakage.

It is usual with **radiator systems** to **have a rotary fan** to assist in inducing a draught of cold air through the radiator tubes and in accelerating the cooling when the car is moving slowly, as in hill-climbing or slow running in traffic. The fan is driven from the engine shaft by a belt or gear and fixed back of the radiator. The alternative method, which avoids the use of a separate fan, is provided by fan-vaned arms in the fly wheel.

WATER—CIRCULATING METHODS

The two systems of circulation are the "thermo-syphon" system and the "force" system.

Thermo-Syphon Water Circulation System

The thermo-syphon system of water circulation is as follows: Upon becoming heated, the water rises to the top, entering the pipe and passing into the radiator at top where it is brought into contact with a large cooling surface, in the shape of the radiator. On being cooled and thereby becoming heavier, the water sinks again to the bottom of the cooling system, to enter the cylinders once more and to repeat its circulation. The cooling action is further increased by a belt-driven fan which draws air through the radiator spaces. The connections are the same as for the force system, except that there is no pump, and the connection from the water-jacket outlet to the top of the radiator slants upward. It is more necessary to have clear passages for the thermo-syphon system than for the force system, because the pump, in the latter, will force the water past an obstruction that would stop the flow of water that moves only because of its heat.

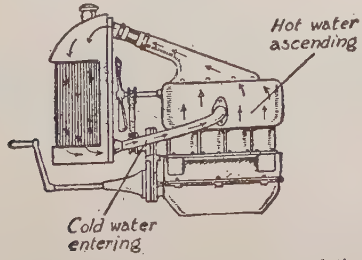


Fig. 1. Thermo-syphon principle of water circulation. See also page 155 for a typical example of a "thermo-syphon" system.

The height of the radiator with the thermo-syphon system must be higher and lower than the extreme top and bottom of the water jacket (see Fig. 1 and also, refer to page 155).

The height of water with the thermo-syphon system should be kept at level above top inlet of radiator to insure proper circulation. Below this point circulation ceases and water boils.

Keep the radiator full: When the cooling water is kept in motion by thermo-syphon action, it is quite important that the radiator be kept reasonably full in order that there be a back resistance to aid in forcing the water forward. It is good engine care to add frequently a little cold water, instead of waiting for the engine to knock, especially in summer.

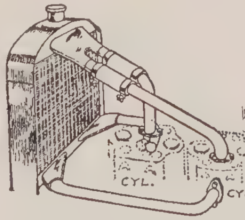


Fig. 2

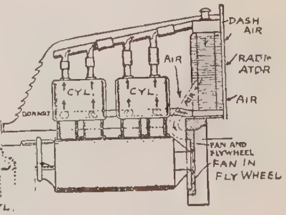


Fig. 3

Fig. 2. **A** thermo-syphon system in which independent pipes are taken from each pair of cylinders, the outlet pipes joining at the upper or tank part of the radiator. Cylinders in this instance are cast in pairs (obsolete). Where cylinders are cast in-block, one water inlet and one water outlet pipe will suffice, as in Fig. 1. See also, page 155.

Fig. 3. Simple thermo-syphon circulation without the use of a fan. The arms of the fly wheel are designed to act as fan blades; a separate fan is unnecessary, but the underpart of the engine must be carefully screened in (formerly used on Renault).

Force Water-Circulation System

In the force system, the engine drives a pump which keeps the water in constant circulation, as shown in Fig. 4. The pump forces the water from the bottom of the radiator to the inlet at the bottom of the water jacket, through which it flows to the outlet at the top, whence it goes to the top of the radiator, and flows through the radiator tubes to the bottom. As it passes through the radiator tubes it is cooled. After passing through in this manner, it is again drawn through the pump and forced again through the same path.

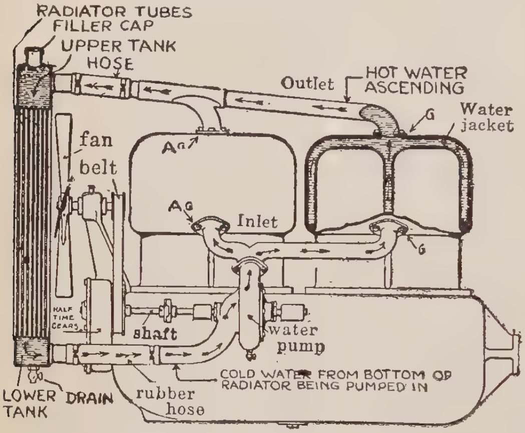


Fig. 4. This illustration shows how the pump shaft on the forced water-circulating system is usually driven, and also the fan. G are gasket connections which must be kept tight—usually made of copper asbestos-lined composition. The path of the water circulation is also shown.

Circulating Pumps

Practically **all water-circulating pumps are driven by a gear on the crank shaft or cam shaft,** so that motion is positive, and without slipping. All forced circulating systems must use a circulating pump.

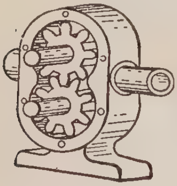


Fig. 5

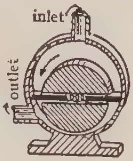


Fig. 6

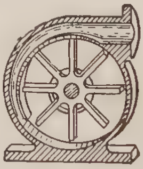


Fig. 7

Fig. 5. The gear type of circulating pump consists of two small gears with large teeth, the two being in mesh, and placed in a casing that fits as snugly as possible. The water enters at one side where the teeth separate and is carried around to the opposite side in the spaces between the teeth, where it escapes through an outlet.

Fig. 6. The rotary type of circulating pump consists of a ring-shaped casing, within which a disk revolves, the disk being "eccentric," or to one side of the center of the casing. Through a slot across the disk are two arms, their ends being pressed against the casing by a spring. As the disk revolves, the water is forced from the inlet to the outlet by the arms.

Fig. 7. The centrifugal pump acts on the principle of an air blower, and has blades projecting from a hub, which revolve at high speed inside of a casing. The water enters at the hub, and is thrown outward by the blades to the outlet in the casing. This is the type in general use.

There are three types of circulating pumps, in general use: the "gear" type, the "centrifugal" type, and the "rotary" type.

Cooling Fans

In order to cool the water sufficiently, **a fan is** driven by a belt attached to a special bracket on the engine. This is shown in Fig. 4.

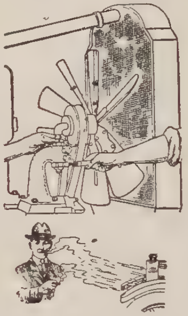


Fig. 9 (upper)
Fig. 8 (lower)

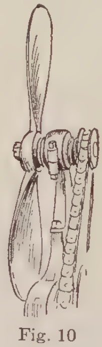


Fig. 10

Fig. 8 shows how the fan draws air in through the cores of the radiator to keep the water cooled. This demonstrates clearly the function of the fan, and shows how futile is its attempt to cool the radiator when a winter cover is placed over the radiator and is fully closed. There is no cooling action to the fan unless the front of the radiator is at least partially exposed. Often obstructions are placed in front of the radiator, as license tags, etc., which cut down the efficiency of the cooling system.

The fan draws a current of air through the passages in the radiator in addition to that driven through it by the forward motion of the car.

There are two types of fans in general use: the multiple blade (Fig. 9), and the two-blade (Fig. 10).

Fan adjustment: the belt can be tightened by raising the fan by an eccentric adjustment (Fig. 8A), or by bodily lifting the fan and its bearing and tightening a bolt holding it (Fig. 9).

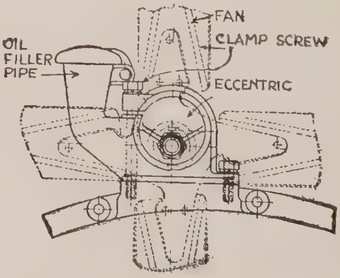


Fig. 8A

The belt should be kept tight. A slack fan belt often causes overheating. Ball bearings are usually provided and they should be kept well oiled. This is quite often overlooked.

RADIATORS

The purpose of a radiator is to keep the water, which circulates around the water jacket of the cylinders below the boiling point.

The early type of radiator (Fig. 11) consisted of a corrugated copper tank, with horizontal tubes running lengthwise of the tank. A tank was placed on each side of the body connected with the water jacket of the engine. A circulating pump was used to circulate the water. Modern constructions are shown farther on.

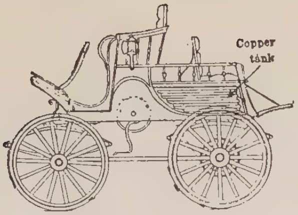


Fig. 11. One of the early methods employed for cooling the water.

The location of a modern radiator is usually in front of the engine, where it will come in contact with the air. The air passes between the tubes or fins on a tubular type of radiator and through the cells of a cellular type. A fan is usually placed directly behind the radiator, which is operated from a pulley on the crank shaft of the engine, for the purpose of drawing a large quantity of air through the radiator, thus increasing the cooling capacity.

Construction of a radiator: There is a reservoir or tank placed at the top and one at the bottom, as shown in Fig. 4. Between these two tanks, the tubes or cells are connected. A flexible hose pipe connection is made with the top and bottom tank from the engine, as shown. When the engine is running, the hot water passes to the top tank, thence downward through the radiator tubes (if a tubular type), or around the cells (if a cellular type), and is thus cooled. The cooled water then passes into the lower part of the engine from the lower tank of the radiator.

Radiators must be used with either the "forced-circulating" system, using a pump, or with the "thermo-syphon" system, which does not use a pump.

Types of radiators: There are two types in general use, the "tubular" and the "cellular," or "honey-comb."

The tubular type consists of vertical tubes placed between the upper and lower radiator tank. The **water passes** downward **through** all of the **tubes.** If one tube becomes clogged, then all of the water must pass through the other tubes. Each tube is a separate path through the radiator.

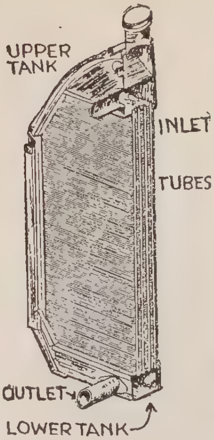
The cellular radiator consists of tubes or cells placed horizontally, through which the air passes and the **water flows** downward **around** these cells or **tubes.**

The honey-comb type of radiator was a term originally applied to a cellular type of radiator, due to its likeness to a honey-comb, but now that tubular type radiators can be constructed so as to have the appearance of a cellular radiator, the term could also be applied to the tubular type.

Tubular-Type Radiators

The tubular type of radiator used in 1900 and 1901 is shown in Fig. 13. The tubes were placed horizontally in heads (H). Crimped fins (F) were placed on the tubes. The radiator was suspended under the front of the car by studs (S). A pump circulated the water.

The vertical tubular type with "spiral" fins (F) (Fig. 14) was the next type introduced. These tubes were placed between an upper and lower tank (Fig. 4, page 146). This type is still in use, principally on trucks.



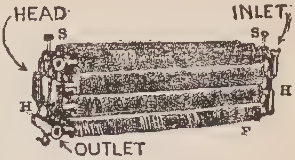
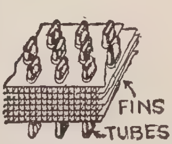


Fig. 13



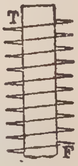


Fig. 12

Fig. 15

Fig. 14

The vertical tubular type with "flat" fins (Fig. 15) was the next type introduced, the idea being to have it resemble the cellular radiator which at that time was introduced on the Mercedes car. A tubular radiator made up with flat fins, is shown in Fig. 12.

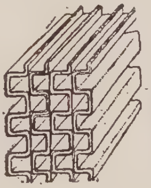


Fig. 16

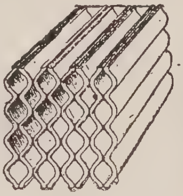


Fig. 17

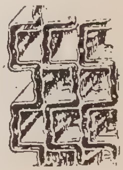


Fig. 18

Variations of construction of the tubular type radiator are shown in Figs. 16, 17, and 18. Note that the appearance is similar to the cellular type, but the water flows through the tubes, whereas, with a cellular radiator, the water flows around the tubes.

Cellular-Type Radiators

The original cellular type was the Mercedes (Fig. 19). It consisted of four or five thousand ¼″ square copper tubes 4″ long, nested horizontally together, being separated from each other by wires arranged to run between the rows of tubes in both directions. The blocks so made were clamped together, and dipped in a bath of solder, both front and back, by which means a space $\frac{1}{32}$″ thick was left on each side of every tube. The blocks (divided into sections similar to Fig. 20) were assembled with the top and bottom tank of the radiator, and water was forced to pass in between the tubes, the air being allowed to travel through the inside of the tubes. A very large radiating surface was thus obtained, and it would be hard to conceive of any arrangement offering a larger radiating capacity for any given size of radiator.

The cellular radiator is a very expensive type to construct. In this country, where large quantities are required, this construction was quickly modified to make the production cheaper.

Honeycomb Type of Radiator

The tubular type construction of radiator is often termed a "honeycomb" type. It is very much like a cellular honeycomb in appearance. See Fig. 18

The Fiat true cellular type of radiator (Fig. 20) is similar to the Mercedes. It is formed in four divisions indicated by horizontal lines. Where these lines cross there are open horizontal passages through which the water may flow from one side to the other. Thus a section can be removed and repaired separately.

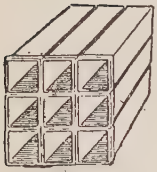


Fig. 19

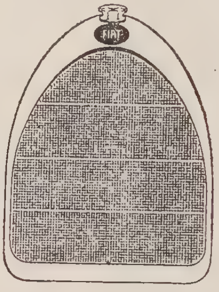


Fig. 20

Some of the modifications employed are shown in Figs. 21 and 22. Note in Fig. 21 that the tubes are expanded at the ends, thus eliminating the wires.

The Mayo is constructed in a similar manner with the water passage to the sides of tubes. In the Fedders (Fig. 22) the hexagon tubes can be removed and replaced. The Harrison hexagon cellular is shown in Fig. 23. Between every other row of cells there is a water passage .08″ thick.

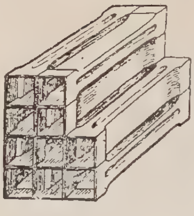


Fig. 21

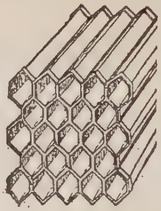


Fig. 22

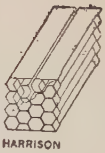


Fig. 23

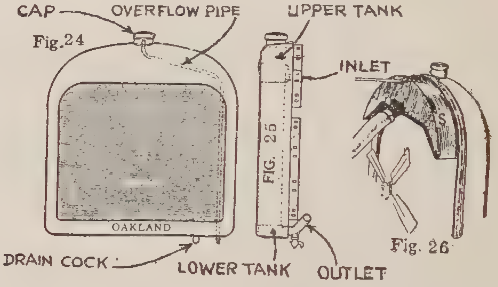


Fig. 24 Fig. 25 Fig. 26

Figs. 24 and 25. Front and side view of a popular type of radiator, showing overflow pipe, upper and lower tank, and connections.

Fig. 26. Extension or syphon tank (S), used on many thermo-syphon systems to give greater body of water and to absorb steam and to maintain a constant level—a desirable feature on all radiators.

WATER TEMPERATURE

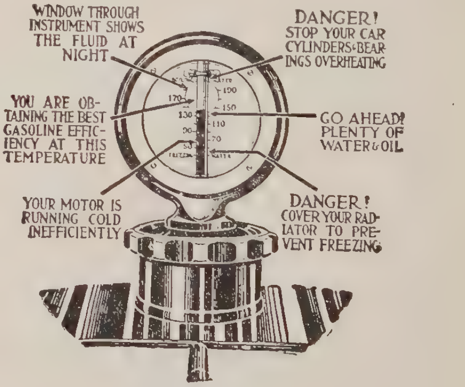
The temperature of the water circulating around the water jackets should be about 170° to 180°, at which temperature gasoline engines operate at maximum efficiency. If over this temperature, or as high as 212°, the water will boil and steam. If the temperature of the water is low, then the cold engine condenses a portion of the gasoline, which leaks past the piston rings, dilutes and thins the lubricating oil, with the result that the engine is not properly lubricated, and furthermore, the raw, unvaporized gasoline produces carbon deposit in the cylinders.

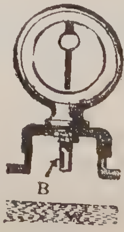
Water boils at a lower temperature in a high altitude, because the pressure of the atmosphere, which water must overcome before it can boil or change into steam, is lower in a high altitude. At an elevation of one mile water will boil at a temperature 10° lower than at sea level. In crossing the Rocky Mountains the road is frequently much more than one mile above sea level, and water boils away very rapidly.

Temperature Indicator

A device which is placed on the filler cap of the radiator (Fig. 27), serves to indicate the temperature of the water vapor. This device is known as the "Boyce Motometer." It is a very useful device for warning the driver when his engine is overheating. This device is placed on the radiator cap. The fluid in the tube reaches different levels according to the temperature. These figures can be seen from the driver's seat. (Note: At high altitudes, say 10,000 ft. above sea level, the boiling point of water is reached about ⅛″ below the point indicated at the top of the instrument.) If the level of the fluid reaches too high a point, the driver is warned to stop and locate the trouble before serious trouble develops.

In this case, first determine the different causes of overheating and try first one, then the other, until the trouble is found. If you think the trouble is in the lack of lubrication, lack of water, or too much


WINDOW THROUGH INSTRUMENT SHOWS THE FLUID AT NIGHT
DANGER! STOP YOUR CAR CYLINDERS & BEARINGS OVERHEATING
YOU ARE OBTAINING THE BEST GASOLINE EFFICIENCY AT THIS TEMPERATURE
GO AHEAD! PLENTY OF WATER & OIL
YOUR MOTOR IS RUNNING COLD INEFFICIENTLY
DANGER! COVER YOUR RADIATOR TO PREVENT FREEZING
170
190
150
130
110
90
70
50
Fig. 27. Boyce motometer; a water temperature indicator. Note that 170° is the point where the engine operates best.



The thermometer bulb (B) does not extend to the water (W). The temperature of the vapor above the water is indicated.

Fig. 27A

asoline feeding at the carburetor, examine each; emedy the trouble and watch the results.

A distance or extension type of motometer is also nade, which can be placed separate from the radia- or and is adapted for use on aeroplanes, motor oats, tractors, etc. (Made by Boyce Moto-Meter o., Long Island City, N. Y.)

Extension type of temperature indicator: This levice (Fig. 28) will indicate the temperature of vater or oil circulating through the engine. The nstrument is placed on the dash and the tube (E) s placed in the top of the radiator.

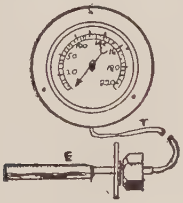


Fig. 28. Extension type of water temperature indicator Boyce motometer with an extension tube).

Principle: The hollow spring in the head of the nstrument and the copper tube (T) and bulb (E) are illed with treated alcohol under pressure. When he bulb (E) is subjected to changing temperatures, he alcohol expands or contracts, thus moving the minute column of alcohol forward or backward in he entire length of the tube, and causing expansion r contraction in the spring which moves the needle.

Temperature Regulation

There are three methods employed to **heat a cold engine** more rapidly than if these methods were not employed, as follows: (1) by the use of a radiator hutter; (2) by restricting the water circulation by means of a water thermostat or sylphon; (3) by heating the inlet manifold.

Radiator Damper

A radiator damper or shutter is shown in Fig. 29. It is a very efficient heat-conserving device. Engineers saw the futility of putting gasoline into an engine to get heat and at the same time permitting great drafts of cold air to be drawn through the radiator to drive away the heat. Therefore the shutter was devised to retain the heat, especially on starting during cold weather.

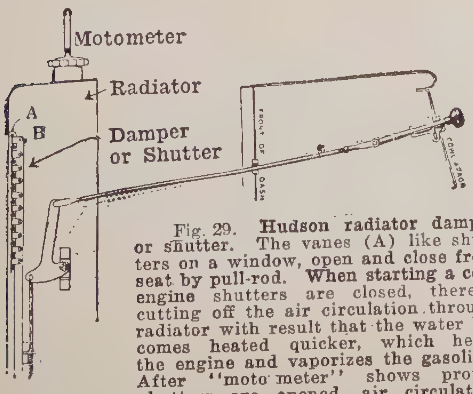


Fig. 29. **Hudson radiator damper or shutter.** The vanes (A) like shutters on a window, open and close from seat by pull-rod. **When starting a cold engine** shutters are closed, thereby cutting off the air circulation through radiator with result that the water becomes heated quicker, which heats the engine and vaporizes the gasoline. After "moto meter" shows proper temperature, shutters are opened, air circulation begins and temperature remains normal.

Thermostat Control of Water Circulation

The thermostat as used on the Studebaker (Fig. 30), is located at the cylinder-block water outlet and serves to make the engine more efficient in respect to power and gasoline consumption by regulating the flow of water through the cooling system. When the temperature of the water in the cylinder-block water jacket is below 150° Fahr., the thermostat valve is closed, allowing the engine rapidly to reach normal driving temperature. As soon as the water reaches this temperature, the valve automatically starts opening and allows water to flow through the usual circulation channels. The small hole in the valve is an air vent, necessary when filling the cooling system with water while the valve is closed.

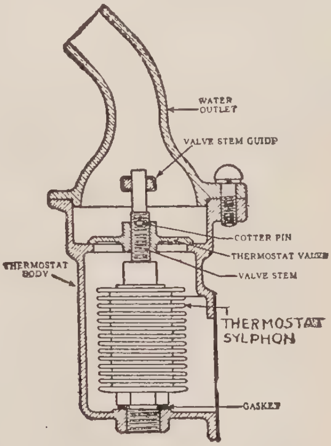


Fig. 30. Thermostat control.

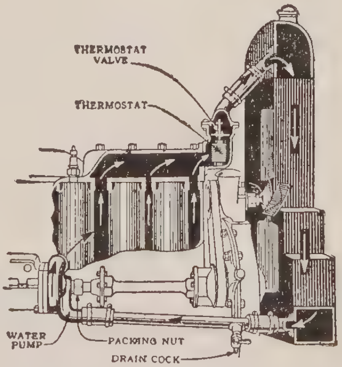


Fig. 31. View showing where the thermostat is placed in the water circulation system (Studebaker as an example).

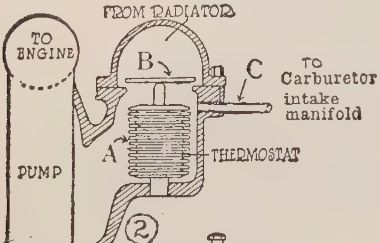
If the sylphon becomes inoperative, the valve will remain open and circulation will continue the same as if no thermostat were used. This necessitates installation of a new sylphon.

To install a new sylphon, remove the thermostat assembly from the engine and disassemble the cover by removing three screws which hold it to the body. Unscrew the sylphon from the body by the use of a wrench on the hexagonal base of the sylphon, and remove the valve from the stem. In replacing with a new sylphon, make sure that it is drawn tight against the copper gasket in the bottom of the body. Then screw the valve on the stem until it just rests on the seat and place the cotter pin through the stem and valve to make secure. If the hole in stem and the notch in valve do not line up at this point, back off slightly to obtain alignment.

Cadillac Water Thermostat

A housing containing a sylphon thermostat and a valve controlled by the thermostat, are located on the cover of each water pump.

The sylphon thermostat (A) (Fig. 32) is accordion shaped. It contains a liquid which is driven into gas when heated. The resulting pressure elongates or expands the thermostat, forcing the valve (B) from its seat.



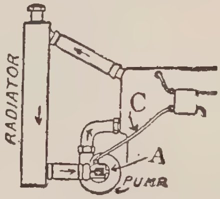


Fig. 32

Fig. 32A

A drop in temperature changes the gas back to a liquid, reducing the pressure in the thermostat and allowing it to contract, thereby bringing the valve (B) back to its seat.

This valve on thermostat is placed in the line of circulation of water, to the side of pump (Fig. 32A). When cold, the thermostat valve (B) is closed, thereby stopping circulation. When warm it expands and opens the valve (B), which permits the pump to draw water from the radiator.

A hand control, connected with a shaft extending from the cover of the pump, is also provided from the seat, which can raise this valve, in order to drain the radiator.

On the Cadillac models 55 and 57, the water-circulation pipe (C) is through the jacket of the inlet manifold. **On the Packard** this thermostat is placed directly at top of the radiator (rear), similar to the Studebaker (Fig. 31).

Radiator and Hood Cover

The use of a **radiator cover** over the cooling surface of the radiator during cold weather is advisable. The roll in front on the radiator cover can be lowered or raised during cold weather, until the engine warms up. Some merely tie a piece of card board over the lower front of the radiator during extreme cold weather.

The radiator cover should be left over the front of the radiator until the engine is heated up, as shown by the motometer. This prevents the fan from drawing cold air through the radiator.

Another point relative to a radiator cover is that the cover should be designed so that the lower part of the radiator remains covered, more so than the upper part, especially with thermo-syphon systems, even though a non-freezing mixture is in the solution, because the solution does not start to circulate until hot and in many instances the water freezes in the lower rubber tubing connecting the radiator with the engine, thus preventing circulation and causing steaming.

To tell whether the radiator is frozen, feel the water inlet pipe at the bottom of the radiator. If it is cold, and the upper connection is hot, then you may know it is frozen at the bottom. See also page 154.

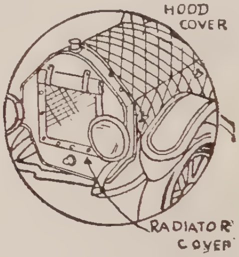


Fig. 33

Hood cover: During cold weather the hood cover is advisable, as it tends to retain the heat under the hood.

WATER-COOLING TROUBLES

Water

In localities where pure water is not easily obtained, it is well to strain the water through muslin. Soft water is better than hard water, because the latter is likely to deposit a scale on the walls of the radiator. The best water to use is rain water.

It is very hard **to tell whether water is hard or soft,** but the following may be used with success: Take a quantity of water in the hands and go through the motion of washing. If it is difficult to rub the hands together, the water is hard. Ordinary city water is generally hard to some extent, but is not as bad as that which is found in streams. Rain water is very soft, and for that reason is desirable for automobile use.

Many automobilists have a rain catcher on the roofs of their garages, while others depend on the old-fashioned rain-barrel. The water should be filtered first, however, if it is taken from the roof, as it is likely to contain impurities. But even with fairly soft water the monthly use of a soda solution will prevent harm (this applies only in districts where the water is unusually hard).

Water-Circulating Pump

The pump requires no attention, other than to see that it does not become choked by using dirty water. There is a "packing nut" on the shaft, which, if the pump should ever leak around the shaft entrance, should be repacked. This can very easily be done by turning off the packing nut (see Fig. 31), removing the old packing, and rewinding the shaft with a few inches of "well-graphited or wick packing" and tightening up the packing nut. The packing should be wound on in the same direction as that in which you turn the nut to tighten it.

Sometimes the pin which connects the pump with its shaft becomes loose or sheared. See page 153, for a discussion of "Broken Pump Shaft."

Where a pump is used to circulate the cooling water, it is wise to fill the radiator to the top and then turn the engine over several times, so as to insure the water reaching and filling all parts of the system. If the engine is not turned, the pump is an obstruction to the passage of the water into the jackets, which remain partly empty, or fill so slowly as to leave the impression that there is more water in the system than there actually is.

Fan

The fan requires no particular attention, except oiling. Sometimes the belt gets loose and causes the fan to slip and not to turn as rapidly as it should, causing overheating of the engine. If this happens, loosen the nut which holds the eccentric arm of the fan, raise the arm slightly, and retighten the nut. This will tighten the belt. Note that this nut frequently has a left-hand thread. Do not tighten too tight, as you are liable to crack the fan support. See also Figs. 8A., 9, and 36.

Cleaning Radiator

The circulating system should be carefully washed out, early in the spring, because the anti-freezing solutions, used in the winter, are likely to leave the tube clogged up. In summer, it is advisable to flush out the circulating system about once a month.

To do this properly, the radiator inlet and outlet hose should be disconnected, and the radiator flushed out by allowing the water to enter the filler neck at ordinary pressure, whence it will flow down through the tubes and out at the drain cock and hose. The water jackets can be flushed out in the same manner.

To remove scale from the inner surface of the radiator: One method is by using hot water, in which a small amount of ordinary washing or baking soda (about one teacupful to each two gallons) has been dissolved. Fill the radiator with this solution, and then start the engine and run it with the spark retarded for about 15 or 20 minutes until the solution becomes hot and has thoroughly circulated through the entire water system. Drain off the solution and thoroughly flush the system with clean water, using a hose for the purpose. Do not permit the soda solution to remain in the radiator for more than an hour. Be careful not to spill any of the soda solution on any painted or varnished surface.

For very hard deposits a solution of one quart of commercially pure muriatic acid to five gallons of water circulated through the cooling system slowly for five minutes is advised by one manufacturer.

Another good method is, to one pint of glycerine add enough boiling water to fill the system, then run the engine slowly and drain out after running, and flush with fresh water. Reversing the flow of water in flushing also helps.

Cleaning a muddy radiator: If the air spaces of the radiator become clogged with mud, after driving over dirty roads, do not attempt to remove the mud with a screwdriver, wire, or other metal instrument. Instead, soften the mud with water. The best way is to wash the radiator by flushing a stream of water from a hose through it from the rear. In doing this, take care not to let water get into the magneto or electrical system, which is likely to be short-circuited in that way.

Hose Leaks

The rubber hose (H, Fig. 34) **and its connections** (C) are often a source of leaking. When the hose is worn it will become ragged-looking on the outside. The rubber which surrounds the fabric will commence to have a torn appearance and the water will seep through the fabric. There are two ways of remedying this; one is to renew the hose, and the other is to repair old hose. The first is the better and more permanent repair. In doing this a piece of hose of the same thickness and length as that now in place is secured. The clamps which hold the hose in place are removed. The new hose is slipped in place and the clamps put over it and screwed up tightly. Paint all threads of water pipes with white or red lead.

A good plan is to use shellac or rubber cement on the ends of pipes before placing on the hose.

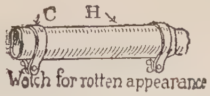


Fig. 34

On airplane engines, where hose connection is made to a pipe, it is connected with a "connector" and then taped and shellacked.

Where gaskets are used on water manifolds, it is not necessary to use shellac. Usually copper gaskets are best, or sheet packing such as "rainbow" or "mobolene," is often used. Do not use leather.

On cylinder heads copper gaskets interlined with asbestos are used extensively. Use heavy oil on both sides when replacing. Be sure the surface is clean.

If gaskets are old, they usually have a rough surface. Clean thoroughly and use shellac on both sides. Do not permit shellac to get into the cylinders, which will happen if put on too thick. See Index under "Gaskets."

Cylinder Leaks

Cylinder leaks: A slight leakage of water from the jacket into the cylinder may be caused by a crack, but more usually will be found to be simply a defect in the seating of the pipe plug fitted in the heads of many engines.

A crack in the cylinder, when on the inside, is difficult to locate. Its action may be of such a nature as to be only operative when the engine is at full working heat (due of course to the expansion). It is generally accompanied by misfiring and boiling, the former owing to leakage of water into the cylinder, and the latter owing to the exploding gases (at a very high temperature) being forced into the water-jacket.

The best means of detection is to fill the radiator entirely to top of cap, run the engine till hot, then stop it and turn it over by hand against the compression in each cylinder. If there is a crack, bubbles will appear at the cap. Thus, by noting the compression of each cylinder, the defective one can be located.

Slight leaks inside of the cylinder have been remedied by rusting, if the hole is very small. See Index under "Rusting a hole in cylinder."

Leaky Radiators

Leaks in the radiator are often hard to reach. They are detected by the steam arising from the water that flows through the leak and down the outside of the radiator. The great facility with which the cooling water will boil after the radiator has been refilled is another clue which, although it is common to all leaks in the system, will lead the operator to the point at which it occurs. On the subject of testing for radiator leaks, see Index.

Scouring out the circulation system with a strong alkali, such as soda, will sometimes tend to seal up any small leaks, and it might also be effective for a slight crack in a water jacket, as the soda, coming in contact with the iron, would form an insoluble filling and prove even better than rusting up the crack.

The standard honeycomb radiator is somewhat prone to these leaks; the metal is so thin and the joints so numerous. It is not always possible to have a leak soldered up at the required time. In this case recourse can be had to a small, useful accessory known as a "leak preventer." It consists of a couple of small plates or washers with a piece of sheet rubber fixed on; these plates have hooks, so that a spiral spring can be fixed on to draw them together. The spring is threaded through the aperture at the leaky cell, the plates hooked on, and thus held firmly up against it. Most accessory houses keep them, and if the car has a honeycomb radiator it pays to carry several of these devices. The construction of this type of radiator lends itself to a repair of this kind, but leaks in other forms of radiators, when they occur on the road, are rather troublesome. Even soldering them is by no means an easy job. There being such a large mass of metal, the solder cools as soon as it touches it.

A temporary repair can be made with white lead, especially if a piece of tape can by any means be bound over the repair. It is often possible to hammer up or plug a leakage in a tank or radiator.

Leak Preventives

There are many so called leak preventives, for instance, a cement called **cold solder.** The manufacturers claim that by pasting externally on the leak (Fig. 35), it will harden and stop a leak temporarily until the radiator can be repaired. (Stone Solder Co., Cleveland, Ohio.) Another leak preventive is a **chemical mixture of cement** which is placed internally in the radiator when the water is hot. The solution is supposed to pass out of the leak in the radiator and as it is exposed to the air it hardens and closes the leak. It is claimed that this preparation will also close cracks in water manifolds, etc.

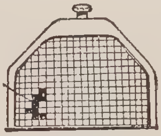


Fig. 35

One radiator manufacturer states that ordinary bran mixed with water will stop a slight leak. The writer has never tried this. Another manufacturer advises against the use of bran, meal, or patented preparations. The best plan is to have the radiator soldered. See Index under "Radiator repairs."

Some of the manufacturers of radiator cements are Woodworth Mfg. Corpn., Niagara Falls, N. Y.; X-Laboratories, 630 Washington St., Boston, Mass.; N. W. Chemical Co., Marietta, O.

Paint for radiator fins can be made from drop black ground in Japan and gold size, thinned with turpentine. See Index under "Painting radiator."

Water Boiling

Water boils at 212° Fahr. at atmospheric pressure. For this reason the cooling system of an automobile is so designed that the water is at a temperature of about 170° to 200° under average running conditions. This leaves quite a margin before the boiling point is reached.

When climbing a hill with a retarded spark, the engine naturally becomes warmer and for this reason the margin is left, although as a matter of fact the engine would run at a higher efficiency if the temperature of the cooling water could run higher. If the cylinders are kept too cool, it means that too much heat is being withdrawn from the explosions. On the other hand, if permitted to become too hot, power is lost through: (a) the entering gases being unduly rarified or prematurely expanded, and thereby containing less combustible material per volume; (b) friction due to the thinning of the oil, and probable binding or seizing of the piston or bearings.

Therefore **the best water temperature** to maintain is about 170° to 178°.

To determine if the boiling is due to stoppage of circulation, feel the radiator. It should be slightly hotter at the top than at the bottom, but if clogged, there will be a pronounced difference in temperature.

Do not get alarmed if the water boils occasionally, especially in driving through mud and deep sand or up long hills in extremely warm weather. Remember that the engine develops the greatest efficiency when the water is heated nearly to the boiling point. But if there is persistent overheating when the engine is working under ordinary conditions, find the cause of the trouble and remedy it. The chances are that the difficulty lies in improper driving or in carbonized cylinders.

No trouble can result from the filling of a heated radiator with cold water, providing the water system is not entirely empty, in which case the engine should be allowed to cool before the cold water is introduced.

OVERHEATING OF ENGINE

In some engines an inclination to overheat gradually develops as the car gets older, and appears to defy all efforts to remedy by attention to carburetion or ignition.

This may be due to the clogging of the cooling system with incrustation or to deposit in the walls of the cylinder jackets and the water system generally.

Assuming that the design and the construction of the engine, including all features of the cooling system, are correct, then, except for leaks, insufficient water, and bursting of the water jackets from freezing, **overheating is the final result of all troubles from the cooling system,** and overheating is generally due to one or more of the following causes:

1. **Insufficient water supply** in the radiator.
2. **Constricted holes in the gasket** where the pipe connects to the cylinders and pump.
3. **Frayed hose connections** clogging the water passage.
4. **Incrustations or lime deposits** on the wall of cylinder or radiator tubes.
5. **Carbon in the cylinders.** In such a case, remove the cylinder head and scrape out the carbon.
6. **Driving on low gear.** The engine should not be raced when driving on low gear, and the spark should be well advanced, because the engine speed is comparatively high. Do not use low, when high speed can be used without straining the engine.
7. **Spark retarded too far.** Keep the spark advanced as far as possible, without causing the engine to knock. As the throttle is opened and the engine slows down, it is necessary to retard the spark.
8. **Poor ignition.** If the engine is misfiring, it is necessary to open the throttle much wider and to retard the spark; this tends to cause overheating.
9. **Valves.** The exhaust valve may not open early enough to discharge all of the burned gas.
10. **Carburetion.** Too rich a mixture, or driving with the throttle open too far and the spark retarded too much.
11. **Insufficient or poor quality of oil.** Lack of oil will cause such friction between the pistons and the cylinder walls that the engine will overheat and the pistons may stick. Poor oil burns up, or becomes thin and runs away so quickly that the parts are left practically without oil. Use good oil—it costs less in the long run.

12. **Racing the engine.** Close the throttle when the clutch is disengaged, and so save gasoline and prevent overheating.

13. **Clogged muffler.** Too rich a mixture or too much oil will deposit soot in the muffler and by preventing the escape of the exhaust, will cause overheating. Clean the muffler by disassembling it.

14. **Water frozen—steams.** To thaw out, open drain cock. Water usually freezes at bottom of the radiator, therefore pour hot water on the bottom until circulation starts. This will be indicated by water running out of the drain cock. Then close the drain cock and fill the radiator with water and keep the engine running. Sometimes when the engine steams, if a blanket is thrown over the engine and radiator, the heat will thaw out the bottom of the radiator. See page 150 under "Radiator and hood cover," on how to tell when the water is frozen at the bottom of the radiator.

15. **Fan not working properly.** A broken or a loose and slipping belt will not rotate the fan fast enough to draw a cooling current of air through the radiator. This will tend to cause overheating when the engine is idling or running on low gear. Tighten or replace the belt. Perhaps it may be necessary to bend the fan blades at a slightly sharper angle, in order to draw more air through the radiator (see Fig. 36).

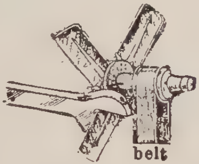


Fig. 36

16. **Poor water circulation** due to low water. Where the thermo-syphon system is used, the water will cease to circulate as soon as the level falls below the inlet to the radiator. Keep the radiator well filled. Leaks may lower the water level. The rubber hose connections may have rotted and a flap of rubber on the inside of one of these hose connections may seriously impede the flow of the water.

17. **Broken pump shaft.** It is difficult to tell whether or not a circulating pump is working. Remove the radiator cap and see if water is circulating while running the engine. The pin holding the pump shaft may be sheared off, yet the pump shaft would continue to revolve.

18. **Brakes dragging.** This would call for an increase of power from the engine. Examine the brakes with rear wheels jacked up.

19. **Bearings.** If the engine is new or just overhauled, the bearings may be too tight. Put in plenty of oil and run until loosened up.

20. **Radiator clogged with mud or dirt,** or an obstruction in front of the radiator, thus preventing passage of air.

Fire Truck Engine—How Cooled

Q.: How does the engine on an automobile fire truck cool itself when the engine is running continuously for long periods with the car standing, which is often the case at a fire?

Ans.: There is a cooling line from the discharge side of the main pump directly into the water manifold. This is a ⅜″ line, and is controlled by a gate valve which enables the operator to keep the engine at any desired temperature. An overflow on the radiator allows this cooling water, which amounts to 8 to 10 gallons per minute, to pass off.

NON-FREEZING SOLUTIONS FOR COOLING SYSTEM

In winter, a water-cooled **engine must be carefully guarded against freezing,** for if the water freezes in any part of the system it will cause the breakage of piping or radiator, or crack a water jacket. When the engine is running, the water is kept warm, therefore the danger is not as great. It is advisable, however, to take no chances, as freezing has been known to occur, even with the engine running.

When leaving the car for several days, during cold weather, the safest plan is to drain the water out of all parts of the system, cocks being provided for the purpose at the lowest point of the system, usually at the bottom of the radiator. The engine should be run for a few minutes to make sure all the water has been removed.

Non-Freezing Solutions

Note. Be sure that there are no water leaks. Tighten up hose connections and drain the water system and wash it out thoroughly before putting in non-freezing solutions.

To prevent the water from freezing when it is not desirable to drain it out, there are a number of chemicals which can be mixed with the cooling water, such as calcium chloride, wood alcohol, denatured alcohol, glycerin, and alcohol.

Calcium chloride (common salt of calcium) or any acid or alkaline solution is injurious to metal parts, and if there are leaks it will corrode the parts. The amount of calcium chloride to mix with water is given in the table below. Calcium chloride is simply mixed with water in the proper proportion. It is best to make a saturated solution of the salt, and then add this to water in desired proportion. It dissolves quickly in hot water.

In using calcium chloride it is the acid in it which attacks the metal. This can be neutralized by adding ammonia or soda ash until blue litmus paper no longer turns red when dipped into the solution.

There are three grades of alcohol: denatured alcohol, which is a disguised grain alcohol of first still (not suitable as a beverage). It sells for about $1.05 per gallon and has a higher boiling point than wood alcohol. Wood or methyl alcohol sells for about $1.60 per gallon, and has a lower boiling point. The high-proof or double-still grain alcohol used as a beverage is too expensive. Therefore, denatured alcohol is cheaper, has a higher boiling point, and is the proper thing to use.

Wood alcohol boils at 153° Fahr. and denatured alcohol boils at 171° Fahr. Therefore alcohol, while it is not injurious in any way, lowers the boiling point of the water. Consequently on warm days, with the car standing and the engine running, the solution will tend to boil easily and to evaporate. However, denatured alcohol and water is the least expensive and is probably used more than any other solution. The proportions of denatured alcohol, or of wood alcohol and water are given in the table below.

For losses by evaporation, use 75 per cent alcohol to 25 per cent water, as the alcohol evaporates quicker. This does not apply to loss by leaks or boiling over. It is best however, to check the solution with a hydrometer before filling, and to add alcohol and water until the specific gravity as shown in the table is reached. It will be observed that as the specific gravity is given in the table, a hydrometer may be used for mixing and maintaining a correct solution, by first testing the original and keeping it up to a standard.

The use of glycerin raises the boiling point of the solution. It is more expensive than alcohol (a pound of glycerin costs about 50c.; there are 10 lbs. to a gallon) and is slightly injurious to rubber.

Glycerin and alcohol mixed with water can be used. The proportions are given in table below.

Where glycerin, alcohol and water are used, only the alcohol need be replaced for evaporation, which should be added occasionally. The glycerin does not evaporate with the water. If there are leaks, however, the glycerin and alcohol should be replaced.

Glycerin and water alone is not advisable, as this solution would form crystals at temperatures slightly lower than zero. Hence the necessity of adding alcohol due to evaporation.

Where engines are equipped with thermostat temperature controls, the glycerine mixture is the best to use.

For a second filling of any of the solutions, the best plan is to take a hydrometer reading of the specific gravity of solutions when mixed, and to keep the solution up to standard.

Non-Freezing Solution Table

The table below prepared by Mr. P. J. McCullough, gives the freezing temperature of four different anti-freezing solutions in various proportions of mixture with water for ten gallons of solution. The number of pints of each liquid required for 10 gallons (80 pints) of solution is given as designated. If a mixture of 5 gallons is required, then use one-half the quantity of each. If a mixture of 15 gallons is required, use the amount shown in the table plus one-half additional.

DENATURED ALCOHOL AND WATER				WOOD ALCOHOL AND WATER				ALCOHOL, GLYCERIN AND WATER				CALCIUM CHLORIDE			
TEMPERATURE °F	ALCOHOL IN PINTS	WATER IN PINTS	SPEC. GR.	TEMPERATURE °F	ALCOHOL IN PINTS	WATER IN PINTS	SPEC. GR.	TEMPERATURE °F	WOOD ALCOHOL PINTS	GLYC. IN PINTS	WATER IN PINTS	TEMPERATURE °F	CAL. CHL. IN PINTS	WATER IN PINTS	SPEC. GR
18° ABOVE ZERO	12	68	.9820	20° ABOVE ZERO	8	72	.9880	20° ABOVE ZERO	6	6	68	18° ABOVE ZERO	9	71	1.092
12° ABOVE ZERO	18	62	.9740	9° ABOVE ZERO	15	65	.9755	9° ABOVE ZERO	10	10	60	12° ABOVE ZERO	14	66	1.015
ZERO	24	56	.9625	2° BELOW ZERO	21	59	.9680	2° BELOW ZERO	12	12	56	ZERO	16	64	1.179
9° BELOW ZERO	27	53	.9578	9° BELOW ZERO	25	55	.9625	11° BELOW ZERO	13	13	54	12° BELOW ZERO	18	62	1.154
20° BELOW ZERO	32	48	.9475	22° BELOW ZERO	30	50	.9535	22° BELOW ZERO	15	15	50	22° BELOW ZERO	20	60	1.230
42° BELOW ZERO	45	35	.9230	42° BELOW ZERO	42	38	.9280					41° BELOW ZERO	23	57	1.264
52° BELOW ZERO	52	28	.9015	52° BELOW ZERO	52	28	.9070					57° BELOW ZERO	24	56	1.300
57° BELOW ZERO	56	24	.9005	60° BELOW ZERO	53	27	.9005					65° BELOW ZERO	25	55	1.330

What to Do if the Water Freezes

If the cooling water should freeze, the usual indication of a frozen radiator is steaming excessively. It would appear that the steam or heat would thaw it out and start the circulation again, but such is not the case. When the water freezes, do not run the engine to try and start circulation as the fan draws in cold air and only assists in keeping it frozen. Find the nearest warm garage and, if possible, turn hot water on the bottom of the radiator until steaming ceases, as a radiator in this instance usually freezes at the bottom first.

When the engine overheats by steaming, due to frozen water, feel the radiator and inlet hose connection between the engine and radiator at bottom. If cold at the bottom and hot at the top, the bottom is frozen; if warm, then circulation is all right, and the trouble is due to lack of water or something else.

In addition to using a non-freezing solution, it is always well, when making a stop, to **cover hood and radiator.** See Fig. 33, page 150.

Also **draw in a full charge of gas** by speeding up the engine slightly and opening the throttle, before stopping.

In carbide-gas lighting generators, using the water drip, a suitable non-freezing solution is alcohol and water in equal proportion (no glycerin).

Kerosene for Cooling

Objections to kerosene are the odor of heated kerosene. When heated, kerosene evaporates and is liable to cause a fire if near a flame; on warm days in winter there is a tendency for the engine to heat on account of difference in the coefficient of heat of kerosene and water or alcohol; kerosene rots radiator tubing and will also deposit a greasy mist over the car. Gas is also liable to form and cause expansion and bulging of the radiator. The boiling point of kerosene is much higher than alcohol. See Index.

Kerosene is used in extremely cold climates where engines are equipped with water-circulating pumps. It could not be used at all with the thermo-syphon system.

Cadillac Condenser

The Cadillac patented condensing device is shown in Fig. 37. With this device it is possible to use with safety the expensive alcohol solution as an anti-freezing cooling medium. A condenser of simple construction is attached to the frame, and is connected by a tube to the overflow which runs from the upper tank of the radiator.

Alcohol vapor driven out of the solution by heat, as well as any water vapor, is restored to liquid form in the condenser.

When the radiator gets cold, the vacuum produced by the contraction of its contents automatically causes the surplus liquid in the condenser to return under atmospheric pressure to the radiator.

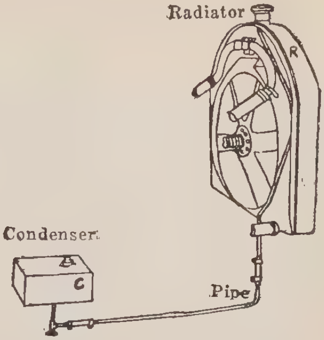
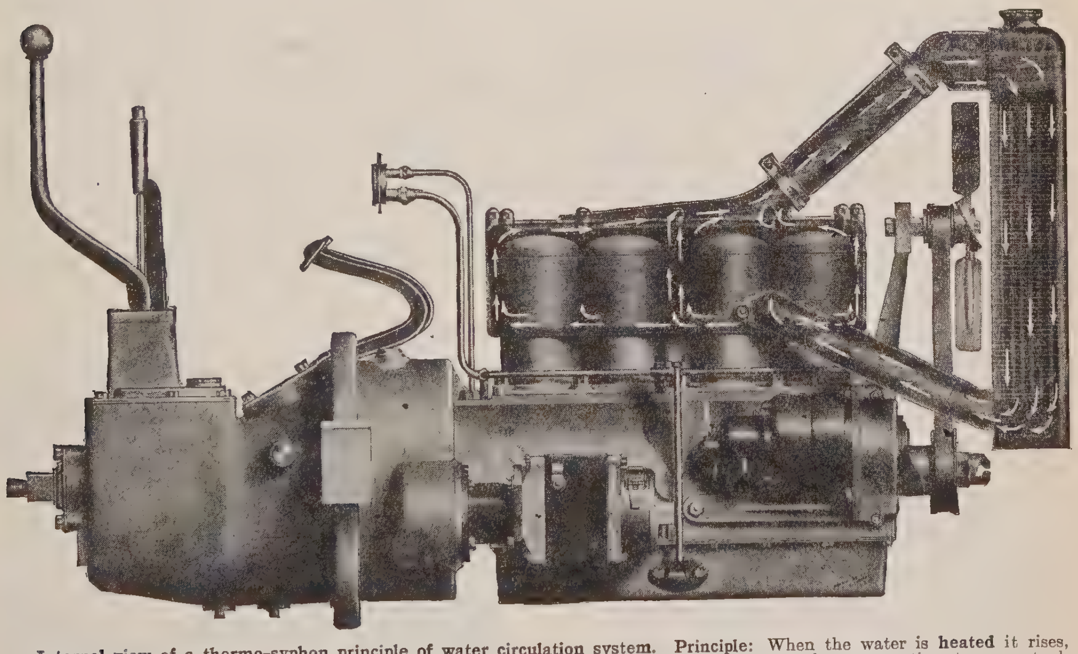


Fig. 37

TYPICAL EXAMPLE OF A THERMO-SYPHON WATER-CIRCULATING SYSTEM

The illustration below is that of the Golden-Belknap and Swartz 4-cylinder engine showing the outer water jacket of the cylinder removed to show the **direction of flow of the water.**

The reader will also gain an idea from this illustration as to the location of a **starting motor** (to the left) and the **generator** (front). The generator is operated by a silent chain (encased). Note that the **fan** is operated from a pulley on the end of the crank shaft. The **pressure oil gauge** is shown to the left, above the foot pedals, and is attached to the dash.



Internal view of a thermo-syphon principle of water circulation system. Principle: When the water is **heated** it rises, and passes from the top of the water jacket at the top of cylinders, through the upper rubber hose connection, to upper tank of radiator, through radiator cores, whence it is **cooled** by air drawn through the radiator openings by the fan. The cooled water then passes to the lower radiator tank, up through lower hose connection, to lower part of cylinder water jackets.

The word **"thermo"** pertains to heat and the word **"syphon"** refers to drawing off a liquid from a higher to a lower level. Thus the water rises from a high level due to the heat in it, or to being lighter, or less dense.

By referring to page 146, Fig. 4, this thermo-syphon principle of water circulation can be compared with that of the "forced water-circulation" system.

AIR COOLING

The object of cooling is to remove the excess heat from the cylinders. There are only a few cars on the market in which this is accomplished by the air direct, without the use of water.

Air-cooled engines usually have small-bore cylinders.

The different methods of air cooling are summed up as follows:

(1) By having a large radiating surface by means of cast flanges or gills, inserted pins, or tubes.

(2) By using extra large exhaust valves, so as to cool the combustion space between power strokes.

(3) By combining large radiating surfaces with low speeds in multiple-cylinder engine.

(4) By the use of auxiliary exhaust ports, combined with surface radiation.

(5) By forced draught of air circulating through an air jacket around the cylinder.

A cylinder with radiating flanges is shown in Fig. 38. When in motion, the current of air blowing against the flanges drives the heat away. This principle is used extensively on motorcycle engines.

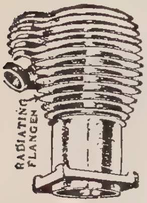


Fig. 38

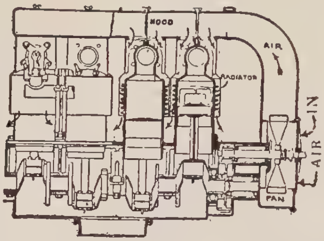


Fig. 39

A forced draught air-cooling system is shown in Fig. 39, formerly used years ago on a prominent make of car. With this system the circulation of air was forced through jackets placed around each cylinder, open at the bottom and top, being connected to a pipe from a centrifugal air blower or fan. The forced air passed the radiator flanges, and out at the bottom. In some respects, this principle is similar to that in use on the Franklin.

The Franklin air-cooled engine is a very successful engine for automobile pleasure cars employing the air-cooled method. The six cylinders are 3¼″ bore and 4″ stroke, giving a formula horsepower of 25.3.

By referring to the illustration (Fig. 40), the path of the air is shown, first through the hood, thence over and down through the air jackets. The air is then deflected downwards and out through the flywheel blades.

Vertical steel fins are made integral with the individual cylinder casting, by having the iron poured around the strips of steel. Very light aluminum jackets guide the air draught downward from the heads of the cylinders.

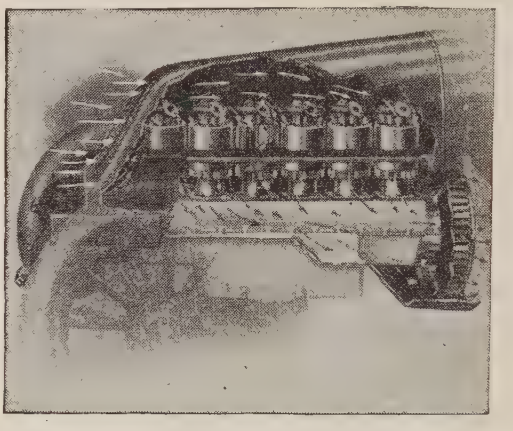


Fig. 40. Direct air cooling of the Franklin. The fly wheel is the only moving part of the cooling system.

Note the vanes in the fly wheel, which create a suction equal to 2,200 cubic feet every 60 seconds; a continuous flow of air literally wiping the heat away. It is stated that the heat on a Franklin engine is about 350° Fahr. (see Fig. 12, page 107, for Franklin exhaust-heated inlet manifold). This heat is shut off after the engine is warmed up.

The Franklin at one time employed **auxiliary exhaust valves** to assist in dispelling the heat of explosion from the cylinder as rapidly as possible. This method, however, has been discontinued.

Another popular make of air-cooled car is the Holmes, manufactured by The Holmes Automobile Co., Canton, Ohio.

HEATING A CAR

There are three methods of heating a car as explained below:

(1) hot water; (2) exhaust gas; (3) hot air.

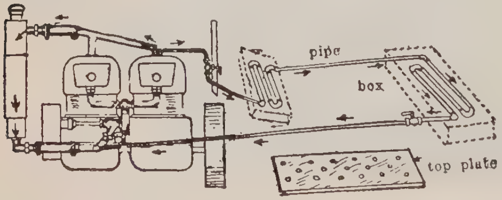


Fig. 41. Hot-water method of heating a car.

The hot-water method is shown in Fig. 41. This method can be used only where there is a forced or pump-circulation system. Connections are made with the circulating system at the top of the rear cylinder. The water circulates through the heater, whence it returns to the bottom of the radiator.

The heater is made of regular water pipe, and the housing of aluminum or light cast iron. The floor is cut away, allowing the surface of the heater to be flush with the floor. The top plate, made of aluminum, is then placed over the heater box.

The exhaust method for heating is to utilize the exhaust gases instead of water. In this instance the pipes would be connected with the exhaust pipe instead of with the water pipe. Only one side, the inlet, would be connected and an outlet is provided for the emission of the gas.

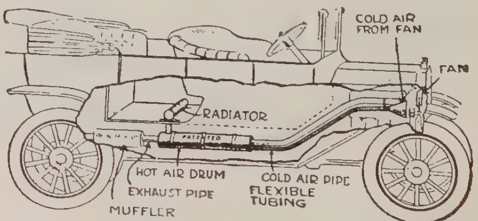
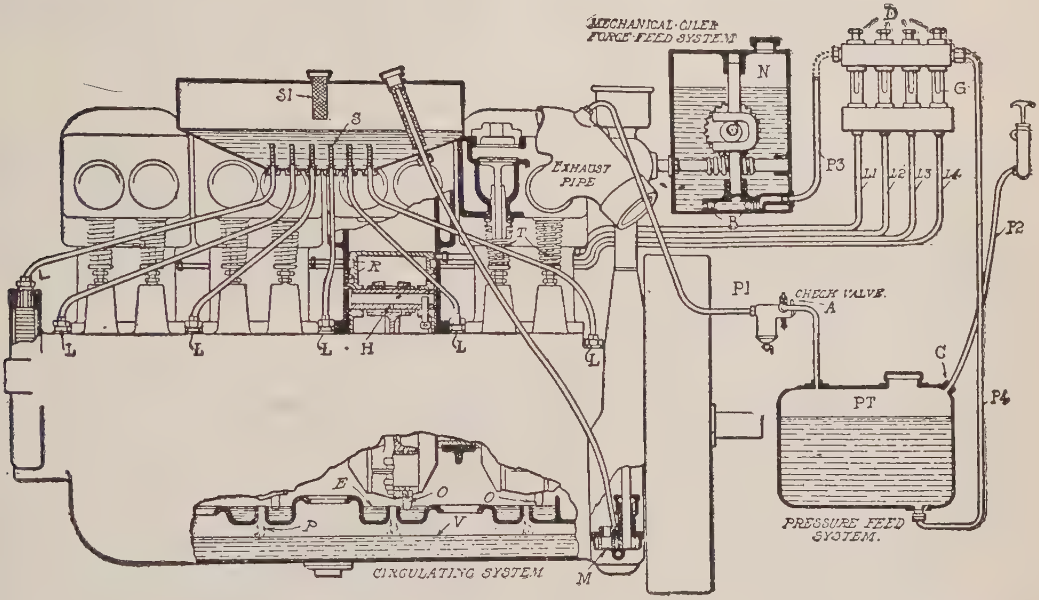


Fig. 42. Hot-air method of heating a car.

The hot-air method is shown in Fig. 42. This example illustrates the Brickly (patented) method. The air is taken from the fan through a funnel opening, and a flexible metal hose drives it through a metal jacket 24 to 30 inches long, which covers the "piping hot" exhaust pipe, and warms it thoroughly. It then drives it through a 1½-inch opening in the floor of the car, into a tubular register, along the back edge of the front seat, sending a continuous stream of heated air into the car. (Exhaust gases are not used.)

INSTRUCTION No. 16

LUBRICATION: Engine Lubrication Methods; Purpose of Lubrication; Oil Gauges; Kind of Engine Oil to Use; Engine Lubrication Troubles; Relation of Carbon to Lubricating Oil; Pointers on the General Lubrication of a Car



Some of the early methods of engine lubrication: There are four different systems shown on this engine in order to clearly explain each system. The systems are enumerated and described below.

EXAMPLES OF SOME OF THE EARLY ENGINE LUBRICATION SYSTEMS

Splash system: We will assume that oil is placed in the crank case through the breather pipe. The scoops (O) on the end of the connecting rods pick up the oil from troughs (E), and splash it to the various parts. This would be termed a "non-circulating" system.

Splash, force, and gravity: We will assume that the splash system just described is a part of this system. The overflow passes to reservoir (V); it is then forced by pump (M) to a gravity feed reservoir placed on top of the engine. The passage is then through the different pipes (S to L) to the bearings, thence back to the troughs (E) and reservoir (V). This system would also be termed a circulating system, as the oil is in continual circulation.

Force feed and splash: The mechanically operated pumps (B) are driven by belt, chain, or gears. There are several small pumps in the oil reservoir box (N), in fact a pump for each feed; the delivery pipe is from (B) to (D) through pipe (P3) and each separate feed (L1, L2, L3, L4) are piped to the different parts to be lubricated. The oil passes through a sight glass (G). The oil then passes to the bearings and falls to the bottom of the crank case. The oil reaches such a level or height in the crank case so that the connecting rods give an additional lubrication by splash. The amount of oil fed is regulated by drops, through the sight glasses, by the regulation of the screws (D), and depends upon the size of the engine and on the speed. (Note that pipe (P4) is not connected with this system.) This would be termed a "non-circulating system."

Exhaust pressure feed and splash: This system consists of an air-tight oil tank or reservoir (PT). A small pipe (P1) connects the tank with the exhaust pipe. A check valve (A) permits the gas pressure to pass into the tank but not to flow back.

The initial pressure is given to the tank by a small hand pump through pipe (P2). After the engine is started, the pressure from the exhaust is sufficient to force the oil through pipe (P4) to the sight-feed glasses, thence to the various parts to be lubricated —thence to the crank case.

This system, like the third system, requires oil to be fed by drops, as it is not pumped over and used again, and would be termed a "non-circulating system."

With the exception of the "splash system," the systems mentioned above are now seldom used.

Note. The illustrations above are not intended to exemplify the latest approved engine lubrication methods. In order that the reader may clearly understand the advantages of the modern engine lubrication systems, it is necessary that he understand the early systems. Furthermore, he may have occasion at times to work on engines equipped with some of the early systems. Moreover, some of the systems shown above are now used on marine and stationary engines.

PURPOSE OF LUBRICATION

When two parts of a mechanism rub together, it is necessary to use some means of preventing excessive friction, and this is usually done by applying a **film of lubricating oil** between them. Without a lubricant the friction would cause heating, and the result would be cuts or scratches on the surfaces of the two parts.

Two parts intended to rub together, like a shaft in its bearing, should be made as smooth as possible, for roughness would cause friction that lubrication could not prevent. The more rapid the movement of the parts against each other and the greater the pressure, the more they must be lubricated.

A bearing in which a shaft is turning at a constant speed requires a constant supply of oil which must be fed to it regularly as required. Too much oil would be wasteful, and too little would permit the bearing to become heated. All the moving parts of an automobile must be lubricated, but as some parts move much more than others and are subjected to greater strain and pressure, the kind of lubrication must be varied to suit these conditions.

ENGINE LUBRICATION SYSTEMS

The principal parts of an engine to be lubricated are: main shaft, cam shaft, crank pin and wrist pin bearings; cylinder walls, piston and piston rings, valves, push rods, and all moving parts.

Methods of engine lubrication may be divided into two general classifications: the "circulating" and the "non-circulating" systems.

The circulating systems would be represented by systems having a continuous circulation of oil and these are frequently termed the "pump over" systems. For instance, a system using a force pump for pumping the oil from the lower part of the crank case to the upper part, with a drain back to the lower part again, would be termed a "circulating system."

A non-circulating system, such as a drip or gravity system, or a mechanical feed, so many drops per minute, depending upon the speed and size of the engine, with no provision for circulating the oil again, would be termed a "non-circulating system."

These systems may be combined, which is frequently done. For instance, the combination of a "forced feed" and "splash" system is often met with.

But, speaking generally, the systems can be grouped under: (1) splash, and (2) forced-feed lubrication.

Drip (or Gravity Feed) and Splash

This non-circulating system consists of a drip or gravity-feed oil cup (Fig. 1) placed over the bearings and also on the side of the cylinder. Special oil cups are required for the cylinder which will prevent the compression interfering with oil entering the side of the cylinder wall.

The oil drips by gravity, and the surplus flows to the oil trough from where it is picked up by the connecting rod and splashed to parts above. (C) is the cylinder and (B) the bearings; (S) is the crank pin. The oil in the lower part of the crank case is kept at a sufficient level for the connecting rod to pick it up and splash. The filling is done once in a while as required, by pouring the oil in by hand.

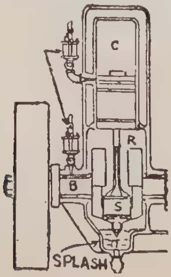


Fig. 1 Gravity or drip feed (oil cup).

The oil cups feed by drops, and usually the manufacturer determines how many drops per minute are required.

The oil flow is not controlled by the engine, and each cup is therefore provided with an adjustment, whereby the feed may be regulated when the engine is running, and turned off when it is stopped. This would be classed as a "non-circulating system."

This system is used extensively on two-cycle marine engines, and stationary engines. Two-cycle engines are also lubricated by mixing the oil with the gasoline through the mixing valve, the mixture being about one pint of oil to five gallons of gasoline.

The Splash System—Non-Circulating

The true splash system alone is non-circulating. The crank case is made oil-tight, and oil is placed in it to such a depth that the bottom end of the connecting rod dips into the oil, and splatters it to all parts of the crank case, the bearings, and the lower part of the piston. An oil groove is sometimes cut around the lower part of the piston, and the oil splashing into this is carried upward and distributed on the cylinder wall and rings. There are no oil troughs in this system.

As the oil is used, more must be added to the crank case to keep the necessary level. This is done either by means of (1) a hand pump connecting the crank case to an oil tank, or (2) by an oil cup that drips a certain amount of oil into the crank case every minute, or (3) by filling through a breather pipe.[1]

With the hand pump, the driver gives it a stroke or two every few miles, experience being his guide as to how often and how much. This latter system, however, is not much used on automobiles, but is extensively used on motorcycles. This system would be termed a non-circulating system.

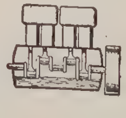


Fig. 2

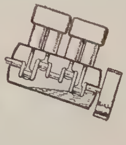


Fig. 3

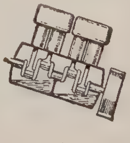


Fig. 4

The objections to the splash system are as follows: a reference to Fig. 2 will show that the engine is in a level position. As long as the engine remains level the splash system gives fairly good satisfaction; that is to say, so long as the level of the oil is kept up to the lowest point of the connecting rod where it can be picked up and thrown to the upper part. If, however, the car is in such a position as that the engine will be tilted, as shown in Fig. 3, then the oil goes to the rear cylinder. The rear cylinder is over-lubricated and the others are under-lubricated. Even though a "baffle" plate is placed as shown in Fig. 4, still there are two cylinders minus oil. Therefore some other means must be employed so that all cylinders will receive their proper share of oil.

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[1] **A "breather"** for an engine is a pipe opening connected with the crank case, and extending slightly above it, where oil is poured into the crank case. The opening is closed by a cap which does not fit tight, but allows the air to enter, and at the same time prevents oil from working out. (See Fig. 19, page 39, for location of breather or oil filler).

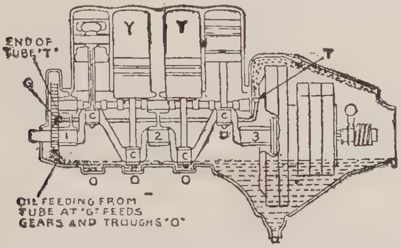

Fig. 5. The Ford semi-circulating system.

Splash System—Semi-Circulating

One method of overcoming the objection just mentioned is to provide troughs (O) under each connecting rod, which is shown in the cut of Ford engine (Figs. 5 and 5A). The troughs retain the oil, even though the engine is at an incline. The next method is to keep the oil at a **constant level** in the troughs. This is accomplished by some means of **circulating the oil.** In this instance the constant level of oil is maintained by the action of the fly wheel.

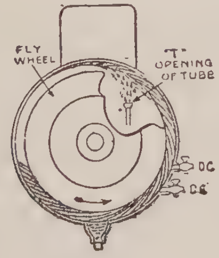

Fig. 5A. Showing how the flywheel circulates the oil.

The fly wheel throws the oil to the top of the transmission case where part of the oil is caught by tube (T) and fed by gravity to the cam gears. The overflow coming back tends to keep the troughs (O) filled with oil. This system would be termed a "semi-circulating system" (used on the Ford engine).

Splash System—Circulating[1]

This system could be termed a "circulating-splash system," also a "pump over" system, and is the true constant level, circulating-splash system because the oil troughs are kept at a constant level by a pump. It could also be termed a "force-feed and splash" system.

The operation of a "circulating" or "pump over" oiling system is shown in Fig. 6; the main oil supply is contained in the reservoir (**R**), from which it is drawn by the pump (**M**) and forced through the pipes or leads (**L**) to the main crank-shaft bearings (**G**).

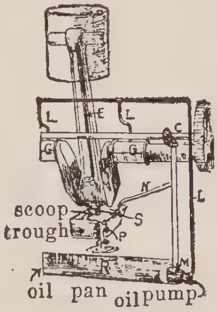

Fig. 6. Circulating system.

The overflow from these bearings is thrown by centrifugal force against the walls of the crank case and cylinders, and, as it runs down, is collected by inclined channels (**N**) which conduct it to troughs.

For lubrication of the connecting rod bearings, scoops (**S**) are fitted to the lower ends of the connecting rods, which dip into the oil contained in the troughs and scoop it up into the crank-pin bearings at the lower ends and through tubes (**E**) running up the rods to the piston-pin bearings.

Overflow pipes (**P**) are provided in the trough, so that the excess oil can return to the reservoir (**R**).

The pump (**M**) is usually a gear type of pump, operated by bevel or spiral gears and vertical shaft from the cam shaft (**C**). On many engines the pump is a plunger type, operated by a cam from the cam shaft.

Force-Feed System

In this system, oil is forced by pressure from the oil-pan by a pump to the crank-shaft bearings, then through drilled holes in the crank-pins, as shown in Fig. 10, page 160. Oil is not forced to the piston-pin, piston and cylinder, but these and other parts are supplied by oil thrown from the crank-pin bearings. The connecting rods do not dip.

Full Force-Feed System

In this system, oil is forced by pressure from the oil-pan by a pump to the crank-shaft bearings, then through drilled holes in the crank-pins, as in Fig. 7. Oil is also forced to the connecting rod, upper part, or piston-pin, through channels or pipes, thence out

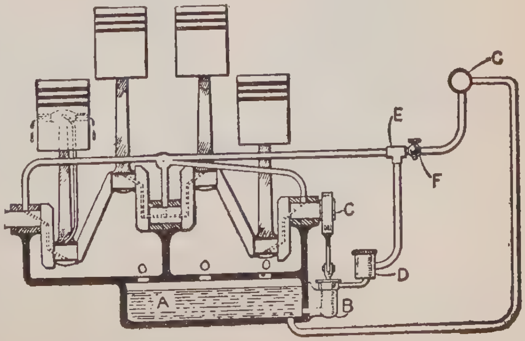

Fig. 7. Diagram of a "full-force-feed" system.

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[1] The depth of oil in the oil-pan of an engine using the splash system should be just enough so that the splash will distribute the oil.

of the piston-pin to the wall of the cylinder. Thus the difference between the "force" and "full force" system will be apparent. The connecting rods do not dip.

Note the dotted lines showing the path of the oil. **(A)** is the oil reservoir; **(B)** the piston or gear type of pump; **(C)** eccentric or gear for operating pump; **(G)** gauge placed on the dash to indicate the pressure; **(F)** check valve; **(D)** a strainer. This would be termed a true "full-force-feed" engine lubrication system.

Where a "full-force-feed" system is used the pistons must fit accurately as to clearance. If there is too great a clearance there will be an excess of oil in the combustion chamber and smoke will come from the exhaust.

OIL PUMPS

There are two types of oil-circulating pumps in general use: the "gear" type (Fig. 8) and the "plunger" or "piston" type (Fig. 9).

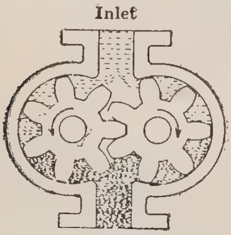

Fig. 8

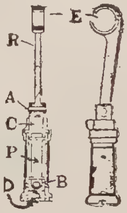

Fig. 9

The gear pump (Fig. 8) is generally used with a "force-feed" system and sometimes with the "circulating splash system."

Gear Pump

The gear pump is usually driven from the cam shaft. The oil is drawn into the spaces between the teeth and then forced out to the distributing pipe.

There are **two methods of mounting a gear pump:** One, by having it **submerged** in the oil as shown in Fig. 10, and another, by having it **elevated** (Fig. 11) above the oil level. In the latter case it is necessary that oil be drawn up to the pump before it will circulate, and quite often, if the oil level reaches a point where the pump loses its suction-effect, it will be necessary to prime it.

The submerged gear-type of oil pump is self-priming. The submerged pump with a large screen will lend itself to the circulation of heavier-bodied lubricants with greater ease than the system with the elevated pump and small screen.

Plunger or Piston Pump

The plunger or piston pump (Fig. 9), quite often used with circulating-splash oiling systems, consists of a plunger **(P)** which draws the oil into the pump at **(D)** on the suction stroke, through a ball valve **(B)**. On the return stroke, the ball valve is closed and oil is forced into the oiling system. The rod **(R)** of the piston pump (Fig. 9) is connected by an eccentric strap **(E)** to an eccentric on the cam shaft, which moves the piston **(P)**.

The adjustment of the piston pump (Fig. 9) is made by screwing the plunger rod **(C)** in, which shortens the stroke, or out, which lengthens the stroke. This shortening or lengthening of the stroke has the effect of regulating the flow of oil. The longer the stroke, the more oil flows, and vice versa.

Rotary Pump

Another type of pump, as used on the Dodge car, is a rotary pump (similar to that in Fig. 6, page 146), which is not submerged. See Index under "Dodge oil pressure."

EXAMPLE OF A FORCE-FEED ENGINE-LUBRICATION SYSTEM USING A SUBMERGED GEAR-TYPE PUMP

A true force-feed engine-lubrication system as used on the King eight-cylinder engine is shown in Fig. 10. There are no troughs and no splash with this system.

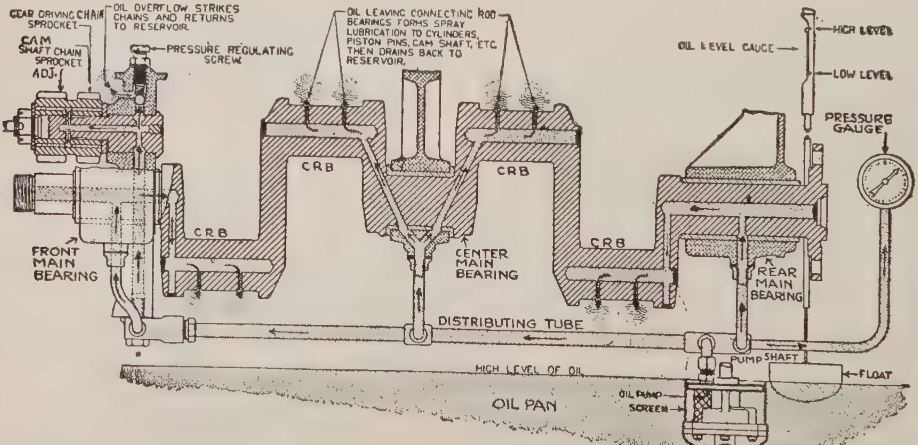
GEAR DRIVING CHAIN SPROCKET
OIL OVERFLOW STRIKES CHAINS AND RETURNS TO RESERVOIR
CAM SHAFT CHAIN SPROCKET ADJ.
PRESSURE REGULATING SCREW
OIL LEAVING CONNECTING ROD BEARINGS FORMS SPRAY LUBRICATION TO CYLINDERS, PISTON PINS, CAM SHAFT, ETC. THEN DRAINS BACK TO RESERVOIR.
OIL LEVEL GAUGE
HIGH LEVEL
LOW LEVEL
PRESSURE GAUGE
CRB
CRB
CRB
CRB
FRONT MAIN BEARING
CENTER MAIN BEARING
REAR MAIN BEARING
DISTRIBUTING TUBE
PUMP SHAFT
HIGH LEVEL OF OIL
FLOAT
OIL PAN
OIL PUMP
SCREEN

Fig. 10. Force-feed lubrication system. (CRB) refers to connecting rod bearings.

Path of Oil Circulation

Oil poured into the filter tube flows down into the oil pan, filling it up to a height indicated by the oil-level gauge on the right-hand side in the center of the engine. Note the float at the bottom of this gauge. From the pan or reservoir the oil is drawn up through the oil pump, which is driven by a vertical shaft from spiral gears on the cam shaft.

The oil pump is a submerged gear-type surrounded by a fine screen, so that all oil entering the system is thoroughly strained to remove the dirt or lint that might stop up the oil ducts and cause damage. The illustration shows the principle of the system, and by following the arrows the oil can be traced from the oil pan.

The gear pump at the extreme bottom of oil pan or reservoir draws the oil through the screen which surrounds it and forces it into a distributing pipe running the entire length of the crank case. From this pipe the oil is forced to each of the three crankshaft main bearings.

From the main bearings the oil is forced through holes in the crank shaft to the connecting-rod bearings. Since, at every revolution of the crank shaft, these holes register with the leads from the distributing pipe, an excess of oil is forced to the connecting rods, where it is drawn off in fine drops or mist on to the cylinder walls. A part of this spray is also utilized for lubricating the cam shaft, valves, and tappets.

Principle of the "spring and ball" valve which regulates the oil pressure. The ball is placed in the path of the oil line with a spring tension behind it. When the pressure of the oil circulation is reached, to which the spring tension is adjusted, the ball is forced open and oil overflows past the hole—in this instance, to the chain sprocket. In other words, it is merely a "relief-valve."

The ball and spring perform the same function as a safety valve on a steam boiler. It can be placed anywhere on the system (preferably farthest point away from oil pump). There are certain positions of the crank shaft when no oil channels register and pressure would build up excessively high, were it not provided with some means of release. When the pressure exceeds that at which the regulating screw is set, it forces the ball off its seat and the oil passes through the channel to lubricate the chains. If this regulating screw were set at too low a pressure, then all the oil would pass out under the ball and the crank pins would go dry. If set too high, the oil feed would be too great and smoke, carbon, and fouled plugs would be the result.

Adjustment

To increase pressure: The pressure-regulating screw (Fig. 10) can be screwed down after releasing the lock nut, which increases the tension of the spring against the ball. Thus more oil pressure is required to force the ball against the spring tension so that it will open the overflow opening.

To decrease pressure, the regulating screw is turned counter-clockwise, which lessens the spring tension on the ball.

It is best **to make adjustment** when the engine is running at a speed equivalent to about 25 miles car speed. At this speed, the pressure should be between 10 and 15 lbs. at maximum car speed, and should not be below 5 to 8 lbs. at minimum car speed. Be sure and **tighten the lock nut.** Always adjust oil pressure when the engine is warm.

Over-lubrication: If the oil pan at any time contains more that seven quarts of oil (King 8), the connecting rods will dip and thus create a splash which will over-oil the pistons and cylinders, more on the right-hand block than on the left, causing smoke to issue from the muffler pipe.

EXAMPLE OF A FORCE-FEED AND SPLASH ENGINE LUBRICATING SYSTEM USING AN ELEVATED GEAR-TYPE PUMP

As an example, the Studebaker Light-six engine is used. Lubrication of the engine is of the circulating-splash force-feed type (Figs. 11 to 11D).

Path of Oil Circulation

Oil is drawn from the oil pan by means of an elevated gear pump, driven by accessory shaft. From the oil pump, oil passes through a pipe to a distributor pipe fastened to the underside of the crank case. By means of four drilled holes in the crank case registering with the distributor pipe holes, oil is conducted to the cam-shaft bearings. Through the bearings of the cam shaft are holes through which oil passes twice every revolution of the cam shaft. When this hole in the cam shaft registers with the hole in the crank case, oil is forced through, allowing gravity feed to the crank-shaft bearings. Besides these holes in the distributor pipe, there is another series of small holes drilled in the under

Fig. 11B

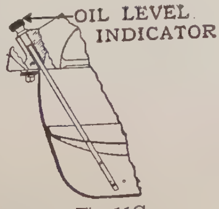

Fig. 11C

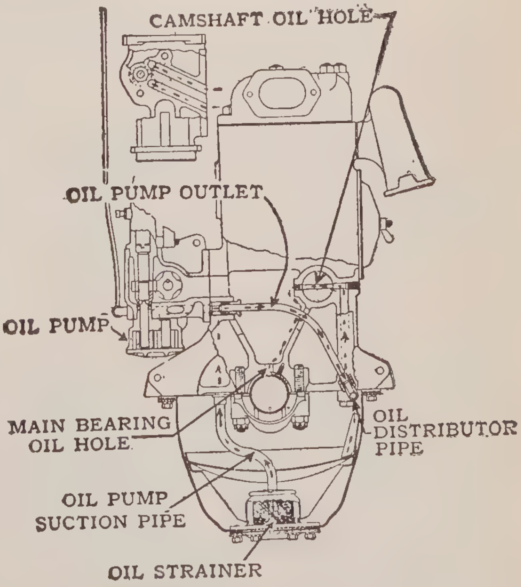

Fig. 11. Force-feed and splash lubrication of Studebaker "Light six" engine.

side of this pipe to keep the troughs in the dip pan filled to a constant level. At each revolution, splashers (Fig. 11B), which are a part of the connecting-rod bearing caps, dip into these troughs, splashing oil which lubricates the connecting-rod bearings, piston, and cylinder walls and piston pins.

From the passage in the case through which oil is forced to the front cam-shaft bearing, is an outlet through the front of the case into which is screwed a plug having four cross-drilled holes near the end. Oil is by this means forced to the silent chain and sprockets, finally returning to the reservoir through a return opening under the front crank-shaft bearing.

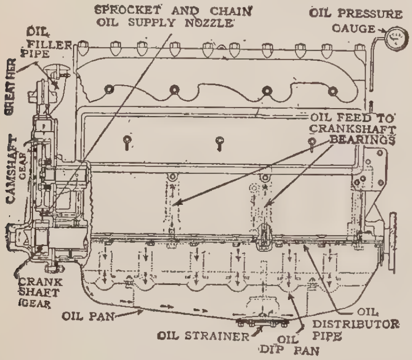

Fig. 11D

An oil-pressure gauge is located on the dash (Fig. 11D), which indicates back pressure on the oil pump. This gauge should normally indicate "one" to "three" when oil has become warm. If the gauge continues to show higher than "three" it is an indication of an obstruction in the distributor pipe, and it is necessary to remove the oil pan in order to clean the pipe. If the gauge does not indicate, the pressure system is inoperative. First make sure that there is oil in the reservoir.

Priming the Oil Pump

If the gauge fails to operate, after finding that the reservoir contains oil, then all joints and gaskets should be checked for tightness and the pump primed by disconnecting the oil-gauge pipe from the distributor base and squirting in oil.

The oil reservoir is filled through a filler tube at front of the engine on the right-hand side.

Oil-Level Indicator; Bayonet Type

Inserted in the right-hand side of the crank case is an oil-level indicator, "bayonet type" (Fig. 11C). In order to determine the quantity of oil in the reservoir, pull the rod out, wipe free from oil, and insert into the case again. Pull the rod out a second time, and the amount of oil in the base can easily be determined by noting the height at which the oil shows on the rod. Empty, half and full positions are shown by grooves in the rod. When the indicator shows that the reservoir is only half full, more oil should be added, but do not continue to add after the indicator registers full.

The quantity of oil required to fill the reservoir is one and one-half gallons.

An oil strainer is located at the lower end of the oil-suction pipe near the middle of the oil pan, as shown in Fig. 11, so that all oil is strained before entering the oil-circulating system. Should this screen become stopped up with foreign substances, it can easily be removed by taking out six cap screws which hold it to the bottom of the oil pan.

After the first 500 miles that a car is driven, and every 1,000 miles thereafter, all oil should be drained from the engine and replaced by new. When draining oil, remove the screen and clean thoroughly.

EXAMPLE OF A CIRCULATING-SPLASH ENGINE LUBRICATING SYSTEM USING A PISTON OR PLUNGER TYPE OF PUMP

As an example, the Hudson Super-Six system is used.

Path of Oil Circulation

The oil is taken from the pressed steel reservoir at **(A)**, straining all of it through a filter or metal screen of fine mesh (Fig. 12).

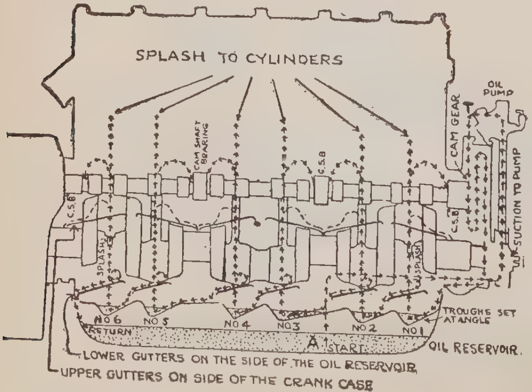

Fig. 12

The oil is fed directly into the front compartment containing the timing gears at (T) and their bearings, and flows from this into the first oil trough immediately under No. 1 cylinder. The large splasher or dipper (Fig. 12A) on the end of the connecting rod practically empties the oil trough at every revolution, throwing the oil into suitable channels or gutters on the side of the reservoir and crank case.

The upper gutters feed the main bearings in a continuous stream. The **lower gutter** feeds the oil directly into No. 2 oil trough (Fig. 12).

The splash from No. 2 oil trough feeds No. 3, and so on until No. 6 oil trough is reached, at which time the oil flows back into the reservoir.

The connecting-rod dipper is sufficiently effective to permit a very high level being maintained, thus insuring lubrication on all grades without excessive oil consumption. The two center bearings are fed by two troughs each.

The front bearing is fed from the timing gears and one trough, and the rear bearings are fed by two large troughs. It is apparent that all oil which enters at the front end must circulate through the various troughs to the reservoir again.

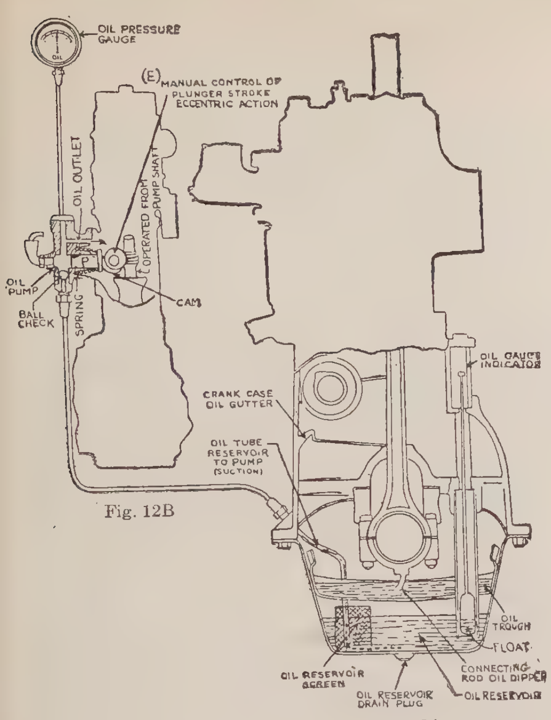

Fig. 12B

Fig. 12A

The Oil Pump

The piston or plunger-type of oil pump (Fig. 12B) is operated by a cam with an eccentric movement. The cam is driven by a vertical shaft from the crank shaft. The pump is elevated.

The cam forces the plunger in and a spring forces it out again, thus creating a suction effect which draws oil from the lower oil-reservoir or oil pan.

The plunger (P, Fig. 12B) is also under the control of another eccentric (E) which is connected with the foot accelerator and throttle control. Thus the quantity of oil pumped to the engine varies with the demand made upon the engine.

At slow engine speed the plunger is held in by the eccentric. Thus a shorter stroke is the result when the cam comes around (Fig. 12 B).

At a car speed of 18 to 20 m. p. h. the gauge should register 1° to 1½° of oil pressure. As the throttle is opened for **higher engine speeds,** the eccentric **(E, Fig. 12B)** is turned away from the plunger, thus permitting a longer stroke of the plunger **(P),** and the gauge should register 3° to 4° at about 30 m.p.h. Thus it will be observed that the pressure is governed by the speed of the engine.

If the gauge does not register the amount in the manner described above, the pump mechanism should be investigated. On indication of a pump being inoperative, or if the gauge needle shows no movement, make sure that there is plenty of oil in the reservoir and that the engine is getting lubrication by splash, and run irrespective of the pump. Then you can drive in carefully and have the system examined.

The oil reservoir on the Hudson contains over 3 gallons of oil in the troughs and in the reservoir itself. It is fitted with a **float indicator** which shows the level of the oil by means of a red button working in a glass tube. This is on the left-hand side of the engine. See Fig. 12A.

If the gauge does not show pressure at all, make sure that the oil pan contains plenty of oil, as shown by the oil-level indicator. Should this show "full," remove the priming plug on top of the pump and start the engine. If oil flows from this, the pump is working and the trouble is with the gauge.

Priming the pump: In case you think that the pump is clogged, it is a good plan before taking it down to try priming it with the same kind of oil that you put in the crank case. To prime the pump, remove the plug, pour in oil until it fills, replace the plug, and start the engine. If priming does no good, then it will be necessary to clean the pipes in order to find the obstruction. It is also advisable to clean the oil strainer occasionally. When the pump is taken down it must be primed with oil, after replacing.

Evidence of Poor Adjustment (Hudson)

1. **Excessive and continued smoking at slow speeds.** Sooty plugs. This indicates that the central eccentric does not shorten the stroke of the pump sufficiently. Adjustment of control eccentric is necessitated.
2. **Oil-pressure gauge readings** other than from ¾° to 1° when idling or 2° to 2½° at high speed. Eccentric adjustment necessary, or there is possibly a leak in the oil pipe lines.
3. **Engine hot.** Dirty oiling system, necessitating cleaning and change of oil, with possible readjustment.
4. **A pressure reading at slow speeds—none at high speeds.** Caused by the control cam permitting the plunger to work at slow speeds, but stopping it at high speeds. Adjustment of cam necessary. It is usually advisable to remove the oil pan, and to clean and refill with new oil in case of any oiling troubles before making any adjustments. A draining and replenishing of the oil supply is advisable every 1,000 miles; or after the first 500 miles with a new car.

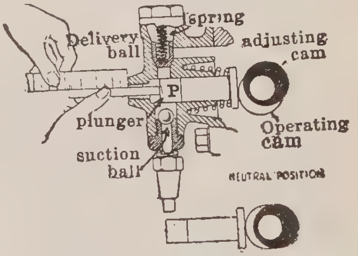

Fig. 13. Sectional view of oil pump, showing adjustment.

5. **If oil pressure is more than** 2½°, stop the engine, remove the spring, as shown in Fig. 13, and stretch it slightly in order that there may be more spring tension on the delivery ball, thus reducing the pressure. Replace spring and again test.
6. **Should the gauge read less than** 2½°, squeeze the spring shorter and test; couple up the throttle lever, as shown in Fig. 14.; start the engine and let it run with closed throttle; turn the adjusting screw (Fig. 14) in a counter-clockwise direction until the oil gauge registers ¾° to 1°; lock the throttle lever in place.

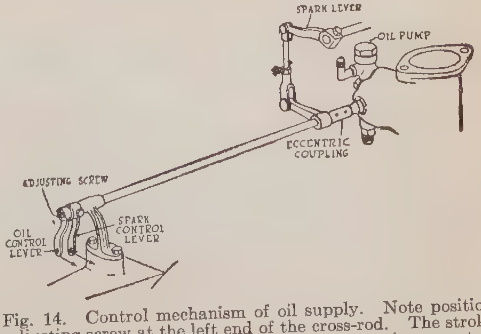

Fig. 14. Control mechanism of oil supply. Note position of adjusting screw at the left end of the cross-rod. The stroke of the oil pump is decreased by turning this screw in a counter-clockwise direction.

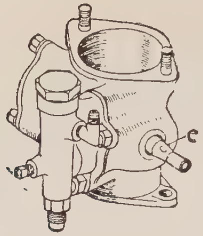

Fig. 15. The letter (C) of the eccentric cross shaft should be just forward of the vertical, when the engine is speeding, in most cases of proper adjustment.

To Check Up Adjustment

1. Remove the plug (Fig. 13) and insert a match or nail in the hole, bringing it into contact with the plunger head. The pump can be felt going through its stroke. (Care must be taken in doing this, as the fan runs very close to the plug and offers opportunity for injury.)
2. When the engine is idling, with the throttle closed, the stroke of the plunger should be about ⅛″ to 3/16″.
3. When racing, plunger should have a stroke of about 3/16″.
4. With the throttle open, the mark (C) on the control eccentric arm at the coupling should be just forward of the vertical (see Fig. 15). (In making any adjustment on the oil pump, always start with the control eccentric in the inoperative position and follow the steps through as outlined, otherwise the cam may be set in the wrong position.)

To Adjust Oil Pump

1. Loosen the throttle arm on the pump-control eccentric at the right side of the engine.
2. Turn the control eccentric arm with a screwdriver until it is entirely free from the plunger. This point can be determined when the engine is idling by turning the adjusting screw (Fig. 14) until a point is reached where the screw turns freely.
3. It is then in the position shown in Fig. 13, permitting the plunger to take a full stroke under all conditions.
4. Speed the engine up; note oil pressure. It should be as stated above.

The Dodge Oil Adjustment (Engine)

The oil gauge on the dash should show a pressure of 2 to 4 lbs. at 20 m.p.h. If the pressure is too low or too high and investigation shows that adjustment is required, remove the springs in the by-pass located directly in front of the water pump, stretching it for more pressure or cutting it off for less pressure.

To determine whether oil is flowing through the feed pipe inside the crank case when the gauge does not work, it is best first to remove the oil inspection plug just beyond the lower rear corner of the rear valve cover plate. If oil spurts out with the engine running, it shows that trouble is in the gauge.

OIL GAUGES

Two types are in general use: (1) "sight-feed"; (2) "pressure."

The sight-feed gauge is generally used with a "splash-circulating" oil system, where oil is only forced to the timing gears and to the oil troughs. The gauge mounted on the dash has two pipes connected to it, and the oil can be seen circulating (not illustrated).

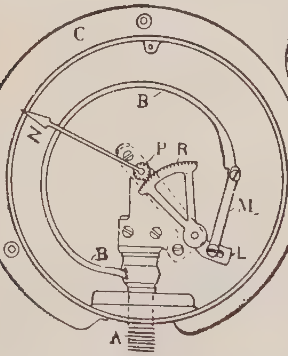

Fig. 16

Fig. 16A

Fig. 16. Internal view of oil gauge.
Fig. 16A. External view of oil gauge.

The pressure gauge differs, in that but one pipe is connected to it, and oil is not supposed to reach the gauge.

At low speeds of the pump the oil will probably go one-quarter the height of the pipe leading to the gauge, and at high speeds about three-quarters.

The oil as it rises compresses the air in this pipe up into the thin metal expanding tube (B) (Fig. 16). The greater the speed of oil pump, the greater the air pressure in (B), which causes it to tend to straighten out, thus operating (R), (P) and (N).

Pressure gauges are of low pressure when operated with a "splash circulating" system (see Figs. 11 and 12, pages 161, 162), and of high pressure when with a "force" system (Fig. 10, page 160), or "full-force" (page 159).

The oil gauge is usually placed in the dash or cowl board, and indicates the pressure of the oil being circulated.

The amount of pressure varies with the speed, temperature, and viscosity or thickness of the oil.

When the engine is cold, the pressure will be higher until the oil thins down. An excessive pressure on the gauge may also indicate the clogging of the system. If after the engine is warmed up the pressure is excessive and the regulation does not vary it, then it can be attributed to clogged pipes.

In other words, **maximum pressures** will be indicated at given speeds when the engine is cold and the oil is fresh; **minimum pressures,** when the engine is hot and the oil becomes thin.

Practically all engine lubricating oils become less viscous from use, even under normal conditions. Running the engine too long with the "choker" control lever pulled back will cause the oil to be thinned more rapidly, owing to the condensation of gasoline from the rich mixture.

Too high a pressure will cause abnormal oil consumption. This should be adjusted according to the pressure recommended by the manufacturers. Always adjust when the engine is hot.

If the indicator needle on the gauge drops to zero, it indicates that the oil level is low, or that for some reason oil is not circulating. In cold weather it may be an indication that the cold test of the oil you are using is not sufficiently low, and that the oil has congealed to a point where the pump cannot draw it from the oil pan. Do not under any consideration continue to run the engine if the hand on the cowl board vibrates or returns to zero, or if it remains at zero after starting the engine.

Oil-Gauge Indications

If the needle fails to indicate: (1) See if there is oil in the oil pan. The "oil-level indicator" (see Fig. 10, page 160), may be stuck. (2) If there is oil, then disconnect the union leading to the oil pump; run the engine. If oil flows, then look for air leaks, in piping, or in tube (B), Fig. 16. If oil does not flow, then look for the clogged strainer, pump, or pipes.

If the needle reads lower than usual: (1) Look for air leaks. (2) Loose bearings permit oil to pass freely, reducing the pressure. (3) Thin oil or oil diluted with gasoline, due to excessive priming may be the cause. (4) Pressure adjustment at pump, or at "ball and spring" relief valve (see page 160) not properly adjusted, or weak, or broken spring, may account for the trouble.

If the needle reads higher than usual: (1) Heavy or cold, congealed oil, which produces back-pressure, due to slow circulation; (2) obstruction in oil pipes; (3) new and tight bearings after overhauling engine, will all produce higher pressure, as the oil will not circulate as freely as when loose. If the oil gauge shows full pressure when running at a slow speed, foreign matter has become lodged in the distributor pipe.

Sometimes, when tube (B), Fig. 16, is expanded out of normal shape by too high a pressure, the needle fails to return to zero. In some instances, this tube can be pressed back into shape with the fingers. It is usually made of light spring copper.

Oil-Level Indicators

The oil-level indicators are for the purpose of indicating the amount of oil in the oil reservoir. There are three types in general use: the "float" type as shown in Fig. 10, page 160, the "bayonet" type as shown in Fig. 11C, page 161, and the pet cocks in the oil pan, as on the Ford and many truck engines.

To Test Oil Pipes or Tubes

If an air leak is suspected, remove the oil pipe at the couplings and test them carefully with air pressure, submerging them in water to make the test.

If the pipe is clogged, remove it, and use air pressure.

THE KIND OF ENGINE LUBRICATING OIL TO USE[1]

At the present time most lubricating oils are straight mineral oils made from different distillates of petroleum.

A good high-grade gas-engine oil is necessary, because the heat inside of an internal-combustion type of engine will burn the oil, leaving nothing for lubrication—hence wear. Therefore nothing but a high-grade oil will answer—one which will stand up under high temperature of the cylinders without thinning down.

Another point to consider is that if the rings are tight and compression is good, then it is possible to use a light-weight oil so that it will splash readily. A light-weight oil, under heat, can hold its body and will lubricate better than a good heavy oil, if of proper quality. Where clearance of pistons is greater than normal, then a good heavy-bodied oil is advisable, if the oil will maintain its viscosity.

If the piston rings leak, which naturally lowers compression, or if the piston clearance is greater than normal, then too light an oil will pass into the combustion chamber where the fire and flame will rapidly turn it to carbon, causing the carbon to stick to the valves, combustion chamber, and spark plug. The result is loss of oil, fouled spark plugs, and carbon deposit.

Some heavy-bodied oils may appear to hold their body or consistency, but under heat it will thin down considerably, whereas a light-bodied oil will hold its consistency equally as well. Any oil however, no matter how thick or heavy, will thin down to a certain extent when heated.

Light-bodied oils will flow freely through small passages. Heavy-bodied oils are less fluid and require large passages.

The viscosity, or the fluidity or the body of oil depends upon many factors:

The operating temperature of the engine[2] is the first factor.

The next factor is the **type of the lubricating system.** Where the "splash" system is used, the oil is splashed and atomized by action of the connecting rods, and light and medium-bodied oils are generally used. Where "pressure" systems are used, the heavier-bodied oil is favored.

Other factors governing the grade of oil, are such as the kind of oil pump used. If a submerged type of oil pump is used, it will probably circulate heavier-bodied oils more readily in chilly weather than the elevated pump. The oil screen, if of a fine mesh, will restrict the use of too heavy a bodied oil. If the oil pump and oil pipes are on the oustide of the engine[3], the oil will readily chill during cold weather, and such a condition demands an oil which will freely circulate. In fact, free circulation of good oil is the correct lubrication.

The proper oil to use is generally recommended by the maker of a car. The object has been to secure an oil that leaves no carbon deposit and that at the same time gives uniform complete lubrication. It must hold its body and form a lasting film on the wearing surfaces. If it thins down too much, it will leave the bearing without lubrication (see also, page 169).

Flash and Burning Points of Oil

A difference in oils is shown by their "flash points" and "burning points" explained as follows:

Oil when heated generates gas, just as gasoline does when not heated.

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[1] A chart of automobile recommendations, also a very instructive booklet, *Correct Lubrication*, is issued by the Vacuum Oil Co., 61 Broadway, New York City. It will be sent free to readers of this book on request. It specifies the correct grade of oil for each car and model for the last five years.

[2] The maximum temperature in the cylinders, at the top of the explosion stroke is approximately 2700° F.; the minimum temperature during the suction stroke, about 250° F.; average temperature during the four strokes, about 950° F. These are temperatures in the cylinders to which the outer side of the oil film is exposed.

The oil which is in contact with the cylinder walls and pistons is kept below the flash point (about 500° F.) by being in contact with the metal which conducts the heat away.

[3] **Cooling the lubricating oil.** On some racing cars and high-speed marine and aeronautical engines of high compression and speed, where heat is excessive, due to operating under full power for long periods of time, the oil is cooled by leading the oil out of the engine base, where the temperature can be lowered, before pumping it back into the engine.

The reason for cooling the oil is the fact that an airplane engine usually runs at full power for long periods of time and considerable heat is generated. The oil also loses its heavy lubricating film that is so very necessary between the bearing surfaces, and thins down to a point where the lubricating film is lost. Hence the advantages of keeping oil at a low temperature.

The best gasoline engine oils generate little or no gas at ordinary temperatures, but at high temperatures of, say, 500° F. it would generate a sufficient amount of gas so that it could be ignited with a match and would thus produce a flash and go out instantly. This is termed the "flash point."

If the heat is increased to, say, 550° F., and the match applied, the generation of gas would be so rapid that it would continue to burn until the oil was all consumed, unless extinguished. This is termed the "burning point."

A low grade of oil would perhaps flash at 300° F. and burn at 350° F., and should not be used because it would burn up at the working temperature inside of a gasoline engine. The flash and burning points are much higher in some oils than in others.

If oil with a low burning point is used in the cylinder of a gasoline engine, the intense heat will burn it before it can lubricate the cylinder walls and piston. If oil of a sufficiently high burning point is used, the temperature of the cylinder will not be high enough to burn it, and the cylinder walls and piston will be properly lubricated.

Simple Method of Testing an Oil

This method is not intended to be regarded as an approved method, but will give an idea as to the quality of the oil.

Drain oil which has been used in the engine, into a long narrow tube. Let it stand 24 hours. If good oil, it will show a small amount of black sediment at the bottom; but floating above it, the sediment is red in color (by transmitted light).

Let a poor oil be tested, which is used under the same conditions. At the end of a few minutes it will turn to a dense black. After standing 24 hours it will show a voluminous black sediment several times greater than that of good oil.

Black sediment indicates sulphur compounds in the oil. Sulphur is injurious to bearings, owing to lack of lubricating qualities; it also pits the valves, causing leakage of compression.

Cold Test of an Engine Lubricating Oil

Another test is the "cold" test which determines the temperature at which the oil congeals. Place some of the oil in a long narrow tube and insert a low-reading thermometer. Pack the tube in a freezing mixture of salt and ice. After the oil has frozen, remove the tube and incline it at an angle of 60°. When the oil starts to run down the tube, read the thermometer. This reading is known as the "chilled point." It should not be above 5° F.

Viscosity of Engine Lubricating Oils

Viscosity refers to the "body" or fluidity of an oil, or any other liquid. The viscosity of oils and liquids varies when heated. The viscosity of an oil does not indicate its lubricating quality, but only determines its fluidity.

To make a viscosity test, a viscosimeter is used. One type generally used is known as the Saybolt Standard Universal Viscometer. In order to give an idea as to the principle involved in the test, a simplified illustration is shown in Fig. 17.

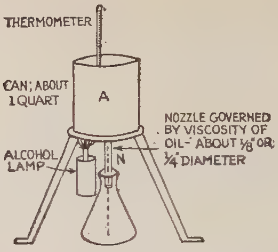
THERMOMETER
CAN; ABOUT 1 QUART
A
NOZZLE GOVERNED BY VISCOSITY OF OIL - ABOUT 1/8" OR 1/4" DIAMETER
ALCOHOL LAMP
N

Fig. 17

The test is made by filling the can (**A**) with oil to be tested and heating it to 70° F. A stop-watch is then used to determine the number of seconds required for the oil to run through the nipple (**N**). The same process is repeated with the oil at a temperature of 212° F.

A good gasoline-engine oil at 70° F. would run through the nipple (**N**) in approximately 140 seconds, and at 212° F., it would require about 62 seconds.

A poor grade of oil would probably pass through in about the same time as the good oil, or in 140 seconds when heated to only 70° F., but when heated to 212° F., its body would thin down and pass through in 50 seconds instead of 62 seconds required for good oil.

A good grade of oil would come nearer maintaining its viscosity or body when heated to a higher temperature, while a lower grade of oil with a heavy body at ordinary temperature would become very thin and useless as a lubricant at high temperature.

Castor Oil for Engine Lubrication

Castor oil is considered an ideal lubricant for airplane engines of both the revolving and stationary cylinder type, for the following reasons as stated by the Baker Castor Oil Co., New York: higher viscosity, lower heat conductivity, no carbon, higher fire test, higher flash test, lower cold test, and that it will not mix with mineral oil.

The Use of Graphite in the Automobile Engine[1]

The Jos. Dixon Crucible Co., Jersey City, N.J., states that the use of flake motor graphite mixed with cylinder lubricating oil, when properly used, will improve compression, decrease the amount of oil required, fill up scores in the cylinder walls, prevent valves and rings sticking, and thereby cure smoky exhaust.

However, assuming that graphite is an ideal lubricant, certain requirements are necessary; for instance:

For the splash-oiling system, the Dixon Co. recommends adding a scant teaspoonful of motor graphite to each quart of oil in the crank case, and then adding another teaspoonful at the end of each one thousand miles. The graphite may be mixed with a little oil and poured down the breather. This is a very small amount of graphite, but it is all that is required.

For the force-feed system it is not advisable to mix the graphite with the oil on account of the possibility of clogging some of the small passages.

A small amount of dry graphite may be placed on the hand and permitted to be inhaled through the air intake of the carburetor directly to the cylinders. This should be done about once a week when the car is in ordinary service.

More graphite can be used when it is introduced in the dry form, because part of it is immediately blown out through the exhaust.

On account of the location of the magneto on **Ford cars** and the possibility of short-circuiting the use of graphite in the crank case or transmission case of these cars is not recommended.

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[1] A free booklet, advising just where graphite as a lubricant can be used on a motor car, and the kind to use, can be obtained by writing the Joseph Dixon Crucible Co., Jersey City, N. J.

Using Oil over again, Adding Fresh Oil, Cleaning Crank Case, etc.

Using cylinder oil over again. The cylinder oil which is drained from the crank case of an engine is usually about one-half or two-thirds gasoline. Therefore it is not advisable to use it again. It may be used for the gear set if it is strained through a filter, and is good oil to begin with. It is then mixed with grease. The oil should be drained in a pan, mixed with grease until the mass assumes the consistency of the regular transmission lubricant, being neither liquid nor solid.

Adding Fresh Oil

It is important to note that **fresh oil of another make should not be added to the oil pan** before thoroughly washing out the old oil. Clean, good oil put into a dirty engine with gummed-up bearings has simply no chance of asserting its superiority under the unfavorable circumstances. It has first of all to get rid of the gumming round the bearings before its lubricating qualities will be manifested.

The engine should be drained and fresh oil added every 500 miles in winter, from the fact that the engine is primed more in winter than in summer, thus more gasoline mixes with the oil. In the summer, every 1,000 miles is sufficient. Oil can be drained by removing a drain plug in the bottom of the oil pan.

Cleaning Oil Pan

It is best to **remove the oil pan** and clean thoroughly with gasoline or kerosene, and at the same time to clean the oil strainer, making sure that **no trace of gasoline or kerosene is left in the oil pan,** otherwise the lubricating oil will be thinned.

If the oil pan is not removed, then the drain plug should be removed and the oil drained off. The plug should be replaced and about one quart of **light fresh oil** poured into the oil pan through the filler tube. With the ignition switch "off," so that the engine will not start, press in on the starter button and allow the starting motor to crank the engine for about 30 seconds.

Also step on the running board and rock the car back and forth. This will allow the fresh oil to wash the interior of the engine thoroughly. Remove the drain plug again, drain off, and refill with the proper grade of oil.

It is very important that kerosene be not used, as it will collect in the pockets inside of the crank case which are often provided to retain oil for the lubrication of the timing gears. Kerosene may be held in these and if left in engine will thin the fresh oil and cause it to lose its lubricating qualities.

The spark plug should be cleaned and properly set after refilling.

ENGINE LUBRICATION TROUBLES

Cause—too much oil: Oil pan too full; oil pressure adjustment too high; piston pumping oil or rings leak oil.

Effect—too much oil: Smoking at exhaust; carbon in cylinders; pre-ignition and knocking; carbon on valves necessitating grinding; spark plugs become fouled.

Cause—not enough oil: Oil level in oil pan too low; oil pressure improperly adjusted; oil pipes clogged; pump not operating.

Effect—not enough oil: Overheating; seized bearings or pistons; scored or cut cylinders; knocking.

Scored Cylinders, Piston, and Burned Bearings

Burned bearings on a crank shaft or elsewhere mean that the bearing surface is cut, caused by friction from lack of oil.

A **"scored cylinder"** means that there are scratches or cuts in the cylinder, caused by lack of oil, which permits the compression and also oil to leak through the cuts. A "scored piston" and rings is due to the same cause as well as to other causes.

If the engine is not getting enough oil, the cylinder will become so hot that any oil that may have splashed on its outside will be burned—the smell being an indication of the condition. Further running without oil will produce a hard metallic knock, and the heat will finally cause the piston to stick or "seize" in the cylinder.

An engine that is run without oil will be ruined, for the piston rings and the walls will be cut and scratched lengthwise (termed "scored"), so that the compression will not hold.

Another common cause of a scored piston and cylinder wall is the **dilution of the lubricating oil by gasoline.** The heavy-grade fuel is difficult to vaporize, especially in cold weather. To get an explosion, priming is resorted to—and right here is where much damage is done to an engine. If ignition is good, the engine probably will start because a little of the fuel has become vaporized at that particular engine temperature. But most of the gasoline remains unvaporized and washes the oil from the cylinder walls. It does not take long for a piston or cylinder to score under these conditions.

Then there enters again the human element. Many drivers forget to "unchoke" the engine, and a vast amount of unnecessary fuel is drawn into the cylinders for a long period. This raw fuel mixes with the oil on the cylinder walls and gradually finds its way into the crank-case sump, with the result that the oil is reduced to the consistency of a thin liquid and has no lubricating value whatever.

It is well to bear in mind, too, that a cylinder which "misses" allows fuel to get into the oil in even greater volume than when the cylinder fires, because none of the fuel is burned.

Another cause of scores is that the piston pin sometimes works loose and cuts the walls of the cylinder.

If the **piston sticks or "seizes"** and pounds from lack of oil, stop—wait until it cools, and then fill the crank case to correct level; also fill the radiator with water after the engine has cooled sufficiently.

The engine should then be thoroughly inspected before driving, to see if any damage has been done. If no obvious damage has been done, a thorough examination should be carried on to determine whether or not the running without oil has burned the bearings or caused other trouble. This can be ascertained by starting the engine, and if it pounds or knocks, it is a certain indication of bearings burned or cylinders scored. See, also, Index under "Seized piston."

A new bearing, or any other new part that has not worn smooth, requires more oil than one that has been run. It is always better to give a bearing too much oil than too little, but the exact amount of oil required for each part of the car should be learned as quickly as possible, in order to prevent waste.

When an engine is permitted to run excessively hot, partial oxidation of the engine oil takes place, which forms a certain percentage of water. For instance, if petroleum oils are treated with air at 300° F., water and carbon dioxide are readily formed. This accounts for the presence of water in the lubricating oil in the crank case, in some instances.

Smoky Exhaust

If the engine smokes excessively, drain the oil pan and measure its contents, as the oil-level gauge may be stuck. If the oil pan does not contain more than the right amount, the oil is probably pumping past the pistons, owing to worn or stuck piston rings or to too great a piston clearance. If this is the cause, new rings should be fitted at once.

Smoke Indications and Cause

If the vapor is black and foul smelling, it is caused by too "rich a mixture" (too much gasoline); this can be remedied in the carburetor adjustment.

If the smoke is white or blue, the engine is supplied with an excess of oil.

If the smoke is grey, there is too much fuel as well as lubricating oil.

The reason an engine excessively supplied with oil smokes is that there is too much in the crank case; the entire lower portion of the connecting rod will dip into it and the lubricant will be forced into the cylinder to work by the rings on the piston, then into the combustion chamber, thence out through the exhaust. The same applies to a pressure feed or force system where the pressure is too high.

Depending upon smoke issuing from the exhaust pipe of a car as a means of testing whether or not the cylinder lubrication is sufficient or over-sufficient is by no means always conclusive. The fact that the exhaust is smoky does not indicate that lubrication is complete, or excessive in all cylinders. If it issues in a steady and continuous stream, there is probably sufficient oil in the engine, and probably too much, but if it comes in intermittent puffs, it may be inferred that one compartment only of the crank case is flooded, or, maybe, one cylinder is getting too much oil. If there is a black gummy deposit on the spark plug it will indicate which cylinder is getting an excess of oil.

Leaky piston rings are quite frequently the cause of excessive smoke. See Repair subject, "Leaky piston rings."

A method formerly used, and still used on some marine and stationary engines, for preventing trouble caused by excessive oil, was a baffle plate as shown at (**BP**) in Fig. 18. This is a simple plate of sheet metal in which a slot is cut, through which the connecting rod works, thus preventing an excess amount of oil finding its way into the mount of the cylinder. This method has also been used in some automobiles.

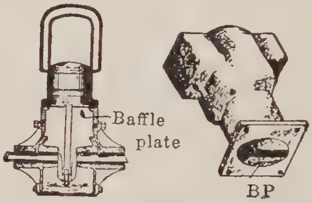

Fig. 18

If the spark plugs are constantly oil-soaked, this indicates leaky piston rings. The oil passes the rings, hence the trouble. It can also be caused by the "piston pumping" oil. An oil-soaked spark plug usually has a black gummy deposit on the spark plug.

Oil Drips from Engine

The average oil drips come from **the cap screws being loose on the crank case.** Other drips come from worn bearings out of the side of the crank shaft and quite frequently from the plungers or tappets above the cam shaft.

On some cars **the fan often picks up the oil** oozing from bearings and throws it over the inside of the hood.

RELATION OF PISTON AND RINGS TO SMOKE AND EXCESS OIL

Piston Pumping Oil

Quite often the combustion chamber will be constantly oil-soaked, thereby keeping the plug fouled and causing "missing." The front or rear cylinders are prone to this, and it appears that it is due to the fact that a necessary amount of oil must be carried in the crank case. When the car is going up or down hill the rear or front cylinders get an excessive amount of oil and the piston assists by pumping it past the rings. This is common where there is excessive piston clearance, especially in old engines and quite often in new ones, where there is excessive clearance to begin with and poor fitting rings in addition.

Another common cause—is **too high an oil pressure.** It is by no means unusual to see pressures of 30 lbs. employed.

Very few people are aware of the fact that the piston and cylinder walls in a well-designed engine should not be placed in the actual path of the big-end splash.

At ordinary engine speeds, the inside of the crank case is in a condition of what can aptly be described as "oil fog," and although all the crank-shaft bearings are fed directly with liquid oil, the cylinder itself should be supplied by "fog" only, which is much denser than one might imagine, and quite equal to its work in this respect.

Any actual splash which gets on the walls simply leads to waste and carbonization through the oil getting past the rings into the combustion head and being burnt.

A method of avoiding this, adopted by many, is to taper off the top of the piston so that the oil, instead of gathering on the head, will gather in the space around the outside diameter between the piston and the cylinder walls, where it does the most good.

A third cause of oil waste is to be found in the piston rings. If worn slightly oval, they will cause leakage if their position is not rigidly maintained.

Under racing conditions, where the piston is a very slack fit and a minimum of friction is essential, a slight advantage in engine speed is obtained by using a surplus of oil, for it is well to explain that in describing these various methods of reducing oil consumption the ideas aimed at are: (1) economy, and (2) prevention of rapid carbonization. It is not intended to convey the impression that any actual mechanical harm is done to the engine by over-oiling.

See page 167, relative to the **dilution of lubricating oil with gasoline** by too much priming, which causes cylinder walls and piston to become scored, thus permitting too much oil to pass to the combustion chamber.

Vacuum Cause of Piston Pumping Oil

When you see blue smoke issuing from the exhaust, it indicates that too much lubricating oil is being consumed. If this occurs regularly at all speeds, it is generally due to piston rings. If it occurs only when the engine is run at low speeds for long periods, or idling at the curb, it is due to either cause as follows:

When the engine is run fast a vacuum is not produced in the cylinder, because so much gasoline and air is drawn into cylinder.

When the engine is throttled down, only a little air is allowed to enter, therefore more of a vacuum is produced, the tendency being for the vacuum to suck up oil from the crank case past the piston rings.

No doubt you have seen many a car start off from a standstill after the engine has been running slowly for a time, and have watched clouds of smoke coming from the muffler. Gradually, as the car gets under way, the smoke gets less, and finally no smoke is evident unless the mixture should be too rich, in which case the smoke is black. See Index for meaning of the word "Vacuum."

Prevention of Excessive Oil in Combustion Chamber

Carbonization, sooty spark plugs, and a smoky exhaust are due to the fact that the oil works up past the piston into the combustion chamber. The usual cause is attributable to the piston pumping oil or leaky piston rings. This is common where there is excessive piston clearance, especially in old engines and quite often in new ones, where there is excessive clearance and poor fitting rings in addition.

If the piston rings leak, the oil passes around the rings, out through the exhaust, causing considerable smoke. Another indication of leaking rings is the constantly oil-soaked spark plugs which cause missing of ignition. Therefore, if the rings are not in the best condition, it would be wise to use heavier oil or to fit new rings.

Another common cause is too high an oil pressure.

Some of the **methods employed to prevent an excess of oil** in the combustion chamber are suggested in Fig. 19. For convenience, the drawing has been divided into quarters, designated 1, 2, 3, and 4.

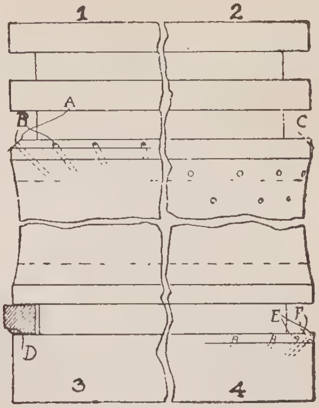

Fig. 19. In 1 at (A) is shown a popular method for overcoming some of the troubles due to an excess of oil. Note the chamfered lower edge of the second ring groove (B); 1/32" holes are drilled from the chamfered edge to the inside of the piston. This is for the return flow of the excess oil. An extra large hole in each side over the piston-pin bearing and running into it will improve its lubrication and insure long life. The number of small holes around the chamfered edge should be determined by the extent of the fouling.

At 2, is shown the chamfered lower edge of the second ring groove and the small holes drilled through the piston in the recessed space about the middle. Here, as at 1, the number of holes should be determined by the extent of the fouling.

At 3 is shown the chamfered lower edge of the bottom or oil ring. This very simple method is highly successful, a great deal easier to perform, and is the one employed in the repair shops of the various Ford branches, and is usually all that is necessary. This should be tried before fitting a patent ring or drilling a piston.

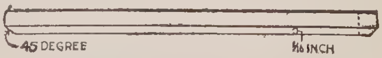

Fig. 20

Fig. 20. Showing a method of chamfering the lower part of the lower ring. To "chamfer" means to bevel the part (as shown in Fig. 20) with a file or emery wheel. The illustration gives an idea of the amount and angle of the chamfer. This will permit cylinders to get oil, but will prevent oil working past the rings into the combustion chamber, providing, of course, that the cylinder walls are not "scored." The treatment applies only to those cylinders in which the spark plugs are constantly oil-soaked, usually No. 1 (front), and often No. 4 (rear).

A repairman who had done considerable Ford repair work states that he changes the pistons in Ford engines which pump oil and allows about .002" to .0025" clearance instead of the usual .003" clearance and this usually remedies the trouble.

RELATION OF CARBON TO LUBRICATING OIL

The oil film which protects the friction surfaces in the engine is hardly thicker than the page you are now reading. It makes no difference how much oil you pour into your crank case. The only oil that protects your engine is this thin film between the moving metal parts.

And this thin film is not the cool oil you pour into your crank case. In use, the oil heats quickly. Then the test comes.

Only oil of the highest quality will retain full lubricating efficiency under the heat of service. Many oils break down under this heat. Part of the oil goes off in vapor, just as hot water gives off steam. With an oil film only .003" thick, this vaporization must be reckoned with.

To get full protection, you must have a constant, full, even oil film. You must have an oil which will stand the heat of service, and oil which is not diluted with gasoline. Hence the reason for changing the oil in the crank case often.

The Cause of Carbon Deposit

Carbon deposit is due mostly to the use of a poor grade of lubricating oil or to too much oil, and quite often to an improper mixture of gas or to too much gasoline being fed.

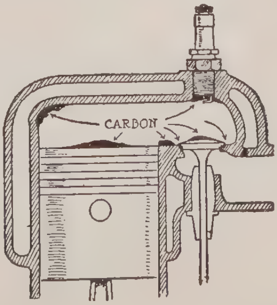

Fig. 21. Showing points in the cylinder where carbon deposits are most likely to gather.

Carbon has many lodging places. It fouls spark plugs and kills the spark. It pits the valve seats and thus weakens compression. By accumulating on the piston heads and in the combustion chambers, it causes knocking and racks the engine with pre-ignition.

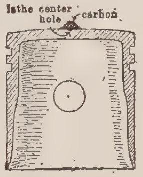

Fig. 22. The collection of carbon on the top of the piston head is often greatly accelerated by the lathe center mark in the head, and where possible this hole should be avoided or filled up. It is the starting point at which the carbon begins to collect, and soon there is a mound at this point. The rapidity with which carbon collects can be greatly reduced by smoothing the walls of the combustion chamber, especially the top of the piston. The surfaces should be polished with emery and crocus cloth.

The amount of carbon deposited in the engine depends upon the carburetion, upon gasoline combustion, and on the character of the gasoline as well as on the quality of the lubricating oil itself and the correctness of its body.

As both gasoline and petroleum lubricating oils are chemical combinations of hydrogen and carbon, carbon is an essential element of each.

Only the free (suspended) carbon can be taken out. To remove the carbon which is in combination with other chemical elements, constituting gasoline and oil, would result in the destruction of the product itself.

Carbon deposit is also likely to occur through incomplete combustion of the gasoline, or through the destruction of the excess lubricating oil which will work into the combustion chamber if the oil is of incorrect body. "No-carbon" oils do not exist.

To reduce carbon to a minimum, the lubricating oil must be of high quality and of correct body for the piston design and lubricating system of the engine.

Lubricating oil adds materially to the carbon deposit in an engine if the following conditions exist:

1. **Poorly fitting piston rings** or scored piston rings and cylinders.

2. **Carrying too high an oil level;** using an oil that is not suited to the engine, both as regards body and quality, or carrying the pressure in a force-feed system at too high a point.

3. **Allowing the oil** in the crank case or oiling system **to deteriorate** to the point that it becomes so thin that even a well-fitting piston ring will not prevent a surplus of oil from passing into the combustion chamber.

Relation of Carbon to Combustion

An important consideration is **the incomplete combustion of gasoline,** for from this source a large proportion of carbon deposit comes. When the charge of gasoline and air (the proportions of which are determined by the carburetor adjustment) is taken into the cylinder of a gasoline engine, it consists of hydrocarbon vapor and air. The oxygen in the air combines with the carbon and hydrogen of the gasoline and forms an explosive mixture. This mixture is fired, and after expansion, the products of the combustion are expelled from the cylinder through the exhaust valve.

If the amount of air entering the carburetor is not sufficient to insure complete combustion, we have what is known as a rich mixture. This is a slow-burning mixture, rather than an explosive one, and will cause excessive carbon deposit. For example, if the wick of an oil-burning lamp is turned too high, too much oil will be drawn through the wick for the amount of air entering the lamp to form complete combustion. The lamp will smoke, and soot (which is carbon) will be deposited on the chimney.

This is exactly what happens in the cylinder of a gas engine. The products of incomplete combustion, together with a portion of lubricating oil passing by the piston rings, deposit a certain amount of carbon in the combustion chamber. That portion of this carbon which does not pass out with the exhaust is baked on the cylinder heads, pistons, and valves by the heat of explosion. This carbon deposit will build up very much more quickly if it has a bed to build up on, such as would be produced by a lubricating oil, which, when exposed to the heat of explosion, would leave a gummy deposit.

Cause of Carbon Deposit

Carbon deposit is therefore due to: (1) the amount and grade of oil; (2) the carburetion mixture. If too much gasoline is used it will cause carbon deposit, just the same as a poor grade of oil.

Excessive heat will also cause carbon, as oil vaporizes. Because oil becomes more fluid when it is heated, the oil feeds should be adjusted after the engine has been running, for if adjustments are made for cold oil, the flow will be much more rapid when it is warmed, and the bearings will be flooded, and the excess oil will pass by the rings, causing carbon deposits.

Bad Effect of Carbon Deposit

Carbon deposit will cause the valves to leak by the carbon gumming under the seat of the valve, thereby decreasing the power.

Carbon deposit cakes on the end of the piston and on the walls of the combustion chamber, which, when the engine is hot, will cause the small particles of carbon to become red hot and cause premature ignition (or pre-ignition), which results in pounding.

Carbon deposit will also cause the spark plugs to become fouled, for if the oil that is being used will cause carbon in one place, it will accumulate on the spark plugs also. In other words, carbon is a bad thing for an engine, and ought to be removed, and, better still, guarded against.

Indications of Carbon

Carbonization of engine—general indications: If you should note that the engine, when fully supplied with water and oil and with the spark lever in proper position, is overheating easily, has weak compression, and develops a "knock" or "clank" when on a hard pull, there is probably a large deposit of carbon in the cylinder compression chambers. This may be due to the use of poor lubricating oil or to incorrect adjustment of the carburetor. Even though it is not affected by these two conditions, a small residue of carbon will adhere to the interior of the compression chamber, and if left for a great length of time, will develop the trouble mentioned above. The carbon sticking to the inside of a cylinder becomes red hot and pre-ignites the charge.

Methods of Removing and Preventing Carbon

This subject is fully treated under the "Repair section" of this book. See also Index.

OIL GROOVES IN BEARINGS

The old-fashioned arrangement of two simple holes on the upper side leading into the oil-way, either straight, starred, or spiral, appears to be as good as any. But, be it noted, the oil-ways should not be cut to the extreme edge of the bush, or their action as reservoirs is apt to be interfered with.

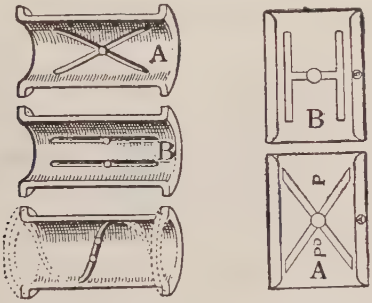

Fig. 23. Oil grooves in bearings.

Similarly, the beveling of the edges of the bush should likewise be discontinued before reaching the outside. The arrangements of oil-ways is shown in Fig. 23.

The usual practice is to make the grooves as shown in the figure at (**A**) like a letter X. The result of using this style of groove is that the areas of the bearing at **p, p,** run dry. A careful series of tests has shown that the type of oil-groove shown at (**B**) and made in the form of the letter H gives results far superior to the other. Some very bad cases of poor lubrication and heating of bearings have been cured entirely by the simple expedient of changing the type of oil groove from that shown at (**A**) to that shown at (**B**). (E. W. Roberts in "The Gas Engine.")

Keep oil grooves out of the pressure side of your bearing, whenever the pressure is one sided, as in the crank-pin bearing.

"Running-in" a New Engine

Fine grooves (not visible to the eye) are left on the piston by the cutting point of the lathe tool when originally made. Also pear-shaped pits are left by the grinding machine on the cylinder walls. When the engine is new the projections are in the fine-line stage.

With an ordinary temperature, at say, .003″ piston clearance, the projections will pass one another. When the temperature of the engine is raised, the projections will touch from expansion, and if the speed is excessive, the temperature is raised which, in turn, increases expansion, and friction takes place. The projections then imbed themselves in the recesses opposite them, which will cause a stuck or "seized" piston, with the attendant condition of a "scored" or cut cylinder wall.

Care is necessary to use plenty of oil and to run at normal rates of speed until the projections gradually change shape, and are bent over in such a way that the high points fill the recesses.

After the engine has been run 1,000 miles with care, the piston and cylinder surfaces become very smooth and polished.

When the engine stands over night, don't immediately race the engine to warm it up, because the oil has drained from bearings, cylinder walls, etc. Consequently it is going to take a few minutes to lubricate these parts properly. Therefore at first let it run slowly for a minute or so.

POINTERS ON GENERAL LUBRICATION OF A CAR

It is a difficult matter to advise just what lubricants to use on all cars, as different manufacturers advise what to use and their advice ought to be followed. However, a few pointers in general are given below:

Lubricated disk clutch: There is much misinformation about the caring for and lubrication of a disk clutch. Heavy oil is often put into such a mechanism with rather disastrous results. At the end of a reasonable distance, say 1,000 miles, the old oil in a disk clutch should be removed. There is usually a drain plug fitted to the clutch housing, and this should be removed to let the oil out, after which the clutch should be rinsed with kerosene, and again allowed to drain completely. Thus cleaned, a supply of a light clutch oil should be put in until the level is about even with the bottom of the clutch shaft. This allows the plates to pass through a bath of oil, and is the desirable condition. Some recommend a mixture of a light oil with kerosene, but as the proportion varies, it is best to purchase a regular light clutch oil.

Where multiple disk clutches are used which run in oil, it is very important that a light-bodied oil be used, else the plates will have a tendency to drag by sticking together. See Index under "Hudson clutch."

On the subject of **dry disk clutches,** see description on page 22 and the Borg & Beck clutch, page 24; if oil gets into the clutch it will cause slipping.

The transmission: On some transmissions, where dry disk clutches are used, there is an oil hole in the main transmission shaft which permits oil to pass to the clutch yoke. With this type, oil of a fairly heavy body is used, such as steam cylinder oil. On other transmissions, a special grease called "transmission compound" is used.

When grease is used, it should really be a heavy oil, or a grease of such consistency that it will flow. Thus, when the gears and shafts pass through it, it does not adhere to them, and there is not the tendency to throw it out of contact with the bearing surfaces. There are many special forms of gear-set and differential semi-fluid greases and heavy oils on the market, and the makers have studied these facts, so that the products perform their function of being just light enough to prevent sticking to the revolving parts. It is obviously wrong, therefore, to put any common grease into a gear-set, for it not only acts as described, but has not the ability to get into bearings like a fluid material.

In filling the gear-set, put in the lubricant to a depth about half the height of the gearbox, that is, have it come about even with the center of the main shaft. This will completely submerge the countershaft in the average gear-set design, and will bring the under face of the main shaft gears into the lubricant. It is important in this connection to see that the packing rings are tight and prevent leakage where the drive shaft emerges from the gear-case and where the shaft from the clutch enters it. If there is leakage here, it not only will act as a collector of dirt and dust, but the gears will be robbed of their proper lubrication.

The differential housing should hold the lubricant in the rear axle gears, so that attention is needed only as stated above. But sometimes a disagreeable-looking rear axle is noticed where the oil or grease oozes out through cracks or leaks in the rear cover plate or through the axle tubes or brakes on to the wheels. This is not so common a fault as it used to be, when axles were not designed so well to trap the oil and keep it where it belongs. However, an occasional careless driver will let his axle get in this condition by not having a proper gasket or felt packing between the differential housing cover plate and the housing itself, or by putting too much oil in the rear axle differential housing. The brake bands become oil soaked and slip when oil passes out at the ends of axles.

The axle: For most rear axles a heavy oil, such as steam cylinder oil, is recommended, but in some instances a semi-fluid grease or even a heavy grease is used. It is next to impossible to give any fixed rule for rear-axle lubrication. There are so many designs, that where a heavy oil or a grease will work satisfactorily in one instance, some other form is better in another. Usually, however, heavy oil is placed in the rear axle housing.

Dodge, for instance, uses 600W—steam cylinder oil, two parts, and one part of medium grease.

The rear end bearings of the drive shaft, which support the drive pinion, are greased and this particular grease cup is often overlooked, owing to its inaccessible location. Many a bearing has run dry under such conditions, because the oil cannot reach it from the rear axle housing.

Example of Lubricating the Parts of a Car

As an example, the instructions for the Allen "43," four-cylinder car will be used.

Systematic lubrication is the most important care that a car can receive. Perfect and continuous lubrication means less wear of parts, less trouble, and a better and smoother running car. Sketches are shown of each of the parts to be lubricated, so that there should be no difficulty in identifying them.

Lubricant is of little value when mixed with dirt, so before oiling or greasing a part, be sure there is absolutely no dirt on or in the parts.

The crank case should be filled daily if the car is being used very much. In this daily filling it is only necessary to add enough fresh oil to bring the level up to the upper mark on the indicator rod. Make this a daily habit and insure yourself against running out of oil unexpectedly. The capacity of the engine lubricating system is two gallons. Light engine oil is recommended for winter and medium for spring, summer, and fall use.

The engine oil level gauge, a bayonet type, is located on the left-hand side of the engine just ahead of the generator. In order to obtain accurate readings, it is necessary to take them when the engine is not running. The oil should never be below the bottom line and never above the top line of the blade. It is advisable to keep it near the top line by supplying oil to the engine at frequent intervals, rather than to allow oil to go to an extreme low level before refilling. In extremely hilly countries there will be a tendency of the pump to run out of oil when going down grade if the level is below half-way between the marks. There is no danger in this as long as the pump picks up the oil when on a level stretch or on upgrade. The **oil pressure gauge** will show whether or not this happens.

The crank case should be drained and replenished with oil every month, except when the car is new, in which case it should be done more often, as directed below. At the end of 300 miles a new engine should have the crank case drained and fresh oil should be supplied. This should be done again at the end of the first 1,000 miles. Thereafter every 1,000 miles will be enough, or every month, depending upon the mileage made during that period. Every 3,000 miles the oil pan should be removed and the entire pan carefully cleaned with kerosene in order to remove the metal and carbon sediment that collects. It is very important to do this, if long life is expected from the engine, because of the dilution of the oil due to the poor quality of fuel condensing and precipitating kerosene and the ability of this to work past the piston rings and into the lubricating oil.

Do not put kerosene in the engine, as it will work its way down to the crank case and thin the lubricating oil.

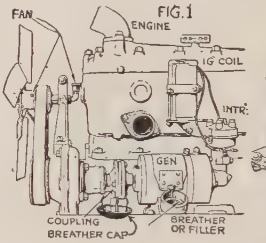
FIG. 1

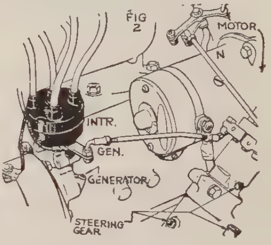
FIG 2

The fan hub is provided with an oil hole that is closed by a ball check. By depressing this plug it is possible to introduce the oil to the bearings of the fan. On some models an oil cup is provided at the rear of the fan spindle instead (Fig. 1). Use medium oil—weekly.

The electric generator and distributor bearings should receive oil monthly. They should not be flooded with oil. Five to ten drops of light oil only should be sufficient. (Fig. 2.)

The electric starting motor should be oiled at the same time as the electric generator. The same light oil should be used, and not more than five to ten drops should be applied to each bearing.

Remove the two plugs in the top of the steering gear case and fill the case with light cup-grease monthly. A grease gun will facilitate doing this. On the steering-gear housing there is a grease cup which should be turned down as far as possible and then refilled at this time.

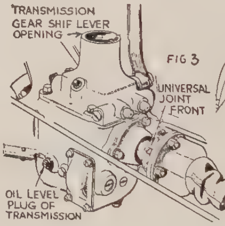
FIG 3
TRANSMISSION GEAR SHIF LEVER OPENING
UNIVERSAL JOINT FRONT
OIL LEVEL PLUG OF TRANSMISSION

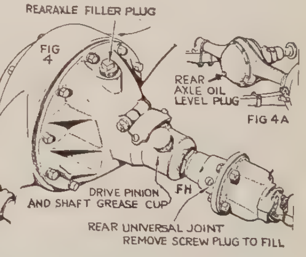
FIG 4
FIG 4A
REARAXLE FILLER PLUG
REAR AXLE OIL LEVEL PLUG
DRIVE PINION AND SHAFT GREASE CUP
FH
REAR UNIVERSAL JOINT REMOVE SCREW PLUG TO FILL

The transmission case is filled with transmission grease every month, or about every 1,000 miles. When the case is filled to a point above the counter shaft it then contains three pints of oil. A plug in the left side of the gear box (Fig. 3) determines this level. Remove the plug while filling the case. The oil is introduced through the gear-shift lever socket after the lever has been removed. The lever is easily removed by unscrewing the retaining cap and lifting lever and cap straight up out of the transmission case.

There are two universal joints between the gear box and the rear axle. These should be filled with about a teaspoonful of light cup-grease every month. Filler holes (Fig. 4) closed by plugs are provided in each universal-joint housing, so that it is not necessary to open the boot when filling them.

Every 1,000 miles **the rear axle** should be drained and flushed with kerosene, then refilled with fresh oil. Four pints of oil are required to fill the differential case of the rear axle. If more oil is used, it is liable to work out upon the brakes. The rear axle filler opening is on the front side of the rear axle and can be reached by removing the rear seat cushion (Fig. 4).

On the rear of the axle is an oil level hole (Fig. **4A**). The plug should be removed from this when replenishing the oil supply if all the oil has not been drained from the axle previous to filling and only enough oil should be added to reach the level of this oil hole. All of the axle holes are closed by plugs.

Drive pinion shaft: Fill the grease cup (Fig. 4) with transmission grease monthly. This point of lubrication is one that is often overlooked, yet it is one of the most important.

There is an oil cup on top of each **steering knuckle** and one on each end of the **front axle tie rod,** which is located just to

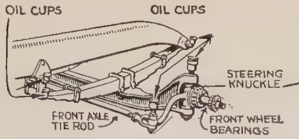

Fig. 5

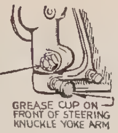

Fig. 5A

the rear of the front axle (Fig. 5). These should be filled with medium engine oil every month.

On the front of each steering knuckle (Fig. 5A) there is also a grease cup. This should be turned down each week and filled with light cup grease when the oil cups are replenished.

The **drag link** which connects the steering-gear ball arm and the steering arm on the front axle (not shown), is provided with ball-and-socket joints at each end. These should be packed with light cup grease every month, or about each 1,000 miles. In order to pack them properly, they should be taken apart. Remove the cotter pin in the ends of the sockets and screw out the sockets with a large screw driver. Great care must be taken in reassembling to see that they are tight and recotter-pinned.

The front wheel bearings (Fig. 5) should be packed with light cup grease once a month, or every 1,000 miles. To do this it is only necessary to remove the hub cap, fill with enough grease to almost fill it, and then screw it back in place. This will force the grease throughout the hub and into both front wheel bearings.

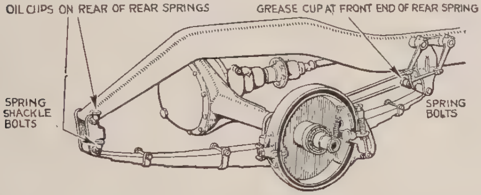
OIL CUPS ON REAR OF REAR SPRINGS
GREASE CUP AT FRONT END OF REAR SPRING
SPRING SHACKLE BOLTS
SPRING BOLTS

Fig. 6

All of the spring shackle bolts, except two, are lubricated with medium engine oil by means of oil cups provided upon the outer ends of the bolts. (Fig. 6).

There are three cups on each front spring and two at the rear end of each rear spring. Light cup grease is used on the two bolts at the front end of the rear springs. These are on the inside of the rear springs and can be reached without getting under the car.

Miscellaneous Lubrication

The carburetor and magneto control rod bearings and connections, clutch and brake pedal shaft bearings, brake cross shaft bearings (reached through holes in the tonneau floor), and brake rod clevises, which are not provided with oil or grease cups, should be lubricated weekly with an oil can.

Lubricating Spring Leaves

Springs will become squeaky if water is allowed to enter between the leaves and rust the contact surfaces.

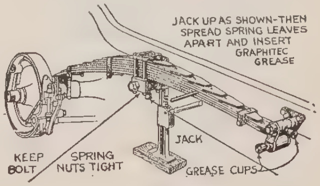
JACK UP AS SHOWN-THEN SPREAD SPRING LEAVES APART AND INSERT GRAPHITEC GREASE
JACK
KEEP BOLT
SPRING NUTS TIGHT
GREASE CUPS

Fig. 7

The best way to lubricate the springs (Willys Six, **Fig. 7,** is taken as an example) is to lift the car by placing a jack under the spring pad or frame, and not under the axle, and allow the weight of the wheels and the axle to pull the spring leaves apart. It will then be possible to force graphite grease between the spring leaves with a chisel or screw driver. Graphite grease is most satisfactory for this service, as the graphite will remain between the leaves and continue to act as a lubricant after the grease itself has become dry.

LUBRICATION OF A SIX-CYLINDER ENGINE AND CAR AS AN EXAMPLE

1. **Engine.** After draining, close the drain valve and fill to the level marked "full" on the measuring gauge. Inspect frequently, and keep the oil level "full." See **Fig. 8.**

2. **Transmission.** Use steam-cylinder oil for all temperatures above freezing. Thin with low cold-test motor oil sufficiently to make it liquid below freezing temperature. Remove filler cap on the left side of the transmission case and fill to the level of the opening.

3. **Rear axle.** Use steam-cylinder oil for all temperatures above freezing. Thin with low cold-test motor oil sufficiently to make it liquid below freezing temperature. Remove plug in the differential housing cover and fill to the level of the opening.

4. **Steering gear.** Use steam-cylinder oil. Insert oil until positive that the housing is full.

6. **Valve rocker arms.** Use motor oil. Insert oil can spout and fill the bracket with oil until the wick becomes thoroughly saturated.

7. **Rear spring seat.** Use motor oil. Lift the cap of the oil cup and saturate the felt in the oil pocket with oil thoroughly.

8. **King bolts.** Use motor oil. Turn the cap on the oil cup until the holes line up; fill full of oil, and give the cap a half-turn. Oil is fed automatically through a wire wick to the bolt.

9. **Tie rod bolts.** Use soft cup grease. Give grease cups half a turn. Keep filled with grease. There is one cup at each end of the tie rod.

10. **Rear spring.** Use soft cup grease. Give grease cups on spring shackles, spring blocks, and ends of springs half a turn. Keep filled with grease. There are four cups to each spring.

11. **Steering connecting rod.** Use soft cup grease. Give grease cups a turn or two. Keep filled with grease. There is one cup at each end of the rod.

12. **Brake and clutch pedals.** Use soft cup grease. Remove floor board and give grease cups one or two turns. Keep filled with grease. There is one cup on each pedal hub.

13. **Clutch release fork pin.** Use soft cup grease. Remove the clutch cover and give grease cup one or two turns. Keep filled with grease.

14. **Clutch release bearing retainer.** Use soft cup grease. Give grease cup (outside of transmission housing) one or two turns. Keep filled with grease.

15. **Brake shaft.** Use soft cup grease. Give grease cups one or two turns. Keep filled with grease. There is one cup at each end of the shaft.

16. **Starter sliding gears.** Use soft cup grease. Give grease cup half a turn. Keep filled with grease.

17. **Front spring.** Use soft cup grease. Give grease cups half a turn. Keep filled with grease. There is one cup at the front end and two at the rear end of each spring.

18. **Brake cam shaft.** Use soft cup grease. Give grease cup one or two turns. Keep filled with grease. There are four cups, two at the inner ends and two at the outer ends of the shafts.

19. **Delco generator.** A. Use soft cup grease. Swing the cover on the front end of the distributor housing near shaft to one side, and inject grease with grease gun, for lubrication of distributor gears and generator clutch.

    B. Use motor oil. Turn the oiler in the rear end of the generator until the hole is open and inject motor oil for lubrication of rear armature bearing.

    C. Use motor oil. Turn the oiler on the distributor cup and inject motor oil for lubrication of upper distributor shaft bearing.

    D. Remove the front housing cover and insert a few drops of oil for lubrication of the forward armature bearing.

Every 1,000 Miles

20. **Front wheels.** Use soft cup grease. Move or jack up car and turn wheels until the pipe plugs in the hubs appear on top. Remove the plugs, fill the hubs with soft cup grease and replace the plugs securely, and at the same time remove the hub caps and fill with grease.

21. **Rear wheels.** Use soft cup grease. Move or jack up the car and turn wheels until the pipe plug in the hubs appears on top. Remove plugs, fill hubs with soft cup grease, and replace plugs securely.

22. **Pinion-shaft bearing.** Use soft cup grease. Remove adjusting cover on pinion flange and fill with soft cup grease. Use grease gun.

23. **Fan hub.** Use motor oil. Remove plug in hub and inject a small amount of oil. Be sure and replace plug securely.

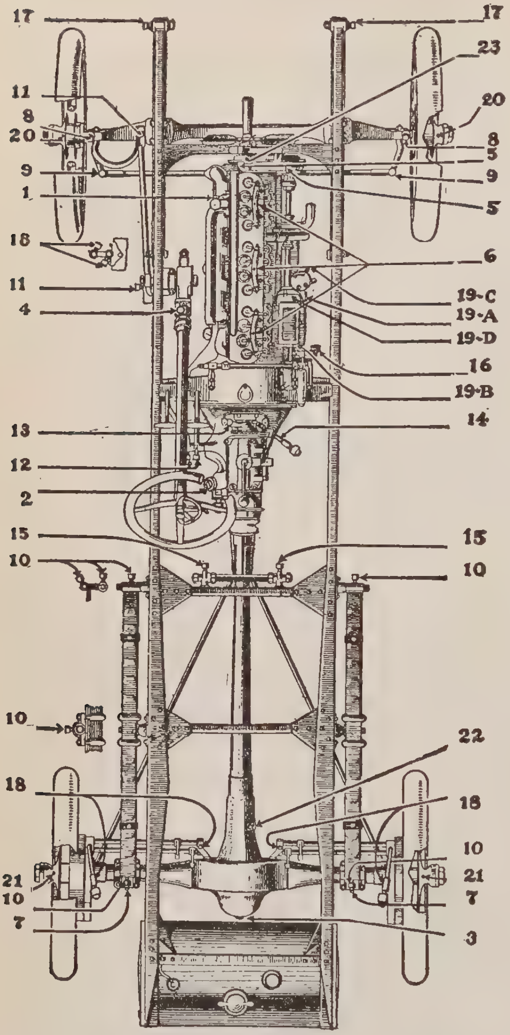

Fig. 8. Top view of a modern six cylinder car showing the location of the parts to the oil and grease.

Overhauling

Three or four times a year all the oil should be drained out of the engine, transmission, and rear axle, and these parts should be washed out thoroughly with gasoline or kerosene. It pays to change the oil in the motor frequently, or whenever it gets thin and watery. Do not use too much oil. Enough is just right, and any more will simply run out of the bearings and collect dust and dirt on other parts of the car.

At least once a year the car should receive a thorough overhauling at which time the engine, clutch, transmission, universal joint, steering gear, and front and rear axle assemblies should be taken apart and carefully cleaned and adjusted before being reassembled.

Lubricants

Motor oil used in the engine, and other places as designated, should be a high-grade, medium heavy, mineral oil, with a flash point of not less than 375° Fahr., and a viscosity of 42 to 60 seconds Saybolt at 210° Fahr., and not less than 190 seconds at 100° Fahr. for use at temperatures below freezing. The cold test of this oil should not exceed 5° Fahr. This oil should be used exclusively in the motor lubricating system, for valve rocker arms, distributor and generator bearings, spring seats, king bolts, and for all small joints not otherwise provided with lubrication, such as spark and throttle rods, brake rods, etc.

Steam cylinder oil used in the rear axle and transmission and steering gear, should be a high-grade heavy mineral oil with a viscosity of 120 to 150 seconds at 210° Fahr., and should be mixed half-and-half with motor oil of a cold test not exceeding 5° Fahr. for use at temperatures below freezing point, for the transmission gears, differential gears and steering gear. It is better for this purpose than most of the so-called "gear greases."

Soft cup grease should be a homogeneous mixture consisting of high-grade mineral oil and pure lime soap. It should be free from acids and other adulterants, and should be of a soft nature and have a sufficiently high melting point to prevent free flowing in warm weather, and should be used in all grease cups, such as those on the tie-rod bolts, starter sliding gear, brake shaft, brake cam shafts, steering connecting rod, and wheel hubs.

THE ALEMITE HIGH-PRESSURE LUBRICATING SYSTEM

This system of lubrication is now the standard method adopted by many automobile manufacturers for greasing the various parts of the car, and is a very handy method where grease cups are located in inaccessible places.

Elbow fittings are substituted for the old-style grease cups on all parts to be lubricated. The compressor is then filled with grease and coupled to the elbow with a special coupling which is easily attached. With a slight turn of the compressor handle fresh grease is forced into the parts to be lubricated and the old grease is forced out. The compressor is capable of exerting a pressure of 500 lbs.

This system can be applied to old cars, and the time saved in labor alone will soon pay for the installation.

The manufacturers are Bassick Mfg. Co., 361 West Superior St., Chicago, Ill.

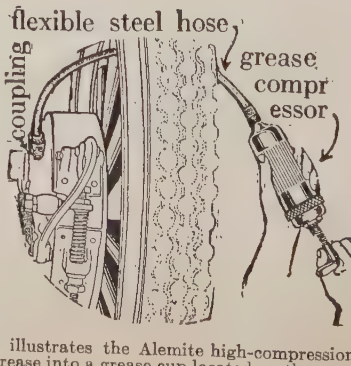

Fig. 9 illustrates the Alemite high-compression grease gun forcing grease into a grease cup located on the rear axle.

INSTRUCTION No. 17

ELEMENTARY PRINCIPLES OF ELECTRICITY AND MAGNETISM: Purpose of Ignition; Ignition Methods; Low-Tension Coil Ignition; Principle of a Low-Tension Coil

ELECTRICITY

Electricity[1]: No one can tell you what electricity is. Electricity is in everything—in your body, in your clothes, in this paper, in the chair; and the only reason you do not know of its presence is because it is not in motion.

If you put a water-wheel in the middle of a pond, the wheel will not revolve. To make the wheel revolve, in order to get any work out of it, you must place the wheel in such a position that the water may flow from a high to a low level and thus produce pressure of the water against the wheel. Thus when the water is in motion we can obtain work or energy from it.

Just so with electricity: when it is put into motion you can obtain work from it.

Before the water-wheel will move, a current of water is necessary. So in electricity, there must be a "current," or a "flowing" of electricity before you can get any work out of it, and a circuit must be provided for it to flow in.

Amperes: The current, or rate of flow, of electricity is termed "amperes." Just so is the flow of so many gallons of water per second or minute. The ampere is the unit of electric current, or the rate of flow, as, for example, so many gallons of water per second.

Electro-motive force: Before a current of electricity will flow in a circuit, there must be a force or pressure to move it. The something which is necessary to put it into motion is an electro-motive force, abrreviated e.m.f., and often referred to as "voltage."

Electro-motive force can be generated "chemically," by means of a battery, or "mechanically," by means of a generator.

When water is pumped into a tank, a pressure is required to force the water to the tank through the pipes. Just so with electricity. When a current of electricity from a generator is sent through a circuit to charge a battery, a pressure (e.m.f.) is required to force the current of electricity to the battery.

Volt: The unit of e.m.f. is the "volt." For instance, we could say a generator had an e.m.f. of 8 volts at the brush terminals at 1,000 revolutions, and at this speed, e.m.f. would force an output or rate-of-flow of current of 15 amperes through a circuit.

To make this clear, take the analogy of water flowing through a pipe under pressure. That which causes the flow is "pressure," which corresponds with e.m.f.; that which resists the flow of water through the pipe is "friction" of water against the pipe, due to the size of the pipe and the rate of flow of water through the pipe.

Just so with electricity, there is resistance offered to the flow of the electric current through a conductor forming a circuit.

Conductors: A conductor is anything that readily carries electric current, such as copper wire, carbon or gauze generator brushes, the frame of a car, the metal part of the car such as the engine, etc. All metals are conductors.

Some conductors offer less resistance to the flow of electric current than do others. The less resistance a conductor offers, the better a conductor it is.

The best conductor is silver, the next best, copper, then aluminum, zinc, brass, platinum, iron, nickel, tin, lead, German silver, antimony, mercury, bismuth, carbon, water. Thus it will be seen that iron offers more resistance than copper, and carbon and water more resistance than iron. **Non-conductors** are slate, marble (if there are no metallic veins), oils, porcelain, glass, rubber, dry paper, silk, gutta percha, shellac, ebonite, etc.

Hence the reason for using copper wire. Silver, as observed above, is the best conductor, but is too expensive. Copper is next best, and not as expensive, and is universally used.

Iron wire offers 6½ times the resistance to the flow of current that the same length and size of copper wire does; therefore if either the iron wire or copper wire is not of sufficient size to permit the free passage of current, the wire will heat. The resistance of the lamp filament is such that it heats and gets quite hot. The greater the resistance, the less total current can pass; hence the pressure or voltage will drop.[1]

Ohm: The ohm is the unit of electric resistance. We speak of a certain size of copper wire of a certain length having so many ohms-resistance.

Electric current flowing in a circuit, is therefore dependent upon something besides pressure (e.m.f., voltage) and that is the **resistance** which opposes the flow of electric current in a circuit.

Resistance is that property of an electric conductor by which it opposes the flow of an electric current. For instance, carbon, iron wire, German silver and water will permit current to flow through, but it opposes, or offers resistance to, the flow. **A rheostat** is a device for the purpose of varying the resistance of an electrical current, and is usually made with coils of iron wire or German silver wire, etc. A lamp filament of an electric lamp bulb offers resistance; in fact, it offers so much that it heats white hot.

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[1] It is said that **atoms** of which everything is made, are composed of two different elements called **"electrons"**: one a **positive**, the other **negative**. They neutralize each other when together. Thus if electricity is to be utilized, it is necessary to separate the negative from the positive electrons, and then electricity will flow. It is easier to separate these electrons in copper than it is in hard rubber, glass, etc. Thus copper is used as a conductor and glass and rubber as insulators.

There are several methods of setting electricity in motion. One method is to pass a copper wire across a magnetic field or a magnetic field past a wire. Thus e. m. f. (electro-motive force) is generated in the wire, causing electricity to flow.

Electricity, and a current of electricity, are different. For instance, we do not notice the atmosphere we are living in until a pressure arises and the wind is caused to move. Then we feel it. Thus with electricity, it is in almost everything, but we do not notice it until it is set in motion by pressure (e.m.f.).

[1] Termed a "potential difference" or "energy lost." For instance, "two volts lost on a line" means this much pressure is lost in sending the current through the line.

Resistance opposes the flow of electric current in any circuit it may travel in. The amount of resistance offered depends upon the circuit, size of wire, etc.

As the pressure (e.m.f., voltage) increases, the rate of flow of electric current increases proportionally; as the resistance increases, the rate of flow of electric current decreases.

The greater the resistance which opposes the flow of electric current in a circuit, the less current a certain pressure will produce.

The less the resistance of the circuit, the greater the current a certain pressure will produce.

For example, if the pressure, say, is 6 volts and remains constant, the rate of flow of current will vary if the resistance varies; that is, if the resistance of the circuit be doubled by adding more lamps, etc., the current in the circuit would decrease one-half.

If the resistance of the circuit be decreased, say, one-fourth, by cutting off lamps, the current will increase four times.

Ohms law: One volt will force a current of electricity through one ohm of resistance at the rate of one ampere per hour.

Volts ÷ ohms = amperes
Volts ÷ amperes = ohms
Amperes × ohms = volts

Thus, if any two terms are known, the third can easily be found by means of this rule.

For example, suppose the pressure of a generator is 6 volts and the resistance of a lamp is 6 ohms. What amperage or current is necessary?

Current (amperes) = pressure (6 volts) ÷ resistance (6 ohms) = 1 ampere.

Again, suppose the pressure of a generator is 6 volts and there is a current of 4 amperes passing in a circuit. What is the resistance in ohms of the circuit?

Resistance (ohms) = pressure, 6 volts ÷ current, 4 amperes = 1½ ohms.

Again, suppose the resistance of a lamp is 3 ohms, what pressure would be required to produce 1 ampere through the lamp?

Pressure (volts) = resistance, 3 ohms × current, 1 ampere = 3 volts.

Coulomb is the unit of electrical quantity, or such a quantity of electricity as would pass in one second in a circuit whose resistance is 1 ohm. We are not interested in the quantity of electricity alone, but in the rate-of-flow, the ampere, and for this reason the coulomb is very little used.

The watt is the unit of electric power. 746 watts is equal to 1 horse power (h.p.). Amperes × volts = watts.

Ampere-hour: 1 ampere of current for 1 hour = 1 ampere-hour.

How Electricity Is Transmitted

Electricity produced in one place may be transmitted to another place, providing a path or circuit is arranged so that it may return to where it started. If the circuit is broken, the flow will immediately stop and will not start again until the circuit is completed.

A switch is usually placed in all electrical circuits to stop the current from flowing when not desired.

Electricity flows from the **positive** (+) **terminal** through the circuit back to the **negative** (−) **terminal.** Therefore in tracing a circuit, always start with the source of electric supply at the + terminal. The copper wire in which the current starts is called the "lead" (pronounced "leed"), and the return path is called the "return."

Insulators: Substances such as rubber, china, porcelain, glass, wood, fiber and mica are called non-conductors or insulators.

A wire is insulated to prevent leakage of current into any metallic substance it may touch, by wrapping it with cotton or silk, which is soaked with rubber to prevent dampness from getting in.

When dry, cotton and silk are insulators, but as water is a conductor, damp cotton and silk cease to be insulators.

Ground: This word is used to express two meanings. It has nothing whatever to do with the ground.

One meaning of a "ground" is a leak. For instance, if there is any way by which the current may "leak" from the wires conducting the current, and return to the starting point without going through the entire circuit, this is termed a "bad ground" or "short-circuit." If the leak is only slight, and not enough to short-circuit the path, then it is termed a "ground," and part of the current may reach its destination and return, but part of it will leak through the "ground," such as damp or oil-soaked insulated wires, or wires too near the hot engine, etc. See Index for the meaning of "grounds" and "short circuits."

Another meaning of "ground" is where a wire is intentionally "grounded" or connected to the metal part of the car, such as the frame, engine, etc. One wire of an ignition coil, contact-breaker, and one terminal of a generator and storage battery are often "grounded" to some metal part of the car. This permits using the frame as a return path, and also less wire is used.

Ignition coil terminals often have one of the terminals marked "GRND," meaning that this terminal should be grounded.

When a battery negative terminal (−) is grounded, the generator − terminal must also be grounded, and vice-versa, if the positive terminal (+) is grounded. The − terminals are usually grounded; however, on some systems, the + terminals are grounded.

Electricity will always take the path that offers least resistance.[1] Air offers considerable resistance to the flow of electricity. This is the reason why such a high pressure (voltage) is required to cause current to jump across the gap of a spark plug (see Fig. 1, page 188, for a spark plug).

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[1] The velocity of electricity through a copper wire is said to be 186,000 miles per second.

HYDRAULIC ANALOGY OF CONNECTING CELLS

In order to explain the meaning of voltage and amperage more clearly, and how these vary through making different connections, we shall use a hydraulic analogy as follows:

Suppose an ignition coil was wound with a certain number of turns of wire, and that a pressure of 6 volts was required to force a current of 5 amperes of electricity through the wire; and suppose we wanted to use dry-cell batteries for this purpose.

A dry cell usually gives about 1¼ to 1½ volts and its rated output or capacity is from 20 to 25 ampere hours, that is, it will deliver 1 ampere for 20 or 25 hours, or 20 or 25 amperes for 1 hour.[1]

If we connected one dry cell to the primary winding of the coil, the pressure of the one dry cell would not supply sufficient electromotive-force to carry the required current through the winding of the coil. It would be necessary to increase the pressure (voltage). As the pressure (voltage) increases, the rate of current (amperage) flow increases. Therefore it would be necessary to add more cells.

If one cell gives 1½ volts pressure, 4 cells would give 6 volts. Therefore if we connected 4 cells in series, we should obtain 6 volts, but inasmuch as the voltage of a dry cell drops quickly to 1¼ volts or less, we should then use 5 cells connected in series.

It is not advisable to use more cells in series than are needed, because the excess of pressure (voltage) would force the electricity through the circuit at too great a rate or amperage, and this would cause sparking at the vibrator points of the contact-breaker of the coil ignition system and would also likely cause such an increase of voltage in the secondary winding that it would puncture the insulation of the secondary winding (if a high tension coil).

Meaning of "Series," "Parallel," and "Multiple" Connections

This can be explained by referring to our hydraulic analogy, as follows: Suppose we had three pails of water, each of them 1 foot high (giving 1 foot pressure), as shown in Fig. 1, and suppose we had three dry cells, each of them giving a pressure of 1 volt. By connecting them in different ways we obtain different pressures.

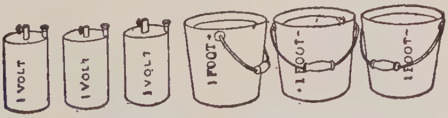

Fig. 1. Comparing dry cells or storage-battery cells with pails of water.

Series connection: In the illustration (Fig. 2), three dry cells are connected in "series," similar to pails of water placed one above the other; the pressure (voltage) is three times as great as if only one pail or cell is used, or 3 volts. The capacity would be that of one cell.

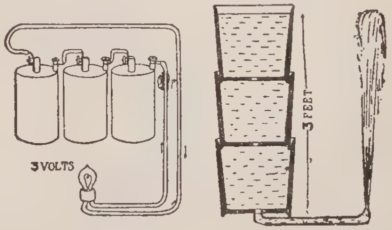

Fig. 2. Dry cells connected in "series," similar to pails of water placed one above the other.

When connecting dry cells mentioned above in series, the carbon terminal (+) is connected with the zinc (−) terminal of the next cell. Thus at the final two terminals, we have one (+) and one (−) terminal, and the voltage at these terminals would be 3×1 volt, or 3 volts.

Note. Illustrations of dry cells are represented as giving 1 volt, and each pail of water as 1 foot pressure, as a matter of easy comparison.

Parallel or multiple connection: The three dry cells are connected in "parallel" or "multiple," similar to pails of water connected one with the other as shown in Fig. 3. The pressure (voltage), is equal to only one pail or one cell. The capacity would be that of three cells.

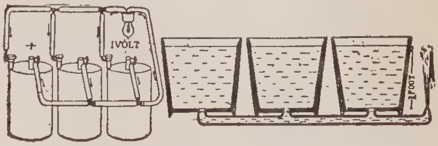

Fig. 3. Dry cells connected in "parallel" or "multiple," similar to pails of water connected one with the other, as shown, to increase the capacity. Voltage is reduced to one cell.

The (+) terminals are connected together and all of the (−) terminals are connected together. The circuit is then between the (+) and (−) group, and the voltage at the terminals would be that of one cell, or 1½ volts.

"Series-parallel" or "series-multiple" connection: Two sets of cells are connected in "parallel." Each set of three cells is connected in "series." This connection is termed "series multiple" or "series-parallel." The pressure is equal to three pails or three cells. The capacity would be that of two cells.

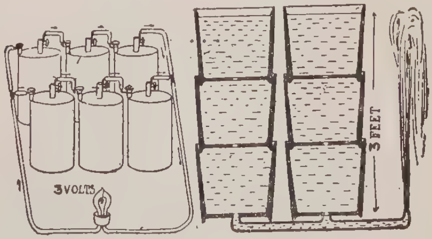

Fig. 4. Two sets of dry cells connected in "parallel," each set connected in "series," similar to pails of water placed and connected as shown, to increase the capacity to two cells and the voltage to three cells.

The two sets of three cells are connected in "series"; then the two series sets would be connected in "parallel" or "multiple." Each of these two sets would then have a (+) and a (−) terminal. The two (+) terminals are connected together, and the two (−) terminals are connected together. The voltage at the terminals would be 3×1½ volts, or 4½ volts.

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[1] A dry cell, in actual practice, would not deliver current steadily for any great period of time, due to the fact that its voltage would drop on continued use; but if used intermittently, such as for such service as ignition starting, and then being switched off, and used off and on for short periods of time, it would deliver somewhere near its capacity as mentioned above. In other words, it is so constructed that the ampere-hour capacity is greater when producing small current than when producing large current. If a dry cell exceeds 25 ampere capacity of the usual standard size, it will likely polarize and set up a counter-electromotive-force. Thus the terminal voltage would drop more quickly than one of normal capacity (20 to 25 amperes).

Where several dry cells are connected together, if there are weak cells in the circuit, they will absorb the strength from the strong ones, as they will then offer resistance to the good ones, thus **bringing the capacity down to that of the weak ones.** A storage-battery cell which delivers 2 volts pressure would hold its pressure nearer to a constant value until discharged.

When connecting two sets of cells in "parallel" it is important that they have the same internal resistance and produce the same pressures, in order that they divide the total current equally. The same thing is true of storage batteries.

If one set has a lower voltage than the other set, then there will be a current through the lower voltage set from the higher voltage set, in a direction opposite to its own pressure. The one of higher pressure will send a current through the one of lower pressure and also the current through the main circuit.

Where dry cells are used for ignition, it is advisable to use two sets of 5 or 6 cells connected in "series." One set is used for a while, then the other set. If both sets give out, as an emergency, connect the two sets in "series-parallel" as shown in Fig. 4.

METHODS OF GENERATING ELECTRICITY

Electrical energy or e.m.f. which forces electric current to flow in a circuit, **can be generated by two general methods,** as used on the automobile. One method is by a **chemical action,** which is the principle of the battery; the other is the conversion of mechanical energy into electrical energy by means of **electromagnetic induction,** which is the principle of the generator and magneto.

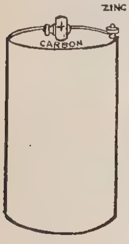

Fig. 5

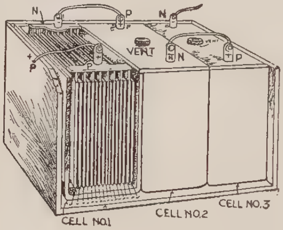

Fig. 6

Fig. 5. Dry cell; a primary cell; a chemical generator.

Fig. 6. Storage battery; secondary cell; a chemical generator.

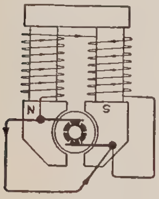

Fig. 7

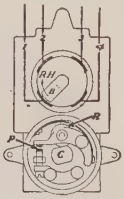

Fig. 8

Fig. 7. Dynamo; a mechanical generator; direct current.

Fig. 8. Magneto; a mechanical generator; alternating current.

Direct current (D.C.), means electric current which flows in one continuous direction.

Alternating current (A.C.), means electric current which alternates in its flow.

Chemical Generators

Chemical generators are of two kinds, "primary cells" and "secondary cells." Only direct current is produced by a chemical generator.

Primary cells[1] (Fig. 5) are usually referred to as "dry cells," and electrical current in a circuit is produced from them by converting chemical energy into electrical energy by a consumption in it of some substance, such as zinc.

Secondary cells[1] (Fig. 6) refer to the cells of a storage battery, where a current of electricity must first be sent through the cell to cause a chemical action, called "charging," which will put it in such a condition that it is capable of producing a current on "discharge," or whereby it will convert chemical energy into electrical energy.

On most cars three cells of 2 volts each, are used thus making a six-volt battery. On some cars, such as the Dodge and Franklin, six cells of 2 volts each, or a 12-volt battery, are used.

There is a set of positive (+) plates and a set of negative (−) plates to each cell, and the cells are usually connected in series. The (+) terminal is usually a dark-brown color, whereas the (−) terminal is gray.

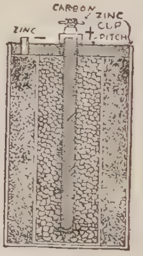

Fig. 9

A dry cell (primary cell, Fig. 9) consists of a zinc cup (−) in which a carbon stick (+) is placed as shown. The space between the carbon and zinc is packed with bits of carbon and the necessary chemicals.

The dry cell contains no liquid, but merely moisture, hence its name—"dry cell."

The chemicals used vary, one formula being chloride of zinc, sal-ammoniac, sulphate of lime, and powdered charcoal.

When the circuit is closed from one terminal to the other, a chemical action takes place between the carbon (+) plate and zinc (−) plate, thus generating an electromotive-force which causes the current to flow.

A dry cell has a pressure or voltage of about 1¼ to 1½ volts, and the capacity or volume of current it will produce, called amperage, depends upon the size of the cell. The average is 20 to 30 amperes.

When in use, a primary cell becomes exhausted, and the voltage drops gradually. It will, however, recuperate if disconnected for a period of time. When it has reached a point where it does not recuperate to give sufficient current, it must be discarded and replaced with a new one.

It should be remembered that dry cells are intended for "intermittent" service, as for ignition starting where a magneto is used, after starting the engine, but for continuous service the dry cell is not a suitable source of current. After the engine has started, dry cells for ignition are not very satisfactory, for they become exhausted in a short time. The less continuous current is used from a dry cell, the longer it will last, and the more efficient it will be.

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[1] Wet cells (not the storage-battery cell) are also referred to as primary cells, but are not used for automobile work.

[1] Secondary cells are also called "storage-battery cells" or "accumulators." One cell, no matter how large or how small, will show a voltage of a little over 2 volts when fully charged, and will drop to about 1.8 volts when discharged.

For continuous-current service, the most efficient means of obtaining current is by means of **a storage battery** consisting of a battery of "secondary cells," or, as it is sometimes called, an "accumulator." This chemical type of electric generator, in connection with a dynamo, is in more common use for ignition than the dry cells.

Mechanical Generators

A mechanical generator of electricity on an automobile is usually driven by the engine and thus produces electromotive-force in the armature coils. This causes electric current to flow out of the armature through the (+) brush, through the external circuit to the (−) generator brush. This action depends upon **electromagnetic induction,** which will be explained farther on.

There are two general types of mechanical generators for automobile work:

1. **The alternating-current magneto-generator** (Figs. 10 and 8) is driven by the engine and is used **only for ignition** purposes, and can be a low-tension (voltage) or a high-tension (voltage) generator. It generates alternating current; therefore it would not charge a storage battery.

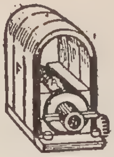

Fig. 10

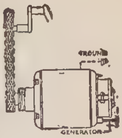

Fig. 11

Fig. 10. A magneto. Generates alternating current.

Fig. 11. A direct-current generator (dynamo). Both magneto and generator are driven mechanically by the engine.

2. **The direct-current electric generator** or dynamo (Figs. 11 and 7) is driven by the engine and generates alternating current. In fact, all mechanical generators generate alternating current in their armatures, but this is changed to direct current at the commutator. Thus, from the brushes the current is direct. This direct-current generator is used **to charge the storage battery and to supply current for the lights and ignition.** When it is running at its normal speed its voltage is higher than that of the storage battery. At other times, the storage battery supplies current for the lights, ignition, and also the starting motor. Approximately, the **generator** gives only from 15 to 20 amperes at 6 or 12 volts. The **starting motor** requires from 150 to 450 amperes of current, depending on how stiff the engine is. Thus only the storage battery could supply this great quantity of current.

PRINCIPLES OF ELECTRICITY AND MAGNETISM

In order to understand the action of an **ignition coil, magneto, and generator,** it is necessary to understand: (1) magnetism; (2) magnetic induction; (3) electromagnetism; (4) electromagnetic induction.

Magnetism

Magnetic circuit: Magnetic lines-of-force are invisible waves that pass from one pole of the magnet to the other. The lines-of-force pass from the north (N) pole to the south pole (S), *outside* of a permanent magnet, and from (S) to (N) *inside*, thus forming a closed magnetic circuit. Magnetism cannot be transmitted through wires like electricity.

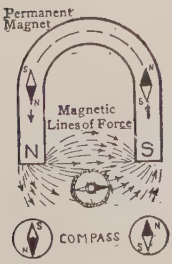

Fig. 1

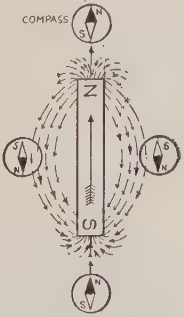

Fig. 1A

Fig. 1. A horseshoe type of permanent magnet.

Fig. 1A. A bar type of permanent magnet.

Polarity of a magnet: If a compass (Figs. 1 and 1A) is placed at the (N) pole end of a magnet the (N) end of needle will point away from the (N) pole, or with the direction of the flow of lines-of-force, which is always *out* at (N) and *in* at (S) pole. This is why the (N) pole of a magnet attracts the (S) pole of a compass needle, and why the (S) pole of a magnet attracts the (N) pole of a compass needle.

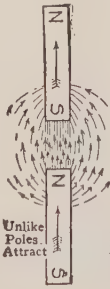

Fig. 2

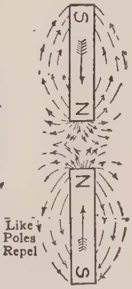

Fig. 2A

Fig. 2. Unlike poles attract.

Fig. 2A. Like poles repel.

This is also the reason why the (N) pole attracts the (S) pole of another magnet (Fig. 2), and why the (N) pole repels the (N) pole (Fig. 2A). Like poles repel, and unlike poles attract, because other lines-of-force pass in a circuit (N) to (S), outside, and (S) to (N) inside of a magnet.

A bar magnet is shown in Figs. 1A, 2, and 2A. Note that the **magnetic circuit** is the same as in the horseshoe magnet (Fig. 1). The magnetic lines flow through the air from (N) to (S) pole outside of the magnet and through the magnet from (S) to (N).

If an iron bar is placed between the poles of a magnet, as in Fig. 3, the lines-of-force will flow freely through the iron bar, because the air-gap between the poles offers 280 times the resistance

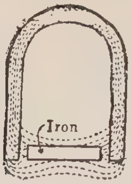

Fig. 3

that iron does. The iron bar tends to gather and collect stray lines-of-force and to concentrate the lines. Thus we obtain a great many more lines-of-force by using the iron bar.

Soft iron is generally used for the armature core on a magneto and also on generators, and for cores of ignition coils also, because soft iron will not retain its magnetism after the magnetic effect has been removed. In generating electric current this is an important factor, that is, the iron bar must become magnetized and demagnetized quickly, as this change of action, explained farther on, is desirable.

Permanent magnet: If hard steel is used, it tends to retain its magnetism, just as the magnets in Figs. 1, 2, and 3 do. Thus they are called permanent magnets on this account. Permanent magnets are used **principally on magnetos.**

When permanent magnets are heated, the iron has a tendency to soften; thus, the more it is heated, the more it loses its magnetism.

Magnetic Induction

Magnetic induction: If a piece of iron or steel is placed in a magnetic field of a magnet, it will become a magnet. Magnetism is "induced" into the iron or steel. See Fig. 4 and note how one magnet will induce magnetism into another magnet if unlike poles are placed together so the lines-of-force will flow from (N) to (S).

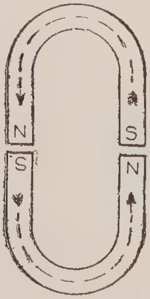

Fig. 4

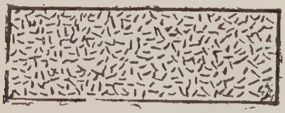

Fig. 5. Not magnetized.

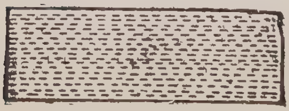

Fig. 5A. Magnetized.

An explanation or theory why hard steel retains the magnetism, and why soft iron does not, is that steel or iron composed, like all matter, of small **molecules,** is made up of minute magnets. If the steel or iron is not magnetized, the molecules have no definite arrangement (Fig. 5). If, however, it is magnetized (Fig. 5**A**), the molecules, like small magnets, all arrange themselves with the (N) pole of each pointing (N), and thus these molecules or little magnets all point in the direction from which the magnetizing force is being applied, and thus form one large magnet.

When all of the molecules or little magnets have been turned around, the iron or steel is then said to be completely magnetized or "saturated," and cannot be further magnetized.

Soft iron permits these molecules or little magnets to return to their original position, and almost all of its magnetism is lost when the magnetic influence is removed. This condition is termed "de-magnetized."

There is, however, always some magnetism left in a soft iron core, called **"residual magnetism"** on generators, where the field poles are wound with wire. When the generator first starts, enough **residual magnetism** is in the iron to supply lines-of-force for the armature wires to cut and thus build up. This is a very important factor when generating current in a dynamo with electromagnetic fields.

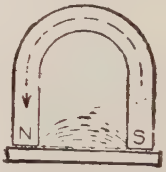

Fig. 5B. Keeper.

Steel requires more magnetic force to magnetize it, but the molecules retain their position if a "keeper" (Fig. 5**B**) is placed on the end of the poles; otherwise the molecules will eventually return to normal condition and the permanent magnet will gradually lose its magnetism.

A permanent magnet would be suitable for magneto field poles, but not for an armature. It is not suitable for any part of a generator or ignition coil, but lines-of-force are very necessary, and, owing to the fact that the lines-of-force must change in value from zero to maximum, soft iron is used for magneto armatures, generator armatures, and field poles and cores of ignition coils.

Magnetic-field-of-force[1] is the space around or between the magnet where the magnetic lines-of-force pass.

Electricity is in almost everything, but requires force to move it in order to produce energy or work.

Electromotive force (abbreviated e.m.f.) is the force or **pressure** which moves electricity, and the unit of electromotive force is a volt. When current is sent through a wire or coil from some source, the e.m.f. is supplied from that source.

Electromagnetism

Electromagnetism differs from magnetism in that the magnetism exists only when the current is flowing through the conductor or wire.

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[1] "Magnetic flux" is a term often used to express the total number of lines-of-force flowing through a magnetic circuit.

If electric current is sent through a straight wire, as in Fig. 6, a magnetic field will be set up around the wire. Its strength or intensity will be in proportion to the amount of electric current flowing through the wire.

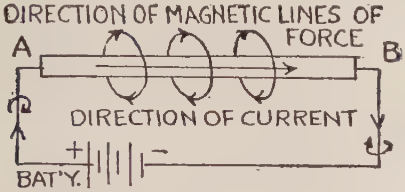

Fig. 6. Magnetic "whirls" around a wire in which direct electric current is flowing.

Electric current always flows from positive (+) to negative (−). Therefore, in Fig. 6, the current is flowing from (+) of the battery, through wire, to (−) of the battery. The magnetic lines-of-force will whirl around the wire in a right-hand or clockwise direction *with* the flow of electric current.

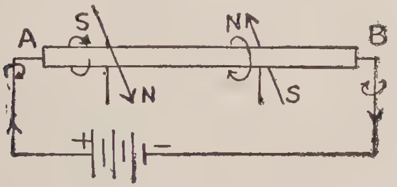

Fig. 6A. Note that the magnetic whirl above the wire is in one direction, and underneath in the opposite direction.

Direction of magnetic whirls around a wire: If a compass is placed above the wire (Fig. 6A), when looking at the end **A**, where the current is going *in*, the lines-of-force will whirl clockwise as in Fig. 6B, and the (N) end of the compass needle will point *with* the direction of the flow of the lines-of-force. If the compass is placed *below* the wire, the (N) end of the compass needle will point in the opposite direction, thus proving that there is a magnetic field circling around the wire.

If the compass is placed above the wire, when looking at the end (**B**) (Fig. 6**C**), where the flow of current is coming *out* instead of going in, the lines-of-force will be whirling around the wire in a counter-clockwise direction, but the magnetic whirls are still clockwise following the direction of the flow of the current in a clockwise direction.

In other words, the lines-of-force are in the same direction, but we are looking at it from the other end; just as the engine of an automobile revolves in a clockwise direction if we look from the front, but it revolves in a counter-clockwise direction if we look from the rear.

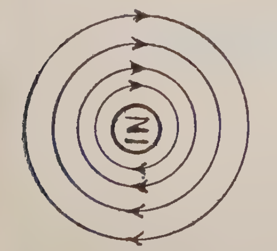

Fig. 6B

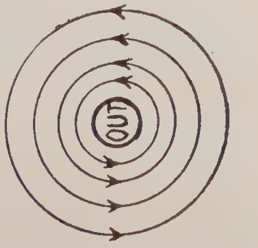

Fig. 6C

Fig. 6B. Note that the magnetic whirls are clockwise when the current is going in the front end of the wire, and counter-clockwise when leaving at the rear end (6C) where the current is coming out.

If electric current is sent through a wire at end (**B**) instead of (**A**), the magnetic whirls would be clockwise, or in a right-hand direction with the flow of electric current, but in the opposite direction to what they were formerly, because the current has been reversed.

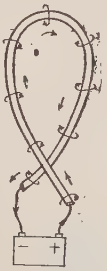

Fig. 7

If an electric current is sent through a wire in the **form of a coil** (Fig. 7), the direction of the magnetic whirls of lines-of-force is clockwise with the flow of electric current in the wire. Note that the whirls are in an opposite direction on either side of the wire. However, the whirls are clockwise with the direction of the flow of current at all points of the circle. Start at (+) and follow the circle in a right-hand direction all the way around, and the explanation will be made clear..

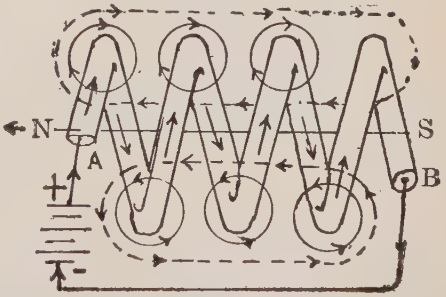

Fig. 7A

If an electric current is sent through several turns of wires or coils (Fig. 7**A**), which would be termed a **"solenoid"** or "helix," the lines-of-force would join together, because when current flows in two wires side by side (Fig. 7**B**), in the same direction, the lines-of-force join, because they are circling around the wire in the same direction.

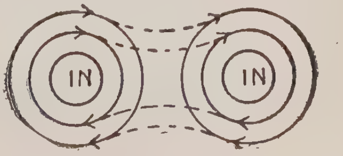

Fig. 7B

Where there are several coils side by side, as in Fig. 7A, note the (+) current is going in the wires at (**A**) and coming out (−) at (**B**), at the other end of the coil. The lines-of-force would then whirl clockwise with the flow of electric current, but in doing so they would whirl at the top, in one direction, and in another direction at the bottom. This is due to the current flowing around a circle. However, if the magnetic whirl is followed in its path around the circle, it will be observed that the direction is right hand or clockwise with the flow of current at any point of the circle.

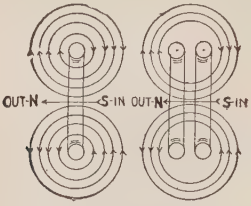

Fig. 7C

Polarity of a helix or solenoid: In Fig. 7C, one coil of wire is cut in half to make the explanation clearer, because the point we wish to arrive at is the advantage of the lines-of-force joining and passing around all of the turns of wire of the coil, which is to make one end of the coil (N) pole, and the other end (S) pole.

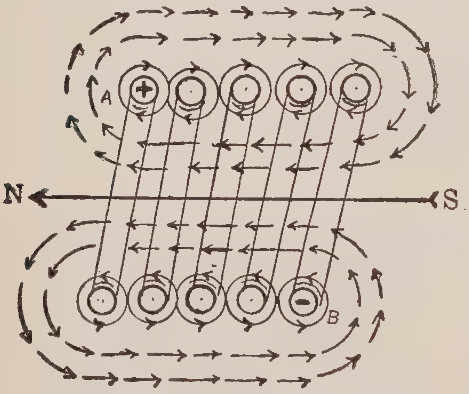

Fig. 7X

We observed in Fig. **1A** that on a permanent magnet, the lines-of-force passed *outside* of the magnet from (N) pole to (S) pole, then from (S) to (N) *inside*. The same effect is taking place in this coil of wire or helix (also called a solenoid), because when the lines-of-force whirl clockwise with the current going in at (**A**) (Fig. **7A**), the lines would whirl *out* of the (N) or left end of the coil, pass over and under and around the coil, and go into the other end (S) (see Fig. **7X**), through the inside of the coil, back to end (N) again. Thus we have the lines whirling *out* at (N) pole and *in* at (S) pole, and we have established a (N) and (S) pole **polarity** of the coil, which is clearly shown in Figs. **7A** and **7X**.

If the electric current was sent into the end at (**B**) of the coil (Fig. **7A**) instead of at (**A**), the whirl would be in an opposite direction. Thus the end (**B**) would be (N) pole, and the end (**A**) would be (S) pole.

The next question is, What is the advantage of having these lines-of-force passing around a coil of wire in this manner? The answer is, To form an electro-magnet.

Electro-magnets: If we place a soft-iron wire core (Fig. **7Z**) inside of a coil or helix which is carrying current, the iron core will offer a great deal less resistance to the passage of the lines-of-force through the center of the coil than does the air. This is due to the fact that the iron will collect a lot of stray lines-of-force and produce a great many more, and thus strengthen the magnetic field (lines-of-force around the coils of wire), as it is this magnetic field which, when the circuit is opened, collapses and passes back into the core and, in doing so, cuts the coils of wires and produces a greatly increased electromotive force. In other words, the magnetic lines-of-force produced from the current flowing through the turns of wires are going to be utilized to transform the primary low-voltage current passing through the turns of wires (primary winding) into a high-voltage current for ignition purposes, as will be more fully explained farther on.

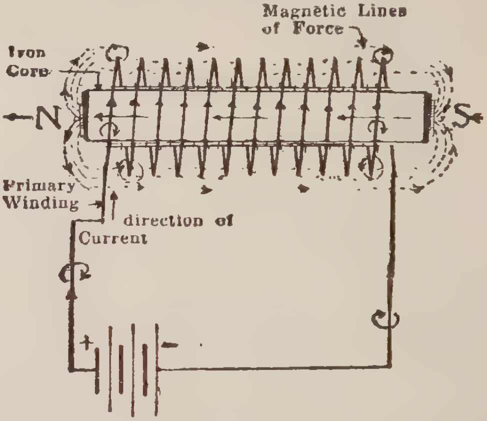

Fig. 7Z. How the magnetic whirls around the wires join forces to produce an electro-magnet.

The strength of an electro-magnet is dependent upon the number of ampere **turns**[1] of wire on the coil. The number of amperes flowing through the turns, multiplied by the number of turns, will determine the magnetic strength of the core.

For instance, if one ampere is carried around the core for 100 turns (100 ampere turns), it will equal in effect ten amperes flowing through ten turns. The effect of the turns decreases as the distance from the core increases. A rule is to wind wire 1 inch deep on a core of about 1 inch in diameter.

Polarity of electro-magnets: In Fig. 8, the (+) current is going in at the right-hand end of the coil, and lines-of-force around the wire would whirl **into** (S) end of the core and then pass through the core and come **out** at the other end of the core (N), thence around the core and coil outside to (S) end again.

The end *into* which the lines whirl would be (S) pole end, and the end they whirl *out* would be (N) pole end.

In Fig. 8**A**, the (+) current is going into the coil at the opposite end from that of Fig. 8. Therefore the magnetic lines-of-force would whirl *in* at end (S) and *out* at end (N). Thus the polarity would be reversed from what it was in Fig. 8, owing to the electric current flowing in the wire in an opposite direction.

In Fig. 8**B**, the electric current enters the wire coil at the same end as in Fig. 8, but the wire is wound *under* instead of *over*. Thus if we follow the magnetic whirl in a right-hand direction where it enters wire (+), we note that the whirl is *out* of

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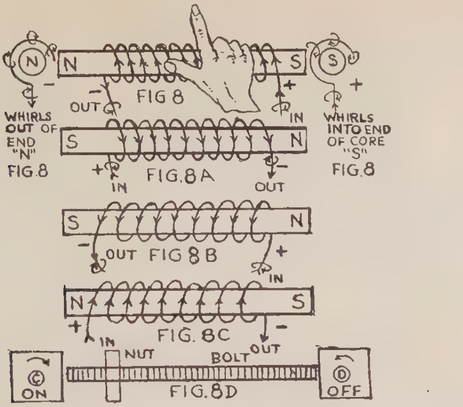
[1] "Ampere turn" is one turn of a winding through which a current of 1 ampere flows.



Figs. 8, 8A, 8B, 8C, and 8D. Explaining how the direction of the current through the wire and the direction of the wire wound on the iron core produces different polarities of an electro-magnet.

core instead of *into* core; thus it is (N) pole at the right-hand end and (S) pole at the left-hand end.

In Fig. 8C, the electric current enters the wire coil at the same end as in Fig. 8A, but the wire is wound *over* instead of *under;* thus the magnetic lines-of-force around the wire at the left end whirl out of core and the left end is (N) and the right end (S).

A good way to remember the direction of the whirl of the lines-of-force around a wire, when the current is flowing in the wire, is to think of a rod with right-hand threads on it (Fig. 8D). If, for example, the current enters *in* the end of rod where nut (C) would be screwed on, the nut would turn in a right-hand or clockwise direction with the flow of current. If, however, you were looking at the end where the nut is screwed off, and where the current came *out*, the nut (D) would still be turning clockwise with the flow of current, but the nut would be turning counter-clockwise when looking at that end.

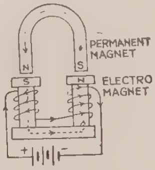


Fig. 9

The difference between a permanent magnet and an electro-magnet is shown in Fig. 9. Note in this instance that the electro-magnet is being used to induce magnetism into a permanent steel magnet. Note that the flow of magnetic lines-of-force is out (N) pole into (S) pole. The permanent magnet of hard steel will retain its induced magnetism, whereas the soft-iron core of the electro-magnet will lose its magnetism when the electric current flow is open. This is an important point to remember in connection with the principle of the action of a coil.

The principle of the ignition coil, magneto, and generator is based on electromagnetism and electromagnetic induction.

How are we going to apply this information to the production of a high electromotive force in an ignition coil, and to the generating of electric current in a magneto, and the generating of electric current in a dynamo or generator?

The reverse-current cut-out, the electromagnetic vibrator type of generator regulator, in fact very nearly all parts of the electric system on a car, have their fundamental principle based on magnetism in some form, especially electromagnetic induction.

Electromagnetic Induction

Electromagnetic induction refers to **an electromotive force, or electrical pressure, set up by induction** at the terminals of a conductor, such as a wire, which is moved in such a way as to cut across the magnetic lines-of-force, or magnetic field, at right angles.[1]

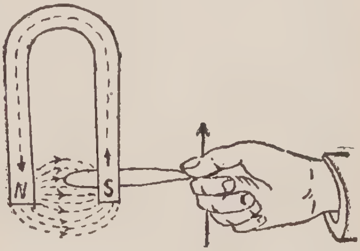


Fig. 10

If the wire is a closed loop the electromotive force (voltage pressure) produced in the wire loop will cause a current of electricity to flow in the circuit. Thus we can produce electric current in a wire by merely moving it across a magnetic field, as in Fig. 10.

How and why the electricity is in the wire we do not know, but if electromotive force is applied to the electricity in the wire, and the wire forms a circuit, the electricity will be made to move.

Copper wire offers less resistance to the flow of electric current, therefore it is used most. Electric currents thus produced are termed **induction currents,** and the principle or method is termed **electromagnetic induction.**

The question then is, How can the e.m.f. be obtained, in order to cause the electricity to move?

The e.m.f. induced in a wire by a magnet is one method of producing electric current in a wire.

For example, if a wire is quickly moved down, so that it will cut the magnetic lines-of-force which flow from the (N) to (S) pole of magnets, a momen-

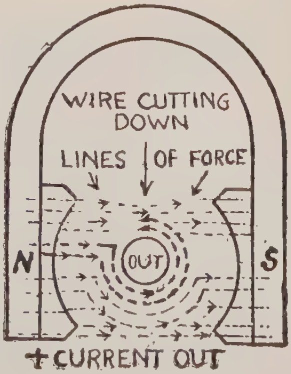


Fig. 10A

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[1] We might also say that whenever a loop of wire forming a closed circuit is placed in a magnetic field, an e.m.f. will be generated in the wire, causing electric current to flow whenever the strength of the magnetic field changes.

tary current will flow in the wire (as in Fig. 10A) which is in a direction *out* of the wire or toward the surface of the paper. This is because the lines-of-force, when forced *down*, will act like rubber bands, i.e., first stretch, then loosen from the (S) pole (the weakest point), and tend to wrap around the wire and whirl counter-clockwise.

These magnetic whirls of lines-of-force around the wire, which are taken from the magnetic field of the magnets flowing from (N) to (S) induce an e.m.f. in the wire which causes electric current to flow which was already in the wire but not in motion.

This momentarily induced e.m.f. is greatest when the wire is moved so that it will cut the magnetic lines-of-force at right angles, or across the magnetic field, the position the wire is cutting, as shown in the illustrations.

An e.m.f. would also be induced in the wire when moved, even though it did not form a closed circuit, and the e.m.f. would be at the terminals the same as on the terminals of a battery on open circuit.

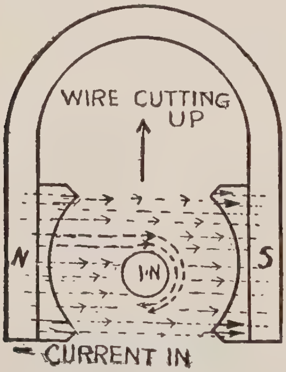

Fig. 10B

When the wire is quickly moved up, as in Fig. 10B, the magnetic lines-of-force will tend to circle around the wire in an opposite direction to that when moving down. Therefore another momentary current will flow *into* the wire. Thus if the wire is moved up and down rapidly, the flow of current in the wire would be first in one direction, then in another direction, or **alternating** in its flow.

Principle of Low-Tension Coil

The e.m.f.[1] induced in a wire of an electro-magnet is another method of causing electric current to flow in a wire. Instead of moving a wire so as to cut the lines-of-force, the lines-of-force, or magnetic field, moves and cuts the wires.

For instance, take an electro-magnet (Fig. 11), which would represent a primary coil, also called a "self-induction coil," or "low-tension coil," which is used to produce a spark or flash inside of an engine cylinder or in the combustion chamber, when the circuit is suddenly opened. This primary or low-tension coil consists of a core made of a bundle of soft iron wires, around which is wrapped about 200 turns and several layers of No. 19 to 24 B. & S. gauge copper insulated wire. When the circuit is closed, the lines-of-force start to build up, and in doing so they spring from the center of the wire and cut the wire up.

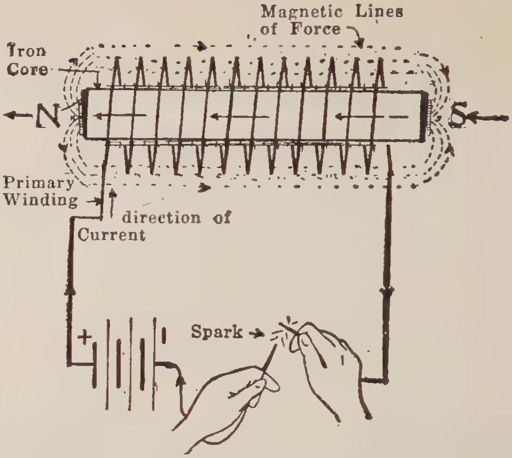

Fig. 11. An electro-magnet being used to produce a spark, by the circuit being opened, thus causing the magnetic lines-of-force to collapse into the core. This generates a self-induced e.m.f. in wires caused by the collapsing lines-of-force cutting the turns of wires. Such a coil is termed a "low-tension coil," or "self-induction coil," or "primary coil."

The **principle or action** is the same as that shown in Fig. **10A**, where the wire was moved down to cut the lines. Therefore this electromagnetic induction or self-induction would tend to cause the lines-of-force to whirl around the wire in a counter-clockwise rotation, causing the generated e.m.f. to buck or oppose the battery e.m.f., called "counter-electromotive force." In other words, we have two electromotive forces to deal with in the same wire: the induced e.m.f. produced by the magnetic whirls caused by current from the battery passing through the wire, and a generated e.m.f., caused by these same magnetic whirls, cutting the coils of wires as they build up around the coil.

The generated self-induced e.m.f. or counter-e.m.f., however, is only momentary, as the steady e.m.f. from the battery will force its current through, and in a brief interval of time the lines-of-force around the wires will have been established at their normal value.

The point to remember in connection with the above is that **when the circuit is closed, the e.m.f. or voltage would not be as great as when the circuit is opened,** principally due to the fact that the action of magnetizing the core when the circuit is closed is slower (due to this counter-electromotive force just mentioned) than the action of demagnetizing the core when the circuit is opened.

The question then is, What effect does the magnetizing and demagnetizing of the core have on producing a higher voltage (e.m.f.) in the wires which will cause a spark or flash at the wires when suddenly separated? This is answered as follows:

The amount of voltage (e.m.f.) and of current induced in a coil depends upon three factors:

1. **The strength of the magnetic field** (number of lines-of-force per unit area).

2. **The speed or rate at which the lines-of-force** cut through the windings or coil.

3. **The number of turns of the wires** that are on the coil into which the e.m.f. is to be induced.

When the circuit was closed, the lines-of-force were established around the turns of wires, which pass outside, from (N) to (S) of the core and inside (S) to (N), thus forming a magnetic circuit around the turns of wires (see Fig. 11).

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[1] If it is difficult to understand the meaning of e.m.f., just consider it as voltage or pressure, or the electric force which moves electric current or causes electricity to move in a wire.

We can greatly increase the rate of speed with which the lines-of-force will cut the turns of wires if the battery circuit is opened, so that the iron core will become demagnetized and thus permit the lines-of-force to die down or collapse more quickly into the iron core.

Thus, when the lines-of-force collapse, they cut the turns of wires at a much more rapid rate than when they were built up; this "self-induced" action causes a greatly increased e.m.f. to be generated in the turns of wires, and is the basic principle of all ignition coils.

The third factor mentioned above, relative to the turns of wires on the coil, also assists in increasing the e.m.f.

For instance, when a conductor is cut by the lines-of-force at the rate of 100,000,000 per second, a pressure of 1 volt is set up at the terminals.

If a single straight wire is cut by a certain number of lines-of-force per second, causing a certain pressure, say 1 volt, and if three wires joined in series are cut by the same number of lines-of-force as the single wire, three times the pressure or 3 volts would be the result. Therefore where there are many turns of wire in a coil and several layers of wire, the induced pressure will be greatly increased, as very nearly all of the lines-of-force produced by each turn of the coil will cut all of the other turns, and the total number of lines-of-force are therefore greatly increased.

From this we learn that when the circuit is opened on a primary coil, we have increased the number of lines-of-force and also the rate of speed at which the lines-of-force cut the turns of wires as they collapse, greatly increasing the "self-induced" pressure in the wires.

Furthermore, the "self-induced" generated e.m.f. in the turns of wires, when the circuit is opened, is in the same direction as the original battery current was. This current from the battery through the primary winding, when opened, did not instantly stop flowing, and with the high "self-induced" e.m.f. flowing in the same direction, the result was a very bright flashy spark at the points of the break, as in Fig. 11. This is what is often seen when a flash follows from the switch-blades when a switch connected with a motor or generator is opened.[1]

This principle might be compared to holding your hand over a water nozzle when water is flowing. At the instant of release, the pressure is greater, due to momentum, although the original pressure which set the water in motion was several times less.

The "self-induced" e.m.f. or voltage (pressure) in a low-tension coil in series with the battery voltage may reach from 150 to 250 volts, owing to the number of turns of wires, length of wire, and strength of current in the wires to build up the original lines-of-force.

Low-Tension Coil Ignition "Make-and-Break" System

The low-tension coil, described in the preceding pages and illustrated in Fig. 11, was formerly used with early ignition systems, such as the "make-and-break" igniter shown in Fig. 12. The principle is clearly shown.

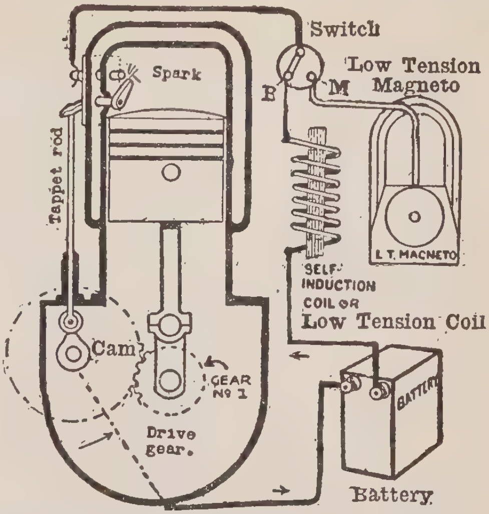

Fig. 12 .A "make-and-break" ignition system using a battery (chemical generator) as a source of electric supply. The current is intensified, or the voltage raised, so as to produce a spark at the break of the igniter points.

Although the low-tension coil ignition system is not now used for ignition on automobile engines, it is very important that the principle be studied carefully, as the low-tension or primary coil is used on the cores of high-tension coils and magneto armatures, but with another winding over the primary, called the secondary winding. Therefore the primary winding is the foundation of high-tension coil and magneto ignition.

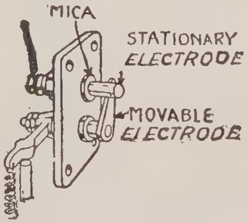

Fig. 13. A clearer view of the make-and-break igniter.

The make-and-break igniter (Figs. 12 and 13) consists of a stationary and a movable electrode insulated from each other and connected with a low-tension coil.

The "movable electrode" is operated by a cam arrangement, exactly as the exhaust valve of the engine is operated. As the spark is needed only once during two revolutions of the crank shaft, the cam is attached to the half-time shaft, and operates the electrode by a rod called a tappet rod, in a manner similar to that in which the valves are operated on a side-valve engine.

The "stationary electrode" is insulated from the cylinder with mica, and one wire of the circuit is connected to it. The "movable electrode" is operated by a cam, which is in contact with the current from the grounded wire of the battery and which allows the current to pass from it to the metal of the cylinder.

When the two points are in contact, the current flows from the positive pole of the battery by a wire to the low-tension coil, through a switch (**B**), to the stationary electrode, then to the movable, because the two are in contact, and back to the battery by the ground.

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[1] This is why a condenser is used in connection with a high-tension coil, as will be explained farther on. While the flashy spark is desirable on a low-tension ignition coil, as in Fig. 11, or as used with a "make-and-break" low-tension ignition system, it is very undesirable at contact points in connection with a high-tension system.

When the two electrodes are separated by the cam acting on the movable one, the circuit is broken, and a spark is formed between them.

Fig. 12 shows the make-and-break ignition system connected with a low-tension coil and battery through the (B) side of the switch and with a low-tension magneto when the switch-blade is on the (M) side of the switch.

When the battery and low-tension coil are used, the magneto is cut out entirely in this example.

Purpose of Ignition

There are three things required before a gasoline engine will run. These are absolutely essential.

First, it is necessary to have a mixture of gasoline and air in the engine cylinders.

Second, this mixture must be compressed.

Third, there must be a spark to set fire to the compressed mixture at the correct time.

In order thoroughly to understand the principles upon which the various ignition systems are built up, and how these systems are operated and maintained, it is well to start at the beginning.

The original and first method for igniting the gas in a gasoline engine was by means of a **"hot tube"** or flame, but this method being now obsolete, we shall deal only with the electric ignition.

The ignition systems used on automobile engines at the present time are all electrical systems giving an electric spark which passes in the cylinder of the engine and sets fire to the compressed mixture. As you will be dealing with electricity and electrical apparatus in these systems, the first thing to know is how electricity acts and how you can make it do work for you, all of which has now been explained and should be studied carefully.

Ignition Systems

There are two general systems of ignition used for automobile engines: the "low-tension system" and the "high-tension system"; the source of electric supply being either by "chemical" means, as dry cells, or a storage battery; or "mechanical" means, as a magneto or dynamo (also called a generator). (The magneto is explained farther on.)

The word **"tension"** means pressure or voltage; high tension being high voltage, and low tension low voltage.

The low-tension system of ignition is not now used on automobiles. The low-tension system was formerly used, to a great extent on boat engines, and is still used to a great extent on stationary engines.

The low-tension system uses a low-tension single-wound primary coil as in Fig. 11, page 184, and its source of electric supply can be a dry or storage battery, or dynamo. Low-tension magnetos are also used, but the coil is wound on the armature (treated under "Low-Tension Magnetos.")

The high-tension system of ignition is the approved system now in use on very nearly all makes of cars. The high-tension system may be either by a high-tension coil and a battery; a high-tension coil and low-tension magneto; a high-tension coil and dynamo in connection with a battery, or by a high-tension "magneto" alone.

Thus we have four principles underlying the production of a spark in a gasoline engine, as follows:

1. **Low-tension coil.**
2. **Low-tension magneto.**
3. **High-tension coil.**
4. **High-tension magneto.**

These four fundamental principles are used either singly or in combination. Thus when the reader masters these four principles he will understand all ignition systems, although the construction may vary in different makes.

In this instruction and in Instruction No. 18, we deal only with coil ignition, both low-tension and high-tension. Low-tension and high-tension magnetos will be treated farther on.

When a low-tension magneto is used with a make-and-break igniter (Fig. 12), the engine is usually started with the battery and low-tension coil, by turning a switch-blade on the (B) side of the switch.

After the engine is started, the switch-blade is turned to the (M) side and the low-tension (single-wound armature) magneto supplies the current, which, by the way, is alternating current. The low-tension coil is not used with the magneto, as the armature of the magneto, which has a single primary winding, serves in place of the low-tension coil.

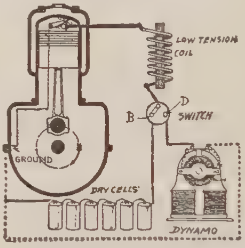

Fig. 14

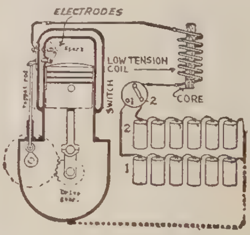

Fig. 15

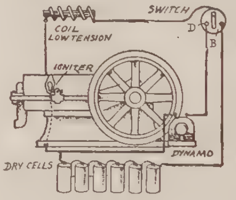

Fig. 16

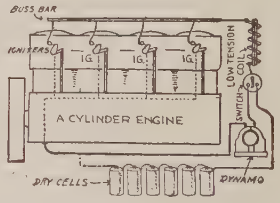

Fig. 17

Fig. 14. Make-and-break ignition, using dry cells to start on when the switch is on the (B) side; after the engine is started the switch is placed on the (D) side and a direct-current dynamo supplies the electric current and the dry cells are cut out of service. The low-tension coil is used with either the dry cells or the dynamo.

Fig. 15. Make-and-break ignition using two sets of dry cells. Set No. 1 is used when the switch-blade is on 1, and No. 2 set is used when the switch-blade is on side 2. Low-tension coil is used.

Fig. 16. Make-and-break ignition on a stationary engine. This principle is similar to that shown in Fig. 14.

Fig. 17. Make-and-break ignition on a four-cylinder engine. The principle is similar to that shown in Fig. 16. Note that the igniters are operated by tappet rods on the side by cams on a cam shaft, similar to a cam shaft operating the valves. The shaft with the cams on are driven by the gears, as in Fig. 12.

Low-Tension Coil Ignition "Wipe Spark" System

The wipe spark igniter, Fig. 18, is another form of ignition used considerably on large slow-speed stationary gasoline engines.

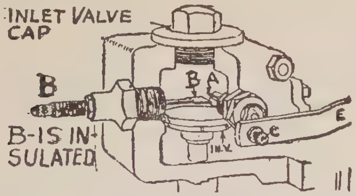

Fig. 18. Wipe-spark igniter. Eccentric "C" can be shifted forward to advance and backward to retard.

Wipe spark ignition is similar to the "Make and Break" in every respect, except that it makes a wiping and rotary motion as the electrode (**A**) of the igniter revolves; being operated by an eccentric rod (**E**) from the cam gear.

The other electrode (**B**) is stationary and looks very much like a spark plug. This type of ignition is never used on the automobile; but is here shown so that the reader can master the elementary principles of the different ignition systems. This system is used mostly on stationary engines.

Remarks On Low-Tension Ignition

The true low-tension ignition system would consist of a make-and-break igniter, as shown in Fig. 13, page 185, or a wipe-spark igniter **arrangement,** shown in Fig. 18.

The make-and-break igniter was at one time used on automobile engines, and is now used on many stationary and marine engines. It is practically obsolete for automobile use.

The wipe-spark igniter was never used on automobile engines, but was and is now used on many stationary engines.

The low-tension coil is used with both igniters when a direct-current source is used, as a battery or a dynamo, as in Figs. 12 to 17.

Where the low-tension magneto, which delivers an "alternating" current, is used, the low-tension coil is not used, because the primary winding on the armature of the low-tension magneto serves in place of the low-tension coil, and the magneto current is alternating in flow, that is, first in one direction, then in another, as explained on pages 250, 253, and 254.

In Fig. 12, a low-tension system of ignition is shown, whereby a storage battery is used for a source of direct electric current for starting, by the switch lever being placed on the "B" side of the switch. After the engine is started, the switch lever is placed on the "M" side of the switch; thus the battery and low-tension coil are cut out of service and the low-tension magneto (explained farther on) takes the place of both the battery and the low-tension coil.

An oscillating type of low-tension magneto ignition system, using a make-and-break igniter and arranged different from that mentioned above, is shown on page 255 (see Fig. 48).

A magnetic plug, instead of an igniter, could also be used for a low-tension ignition system, as shown in Figs. 49, 50, and 51 (page 255).

The Ford magneto (pages 248 and 249) **is also a low-tension magneto, but is not a low-tension ignition system,** because the low-tension current of the magneto is transformed to a high-tension current by means of a high-tension coil, all of which will be explained farther on.

Where a dynamo, which delivers a "direct" current of low-tension is used, as in Figs. 14, 16, and 17, note that the low-tension coil is used in connection with the batteries or with the dynamo, because the dynamo delivers a direct current flowing in one direction and at a low voltage, or approximately the same voltage as the batteries and thus merely acts as a mechanical source of electric supply instead of a chemical source.

Disadvantage of the true low-tension ignition system, using a make-and-break igniter and a low-tension coil: It would appear that this system would be a very simple and effective ignition system, as it requires less care in wiring than a high-tension or jump-spark system, but while this feature may predominate, there are several disadvantages.

For example, the word "make-and-break" refers to the igniter as shown in Figs. 12 and 13 (page 185). The movable electrode first makes contact with the stationary electrode, and after "making" contact, it then "breaks" the contact (due to the action of the tappet rod); thus the derivation of the name, "make-and-break."

On each of the electrodes there are platinum points. When the contact "breaks," a spark occurs just as it did as shown in Fig. 11 (page 184). This spark soon pits the points, burns them off rapidly, and they often stick. Platinum is used because it withstands this action better than any other metal, but even so, where the mechanical arrangement is all within the cylinder, exposed to the combustion heat, it is a difficult matter to keep the points from pitting.

Then another difficulty was in insulating the stationary spark point or electrode, and making an easy working but tight joint for the movable electrode.

Still another disadvantage was in the great advance and retard range of ignition as required on **variable-speed automobile engines,** where the engine varies in speed from 200 to 1,500 r.p.m. This action is limited with the make-and-break system.

Where a slow, constant-speed engine is used, this system serves fairly well.

The low-tension ignition systems are not now used on automobile engines, but were formerly used in the early days of motoring.

The reason for explaining these early systems of ignition is the fact that the **underlying principles** of the more modern systems are founded upon the principles of these early days. Therefore it is essential that they be mastered first in order more clearly to understand the modern systems treated farther on.

The next subject will be that of a high-tension coil ignition system using a magnetic vibrator. This system is now seldom used, but must be understood before the modern battery and coil-ignition system can be thoroughly understood.

INSTRUCTION No. 18

HIGH-TENSION COIL IGNITION: Vibrator Type Coil; Condenser Principle; Master Vibrator Coil; Distributor Principle

The Jump Spark

The voltage produced by a low-tension coil as used for the "make-and-break" ignition system, explained on page 185, would not have enough pressure to jump across the gap of a spark plug. It must therefore be intensified (or the pressure must be increased) still more.

Where simple low-tension coils are used for the make-and-break system, coils of another kind, called "high-tension induction coils," are used to intensify or transform the current to a high voltage in order to force the current to jump across the open space or gap of a spark-plug point (Fig. 1). Therefore it is called the "jump spark" or "high tension" (meaning high pressure).

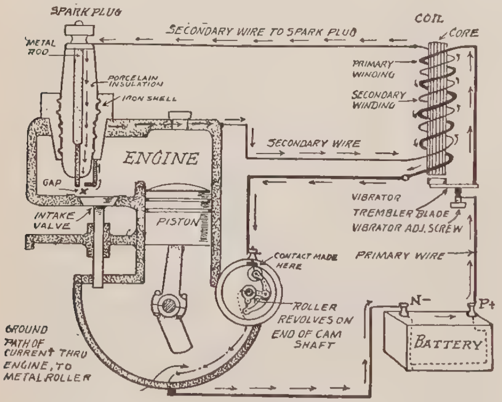

Fig. 1. Relation of the spark plug to the cylinder and to the commutator.

A spark plug (Fig. 1) is screwed into the cylinder of the engine, and when the piston is in the right position to receive a spark, a high-tension current of electricity is sent along the metal center rod (called the "electrode") of the spark plug and across the small air-gap (**X**) at the bottom and into the outer sleeve or iron shell of the spark plug which screws into the cylinder.

Although this air gap (**X**) is only about 1/64" to 1/32" wide, the air in the gap offers such a tremendous resistance to the current that it requires in the neighborhood of 5,000 or more volts' pressure to force a very small quantity of current across the gap. In other words, the current must be of such high pressure that it will jump across a space between two points, forming a spark as it passes.

The amperage of current across this gap is so small a quantity that it cannot be measured with a meter, but is measured with an instrument called an **oscillograph** and the current is measured in terms of **milliamperes** (one-thousandth of an ampere).

To give an idea of the quantity represented by a milliampere, suppose we have a high-tension coil with 5 amperes at 6 volts pressure flowing through the primary winding and the voltage at the secondary terminal or gap is 10,000 volts, what would be the amperage of the secondary?

5 amp. × 6 volts = 30 watts. 30/10,000 = 3/1,000 part of an ampere.

K-W ignition coils are constructed to operate on a current consumption in the primary from the battery of 1 to 1 2/10 amperes at 6 to 8 volts. The "self-induced" voltage in the primary has a sufficient number of turns to give 145 volts when the circuit is broken. The voltage at the secondary is 5,000 and up, depending on the number of turns. High-tension coils which give a ½" spark, in the open air, require about 10,000 volts at the secondary, and if the coil is of a vibrator type, the voltage can be still further increased when the spring tension on the vibrator spring is increased, so that the coil will draw a heavier current (amperage). This, however, should not be made a practice, inasmuch as the insulation is not designed to stand current values above those recommended by the manufacturer. Always adjust according to instructions. See Index for Ford vibrator coil adjustments.

Note that the battery or primary current does not jump the spark-plug gap. It is used to magnetize the iron core; and when the circuit is opened and this core is suddenly demagnetized, a high voltage is induced from the primary winding into the secondary winding. This is due to approximately 12,000 turns of fine wire used in the secondary winding, wound over the primary winding.

Construction of a High-Tension Vibrator Coil

The high-tension coil (also called a "jump-spark coil," "secondary coil," "transformer coil," etc.) differs from the low-tension coil in that there are two windings on the coil core; one, a coarse wire winding, called the **primary** winding, just the same as in a low-tension coil and the other, a **secondary** fine wire winding which is wrapped over the primary winding, both windings being insulated.

There are usually about 200 turns of No. 19 to 24 B. & S. gauge insulated copper wire for the primary winding, and about 12,000 turns of very fine No. 34 to 38 B. & S. gauge enameled silk-covered thin insulated copper wire in the secondary winding, so that the layers can be close together and with as many turns as possible. Thus the ratio of the primary winding to the secondary is about 60 to 1.

The windings can be in either direction. They are usually in the same direction, because it is more practical from a manufacturing standpoint.

The original and early form of a high-tension coil ignition system consisted of the parts as shown in Fig. 2. This system is termed a **"magnetic vibrator-coil"** ignition system.

A commutator, which is nothing more than a revolving switch, has a roller (**R**) connected to an arm which is connected to the cam shaft. This roller, therefore, makes one revolution while the crank shaft makes two revolutions. Thus on a

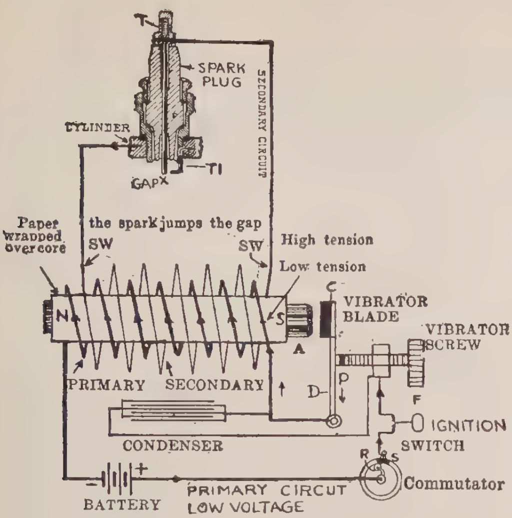

Fig. 2. A high-tension coil using a magnetic vibrator.

single-cylinder engine, there would be one insulated commutator contact segment (S), and one spark would occur during two revolutions of the crank shaft.

Primary circuit: The current flows from the positive terminal (+) of the battery, through the roller (R) and segment (S), through the ignition switch, vibrator screw and points (P), through the trembler or vibrator blade (D), through the primary winding wrapped around the coil iron core, to the (−) terminal of the battery.

If the roller (R) is on contact with the commutator segment (S), and the ignition switch is "on," the current would then pass through the entire primary circuit.

The moment the primary circuit is completed, the vibrator blade (trembler blade—D) is drawn to the soft iron core (A), because the soft iron core becomes magnetized the moment the primary circuit is completed.

When the vibrator blade (D) is drawn to the soft iron core (A), the primary circuit is opened between the platinum points (P) on the vibrator blade and on the vibrator screw. Thereupon the core loses its magnetism and the vibrator blade is released; on account of its spring tension, it rebounds, closing the primary circuit again at the point (P).

This action takes place repeatedly and the blade vibrates back and forth, so long as the circuit is closed by the roller (R) of the commutator being on contact with the segment (S).

The moment the roller (R) leaves contact with the segment (S), the coil is out of action. Thus we have what is termed a "magnetic" method of making and breaking the primary circuit, instead of a "mechanical" method. The mechanical method, however, is a popular method and will be explained farther on.

Secondary circuit: When the primary circuit is opened and closed by the magnetism of the core (A), which is produced by the current flowing through the primary winding, a very high electromotive force is induced into the secondary winding, which is wrapped around the primary winding. This induced e.m.f. in the secondary winding causes current of a very high voltage to flow in the secondary winding, of sufficient intensity to jump a gap (X) of about 1/32″ at the points of the spark plug, which is screwed into the engine cylinder and to cause a spark which ignites the compressed gas.

To develop a high voltage (e.m.f.) at the secondary terminals it is necessary that a very large number of turns be used. For instance, if the primary winding consisted, say, of ten turns of wire and the secondary consisted of one hundred turns, the "induced" voltage in the secondary would be ten times as high as that in the primary, but the current value (amperage) in the secondary would be ten times less than in the primary.

The secondary winding is insulated wire, as is also the primary winding. One end of the secondary winding leads to the metal rod connection of the spark plug which is insulated from the engine by porcelain, then passes through it, jumps the gap (X) to the metal point of the spark-plug shell, which is an iron shell screwed into the cylinder, and then passes through the frame of the engine back to the other end of the secondary winding. As the vibrator on the coil vibrates, a "succession of sparks" is produced at the spark-plug gap (X). Bear in mind, however, that there is but one spark produced at each break of the contact points (P). Sometimes the secondary and primary windings are connected together inside of the coil, and one wire leads from both, to a ground connection on the engine. But it should be noted that the secondary circuit and the primary circuit are two independent circuits. Of course the secondary circuit, which is of a very high voltage, is dependent upon the primary circuit, not by means of metallic connections, but only by induction, as will be explained farther on.

The magnetic vibrator blade (D) (Fig. 2), as previously stated, vibrates rapidly and opens and closes the circuit a great number of times, during the time the commutator roller is in contact with the segment (S).

This is the principle of **the Ford ignition coil,** and by adjusting the tension of the vibrator, by screwing the adjusting screw in or out, the number of times it opens and closes the primary circuit can be regulated. The more times it opens and closes the primary circuit during a given period of time, the higher the voltage (see Index under "Ford ignition coil").

Time of spark: The commutator roller is set so that it makes contact with the segment (S) when the piston is at the top, or slightly over the top, of the compression stroke. This is termed "ignition timing" and is treated farther on.

Condenser: A condenser is always used with high-tension coils, by placing it across the interrupter points, to prevent a spark at the interrupter points, which would otherwise occur as shown in Fig. 11, page 184, if a condenser were not used. The condenser is not shown in Fig. 1, but is shown in Fig. 3. The condenser is fully explained farther on.

How and why the **high tension, or voltage is induced into the secondary winding** of sufficient intensity to jump the spark-plug gap (X) is explained in the text following.

Note. In Fig. 1, the circuit is slightly different from that in Fig. 2. The principle is the same. Fig. 1 explains the relation of the spark plug to the cylinder and also how the current flows through the engine frame. The connections from the battery to the coil, etc., could be as in Fig. 1 or 2. The connections shown in Fig. 2, however, are in conformity with the general practice.

Note that, as shown in Fig. 2, the (−) terminal of the battery is usually grounded. The secondary and primary windings are also usually grounded together. For instance, if the left ends of both primary and secondary winding were connected together in the coil and then grounded, and if the (−) terminal of the battery was grounded, the circuit would be a "grounded" system instead of an "insulated" system, as shown in Fig. 2.

Principle of a High-Tension Coil

How a high-tension current is induced in the secondary winding can best be understood after first reading the explanation of the principle of the low-tension coil on pages 182, 184; since the **self-induction** action of the primary winding is the base for building up the high-tension voltage in the secondary, by what is termed **mutual-induction.**

The difference between "self-induction" and "mutual-induction" is that self-inductance is produced in the same coil in which the current was allowed to flow, as the primary winding. Mutual inductance is where an e.m.f. or current is induced into a separate coil of wire, as in the secondary winding.

We learned on page 184 that the greater the number of lines-of-force and the greater the rate of speed at which the lines cut the turns of wires, the greater the induced e.m.f. for voltage.

Therefore, as we have several thousand turns of wire in the secondary and a few hundred turns of wire in the primary, we thus have a greater number of cuttings of lines-of-force, because very nearly all the magnetic lines-of-force produced by each turn in the primary will cut all the turns in the secondary coil, hence the total number of cuttings of lines-of-force will be greatly increased. The lines-of-force will cut the turns of wires at a greater rate of speed when contact is broken than when contact is made, thus the voltage developed at the "break" of the circuit is enormously greater than at the "make." This is explained as follows:

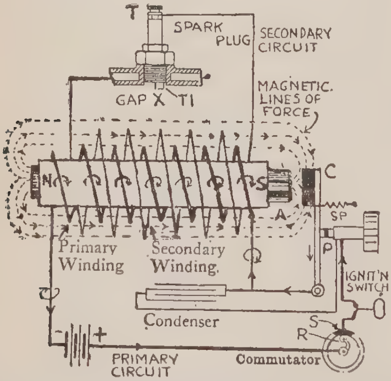

Fig. 3. Showing how the lines-of-force build up around the windings when contact is closed, and how they collapse and cut the turns of wire when the circuit is opened.

When the primary circuit is closed by the commutator (Fig. 3), the primary circuit is completed through the points (P) on the vibrator screw and blade (C), and the lines-of-force spring from the primary turns of the wires, and a magnetic field is built up around the wires, as explained on page 181. This magnetic field in building-up forms an electro-magnet, with lines-of-force flowing from (N) to (S), therefore these lines must necessarily cut (*up*) through the turns of wires on the iron core as they build up. In doing so, they generate an induced e.m.f. which has a tendency to create a counter-voltage, or counter-electromotive force, which bucks or opposes the incoming current from the battery (see page 184). Consequently the magnetic field is momentarily retarded and builds up with comparative slowness, and thus we do not obtain a very high rate of speed of the lines-of-force cutting the wires during the building-up process.

In building up this field, the lines-of-force cut through the secondary as well as through the primary. In doing so, an e.m.f. is generated in the secondary which flows in an opposite direction, due to the movement-up of the lines-of-force, which is an operation similar to that of moving a wire *down* in a magnetic field (Fig. 10**A**, page 183).

The induced voltage in the secondary is thus not great enough to jump the spark-plug gap (**X**). Therefore we must make use of another action. This is accomplished by breaking, or interrupting or opening the primary circuit. In other words, the moment the lines-of-force build-up, the core (**A**) becomes an electro-magnet and draws the interrupter blade (**C**) to it, thus interrupting, or opening, the primary circuit.

When the primary circuit is opened or interrupted quickly, an entirely different action takes place. The magnetic field of lines-of-force, which have by this time built-up around both windings and reached maximum value, collapse or recede into the iron core. In doing so, the lines-of-force cut at a great deal more rapid rate than when being built up. Therefore, as the lines-of-force collapse or recede to the iron core with great rapidity, they cut the secondary turns of wire in an opposite direction to that in which they did so in building-up, and the current then flows in the same direction as the dying primary circuit. They thus assist in causing self-induction[1] in both the secondary and primary circuits, which generates a very high voltage, but still not as high as necessary.

Bear in mind that the primary circuit is now open. Thus we are dealing with "self-induced" current, produced by the lines-of-force cutting the turns of wires as they collapse or recede to the core.

The point to be noted is, that if this iron core is demagnetized, so that the lines-of-force can pass back to it at a greater speed, the turns of the wires would be cut at a greater rate, correspondingly increasing the induced e.m.f. in the turns of the wires.

Owing to the fact that this primary circuit is now carrying a self-induced current, caused by the line cutting its own turns of the wires, this prevents the rapid demagnetization of the iron core, and a heavy spark will occur at the interrupter points (P), just as it did on the break of the low-tension coil (Fig. 11, page 184).

The condenser assists in demagnetizing the core. Therefore, if we could absorb this spark at the interrupter points (which comes from the self-induced current in the primary winding) in some way, and thus cause a more rapid demagnetization of the iron core, the lines-of-force would then pass back to the iron core more quickly and would thus cut the secondary turns of wires at a still greater rate of speed. In other words, it is the secondary winding into which we wish to induce a very high voltage. Therefore, by placing in the coil a **condenser** which is connected across the interrupter points (P, Fig. 3), we can absorb or suppress the spark across the interrupter points (P) of the primary circuit and stop the flow of self-induced current which is still trying to build up lines-of-force in the core, and thus aid the primary current to fall to zero value more quickly. Hence the reason for placing the condenser (Fig. 3) across interrupter points (P) of the primary circuit.

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[1] **"Self-induction"** means induction produced in a circuit at the moment of starting or stopping the currents flowing therein, by induction of the current on itself. For instance, when starting current to flow through the primary circuit, if the circuit is closed, lines-of-force spring out from the center of the wire through which the current is flowing, and thus produce a temporary "self-induced" current in an opposite direction, thus momentarily retarding the building-up of the lines-of-force.

When stopping or opening the circuit of the primary, the lines-of-force collapse into the core and, in doing so, cut in an opposite direction, or in the same direction as that in which the battery current was flowing.

Purpose of the Condenser

1. To **absorb** the self-induced current of the primary, thereby allowing the magnetic field to collapse with the greatest possible speed, and also eliminating the spark at the contact points.
2. To **discharge** in an oscillating (alternating) manner back and forth into the primary circuit, thus completely neutralizing or demagnetizing the iron core and thereby preparing it for repeated action.

Condenser Construction

The condenser consists of a series of sheets of tinfoil separated from each other by a good insulator, such as mica, or several sheets of wax paper.[1] These are built up in a pile, somewhat as shown in Fig. 4. The even-numbered sheets of tinfoil, 2-4-6, etc., are connected, making one terminal (T) of the condenser. The odd-numbered sheets, 1-3-5, etc., are likewise connected, making the second terminal (T1) of the condenser. There is no connection between the two series of sheets. These connections are then made across the primary circuit at the contact points, as shown in Fig. 7.

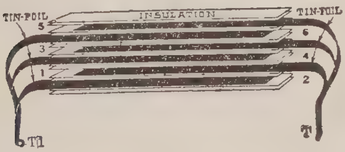

Fig. 4

Fig. 4A

Condenser Action

With contact points (P) closed (Fig. 5), the current flows as shown by arrows through the primary winding. The condenser and secondary winding are not considered, as they are inactive. A current of low value is induced in the secondary in a direction opposite to that of the primary-current flow.

With contact points (P) open (Fig. 6), the condenser is charging. The spark of highest value is now at the secondary terminals. Note that when points (P) open, the magnetic field of lines-of-force collapse, and the induced current in the secondary is then flowing in the same direction as that in the primary. This spark is greatest just as the points open, because the condenser absorbs the self-induced current of the primary and thereby stops its flow, thus preventing it building up lines-of-force in the core. On the other hand, it neutralizes the core, and also eliminates any flow of current or of sparking at the contact points.

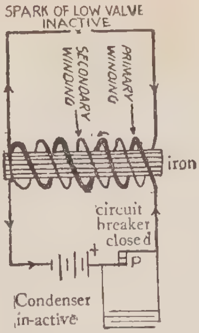

Fig. 5

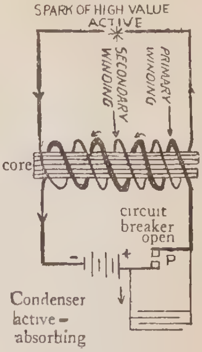

Fig. 6

On account of this action the lines-of-force or magnetic field can collapse with greater rapidity and cut the turns of wires faster, thus inducing a current in the secondary winding of a much higher voltage.

The current flows into the condenser in one direction when charging, which action takes place immediately the points are opened.

When the condenser is charged with the (+) positive current flowing into the (+) side, it will establish a (−) negative charge on the other side.

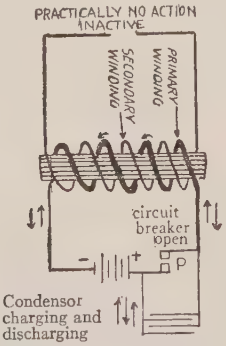

Fig. 7

The condenser, after being charged, makes an oscillating discharge of high voltage and frequency through the primary winding and battery (Fig. 7). That is, the discharge is first in one direction and then in the other, the strength of this current gradually decreasing (owing to the resistance of the circuit) until it dies down to zero. This alternation or reversal of the current flow is very rapid, sometimes reversing from one direction to the other as many as two hundred thousand times every second, and its discharge can therefore be considered almost instantaneous.

The main purpose of the alternate discharges shown in Fig. 7 is to completely demagnetize or neutralize the iron core, thereby preparing the core for a repeated action of building-up again as shown in Fig. 5, and collapsing, as shown in Fig. 6.

As this is written out, or as it is read, it seems a rather long action. The process, however, does not require one-thousandth of a second, inasmuch as the current alternates at an extremely high frequency, sometimes having as many as 100,000 cycles per second.

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[1] **Never attempt to open a condenser,** as this will destroy it. In the manufacturing process the tinfoil and insulating sheets, with the aid of an insulating compound, are pressed closely together under heat, with high pressure (Fig. 4A). Obtain a new one when necessary.

Meaning of Cycle and Frequency

A cycle means a series of events which continually reoccur. In the case of a condenser, for example, the current discharge at one instant is a maximum (+), as shown at (C) (Fig. 7A). It gradually declines to 0 at (A), then builds up to a maximum (−) as shown at (D), again declining to 0 at (B), reversing in direction and building up to a maximum (+) at (E), which is the same condition as at (C), thus reversing the direction twice at (A) and (B) and completing the cycle evolution, which is repeated over and over again until the discharge dies down to 0 (zero).

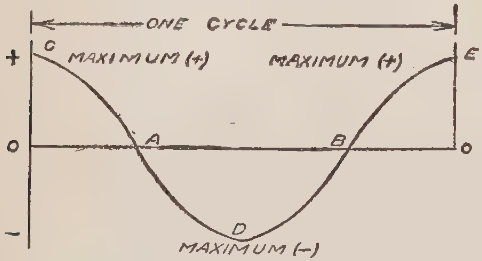

Fig. 7A. Explanation of the meaning of cycle.

Frequency means the number of cycles completed per second. As mentioned above, it is 100,000.

The Ignition Commutator

Because the secondary current is only needed when it is time for the spark to pass and ignite the mixture, the primary current is switched into the primary winding only once during two revolutions on a single-cylinder engine. The switching is done by a commutator, which might be termed a revolving switch.

Where there are four cylinders to an engine, then it would be necessary to have four segments (S) on the commutator, because four sparks are required during two revolutions of the crank shaft.

A four-cylinder ignition commutator is shown in Fig. 8. An ignition commutator is used only with a vibrator-type coil, as on the Ford. The vibrator-type coil and commutator are seldom used on any other make of car.

The spark timing device (commutator) is so named because it "times" the spark at the right time. In other words, the roller makes contact with one of the segments (1, 2, 3, or 4 on a four-cylinder engine). Each segment controls one of the spark plugs (through a coil) in one of the four cylinders. When the right cylinder is ready to fire, the timer makes contact and starts the vibrator on the coil, which causes a spark at the points of the spark plug. This device is called a "commutator," and is used only with a high-tension coil using a vibrator.

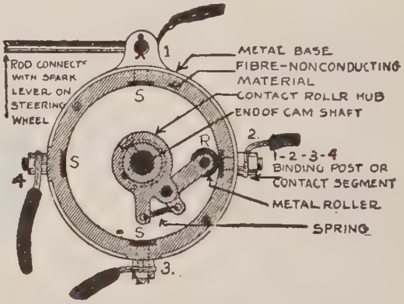
ROD CONNECTS WITH SPARK LEVER ON STEERING WHEEL
1
METAL BASE
FIBRE-NONCONDUCTING MATERIAL
CONTACT ROLLR HUB
END OF CAM SHAFT
2.
S
R
S
S
4
1-2-3-4 BINDING POST OR CONTACT SEGMENT
METAL ROLLER
SPRING
3.

Fig. 8. A four-cylinder ignition commutator.

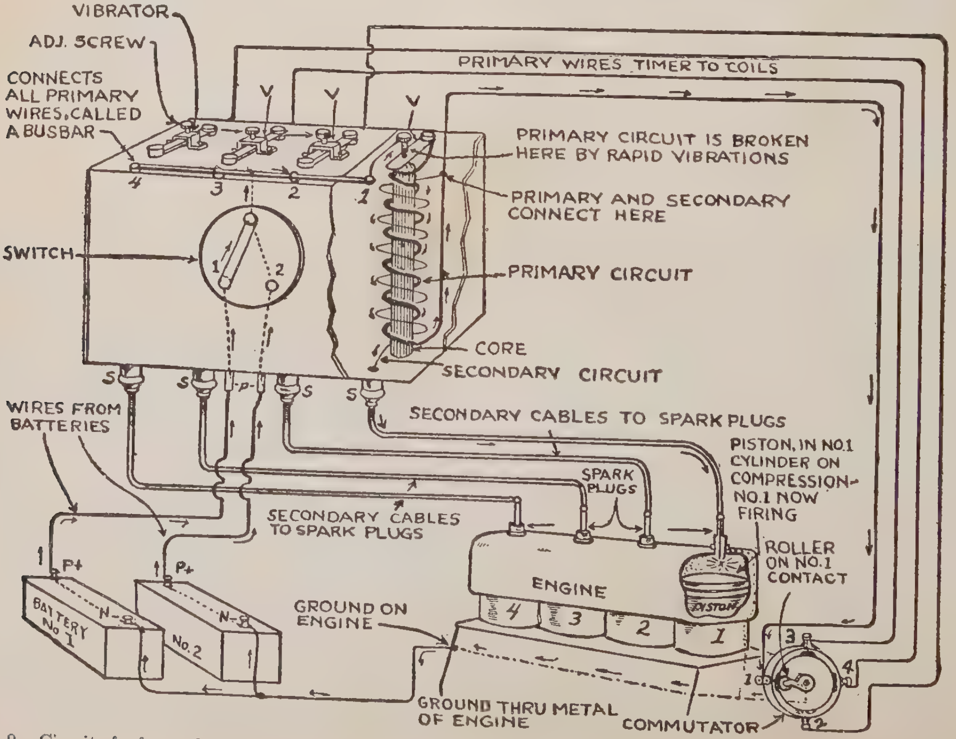
VIBRATOR
ADJ. SCREW
CONNECTS ALL PRIMARY WIRES, CALLED A BUSBAR
V
V
V
4
3
2
1
PRIMARY WIRES TIMER TO COILS
PRIMARY CIRCUIT IS BROKEN HERE BY RAPID VIBRATIONS
PRIMARY AND SECONDARY CONNECT HERE
SWITCH
1
2
PRIMARY CIRCUIT
CORE
SECONDARY CIRCUIT
S
S
-P-
S
S
SECONDARY CABLES TO SPARK PLUGS
WIRES FROM BATTERIES
PISTON, IN NO.1 CYLINDER ON COMPRESSION-NO.1 NOW FIRING
SPARK PLUGS
SECONDARY CABLES TO SPARK PLUGS
P+
P+
BATTERY No 1
N-S
No. 2
N-S
GROUND ON ENGINE
ENGINE
4
3
2
1
ROLLER ON NO.1 CONTACT
3
4
1
2
GROUND THRU METAL OF ENGINE
COMMUTATOR

Fig. 9. Circuit of a four-cylinder vibrator coil ignition system using a commutator (exaggerated) and two sets of batteries.

Commutator construction: There are many different constructions. One which will explain the principle of a commutator is shown in Fig. 8.

The metal roller hub is connected to the cam shaft of the engine. A roller (**R**) revolves in a housing lined with an insulated, non-conducting material, usually fiber. Metal segments (**S**) are placed 90° apart for a four-cylinder engine. These segments are connected with one terminal of the primary winding of the coil. There are as many segments on the commutator and as many coils as there are cylinders. Since the cam shaft makes one revolution while the crank shaft makes two revolutions, then the roller (**R**) would revolve the same number of times as the cam shaft, because it is connected with it. Thus roller (**R**) would make contact with each of the four segments during one revolution, and so would produce four sparks in the engine cylinders, or one spark for each cylinder during one revolution of the roller (**R**), or two revolutions of the crank shaft of the engine.

Electric Circuit of a Four-Cylinder Vibrator Coil Ignition System

The illustration (Fig. 9) explains how a commutator is driven from the cam shaft of a four-cylinder engine and how it is connected with the primary windings of four-vibrator type coils contained in one coil box.

The illustration also shows the primary wiring connection from the battery, through one of the coils and connections to the other three coils and to the commutator, back to the battery; also the secondary circuit from coil to spark plugs, back to the coil.

Primary circuit: Place your pencil on the drawing at the positive pole (P+) of No. 1 battery, and follow out the circuit.

We will begin with the positive pole connection of No. 1 battery; there are two sets of batteries, but only one set is used at the time. If one runs down, the other one is thrown into service by a switch on the coil.

The switch is now on No. 1 contact, and the circuit is from No. 1 battery to the switch, through the switch lever to the bus-bar on the front of the coil, which connects to the contact screw (V) of the coil, thence through the platinum points, through the magnetic vibrator spring, to the primary winding which is wrapped around a core or bundle of soft iron wires.

The other end of this primary wire of coil connects with the segment on the commutator; the current is closed here at the proper time. The commutator roller-contact revolves as explained previously. When this contact is completed, the primary circuit is closed on one of the four coils (it is now closed on No. 1 coil). When this circuit is closed, the bundle of iron wires (core) becomes magnetized and draws the vibrator down, but the moment the vibrator is drawn away from the contact with the vibrator screw, the circuit is broken and the vibrator springs back and makes contact again, but is immediately drawn down again; this, of course, is quick and rapid. This vibration is kept up as long as the contact is made on the timer, which, of course, is only for a moment, but during that time the vibrator makes several vibrations or "buzzes" as explained previously.

Secondary circuit: When these vibrations, or interruption of current, occur, a current is "induced" into the secondary winding of fine insulated wire wrapped around the primary winding of the coil, called a "secondary winding." (How and why this current is induced into the secondary winding without any metallic connection was explained).

This secondary winding, of course, has two terminals; one end goes to a spark plug, and the other end connects to one side of the primary wire, which grounds it through the commutator roller to the engine, when the roller makes contact; thence the circuit is to the metal shell of the spark plug in the engine, across the spark-plug gap, to the insulated part of the spark plug, back to the coil. A separate coil unit is provided for each cylinder.

The duty of the commutator, therefore, is to make contact at a certain time in order that the right coil will operate and supply an electric spark to the right cylinder at the right time.

Note. When one wire (on any wiring diagram) passes over another wire without making contact, a half-circle is made, as shown above.

How the Commutator Helps Control the Speed

The commutator is connected to the spark lever on the steering wheel (Fig. 10). When the spark-lever is pushed forward, the commutator is shifted forward so that the metal roller makes contact earlier with the contact segment. This is called "advancing" the spark.

If the commutator is shifted back instead of forward, the contact is made later. This is called "retarding" the spark.

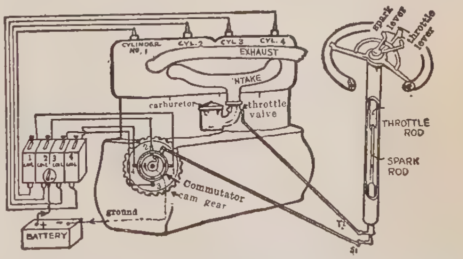

Fig. 10. Note the manual (hand) method of "advancing" and "retarding" the commutator. (Four-cylinder engine as example.) If the roller is revolving to the left, by shifting the commutator housing to the right, contact would be made earlier. This would be called "advancing" the spark. If the commutator is shifted to the left, contact would be made later—called "retarding."

When using a vibrator coil (which is the case here), the time of the spark is set earlier than when using the single-spark system, because plenty of time must be given the spark to ignite the gas so that it will ignite and combust when the piston is at the top of its stroke instead of after the top. (Note the connections to the commutator for firing order of 1, 2, 4, 3.)

The setting for the time of spark to occur is done by placing the contact roller at a certain position, as will be explained under "Ignition timing."

The gas-throttle lever is the lever used to run on, and is used to increase or decrease the speed of an engine. This is done by opening and closing the throttle, as explained under the subject of Carburetors.

It is well to run with the spark lever as well forward, or advanced, as possible, as it will tend to keep the speed of the engine up and consume less gasoline and create less heat. If the spark lever is too far advanced, then the engine will pound or knock, because the ignition will take place before the piston is over the center. A retarded spark produces heat.

The amount of advancing and retarding of the spark by hand must be learned by actual practice, in order to get the best results.

High-Tension Vibrator Coil Using a Commutator as Used on One, Two, and Four-Cylinder Engines

As previously stated, the vibrator-type coil is now seldom used on automobile engines. It will often be found on small marine and stationary engines. A few examples of connections are shown below.

There are as many coil units and as many commutator segments as there are cylinders.

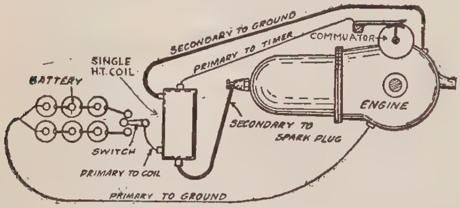

Fig. 11. One-cylinder engine with a vibrator type of jump-spark coil and two sets of dry batteries for ignition. Only one set of batteries is in use at the time. The commutator revolves at one-half the speed of the crank shaft. Note that there is one commutator segment.

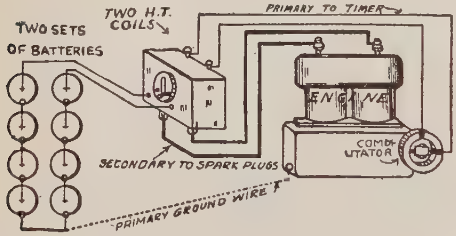

Fig. 12. Two-cylinder vertical engine (180° crank shaft) with a vibrator-type of jump spark coil and two sets of dry cells for ignition. Note the position of the segments on the commutator. The commutator revolves at one-half the speed of the crank shaft. (This type of engine is seldom used.)

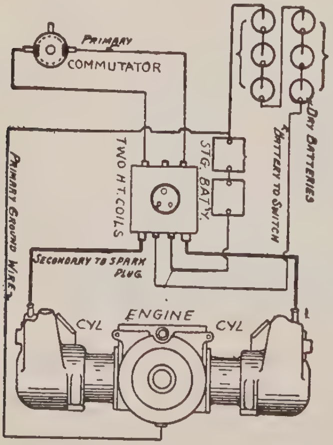

Fig. 13. A two-cylinder opposed-type of engine with a two-cylinder jump-spark coil and a set of dry cells and a storage battery, either of which may be used. The two contacts on the commutator are placed opposite. This revolves at one-half the speed of the crank shaft.

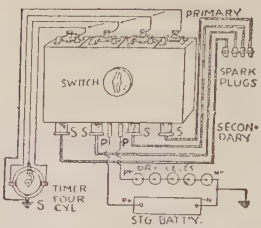

Fig. 14. A four-cylinder vibrator-type coil, using a commutator with four segments and a set of dry cells and a storage battery, either of which may be used. (S) are secondary terminal connections to the spark plugs.

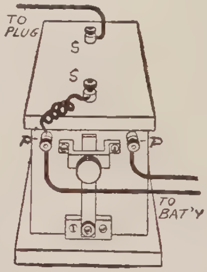

Fig. 15. A single-cylinder vibrator-type of jump-spark coil. This type is usually called a "box coil," and is only used on small marine or stationary engines. Quite frequently a single-cylinder box coil has but one secondary connection on top. In this case the secondary connection shown at the front of the coil is connected inside of the coil to the primary wire which connects to binding post (P).

The Master Vibrator Coil

With the "high-tension" vibrator coil system, just described, as many coil units, each with vibrators, would be provided as the engine had cylinders. If a four-cylinder engine, four vibrator coil units would be necessary. If a six-cylinder engine, six vibrator coil units would be necessary.

It will be noted that with this number of vibrators, one or more would be constantly sticking, unless a great deal of attention was given to them.

Therefore, by using a **master vibrator,** only one vibrator coil is used, which is connected with the other coils as shown in Fig. 16 (page 195).

The master vibrator coil has but a **single primary winding,** and is connected in series, so the primary current must travel through it before reaching any of the coils. The usual commutator is employed.

The master-vibrator coil can be connected with a "multiple" of coils, by screwing down the vibrators on all coils and short-circuiting them, by connecting as shown in Fig. 16A. Note that the coils are the regular double-wound, high-tension coils.

The advantage of such a system is that there is but **one vibrator** to keep in adjustment, since this vibrator serves for all the cylinders; whereas, with several vibrator-coil units the difficulty of keeping several adjustments is a considerable factor.

The disadvantage is the great amount of wiring necessary with the multiple-coil system. Although the master vibrator is easily connected and requires very little wiring, the "distributor" system, which will be explained next, requires considerably less wiring. The master vibrator is an excellent addition to be applied to a multiple system of ignition, already installed, which uses vibrator-type coils.

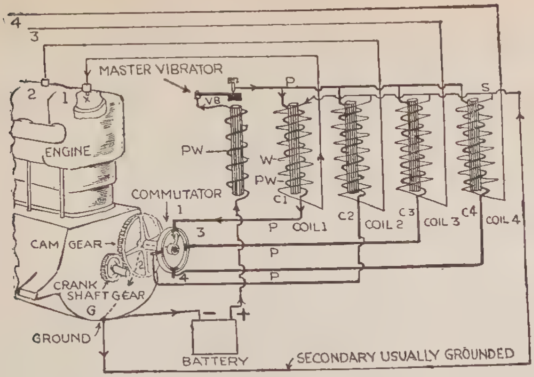

Fig. 16. A simplified illustration of a **master vibrator coil** on a four-cylinder engine, as an example. (**W**) secondary winding; (**PW**) primary winding; (**P**) primary wire; (**VB**) vibrator; (**C**) coils; (**G**) secondary ground wire; Fig. 16A, shows how the vibrator on the coils **C1**, **C2**, **C3**, and **C4** are short-circuited.

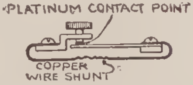

Fig. 16A. How to short-circuit vibrators on coils.

The firing order is 1, 2, 4, 3. No. 1 segment of the commutator is now connected; therefore coil (C1) is firing No. 1 cylinder. Note that the master vibrator is in series with this coil. The primary circuit in this instance is from (+) battery, through the winding of the master vibrator, through the vibrator points, through the primary winding of coil (C1), to the commutator segment, through the metal roller, through the ground of the engine, to the other terminal of the battery.

The secondary circuit is from wire (S) to the spark plug, through the engine, back to the other end of the secondary winding on the coil.

The next cylinder to fire will be No. 2, and coil (C2) will be the next one connected by the roller on the commutator. The next to fire will be cylinder No. 4 through coil (C4), then cylinder No. 3. through coil (C3).

The "Distributor" or Synchronous System of Ignition

In the foregoing examples it will have been noted that the amount of wiring required for engines having more than one cylinder becomes increasingly complicated. A system now generally used, known as the "distributor system," very considerably simplifies the wiring, and at the same time a more accurate timing of firing of the respective cylinder is obtained. (See Fig. 17).

One vibrator coil only is necessary, this having the high-tension terminal joined up to the "distributor," which is a special form of rotating switch highly insulated, which directs the high-tension current to the cylinders in the required order.

The secondary distributor brush (B) rotates at the same speed as the commutator roller contact-maker, and in perfect unison with it; that is to say, when the low-tension circuit is completed, the high-tension circuit is completed likewise. The diagram should make the system clear, it being borne in mind that the distributor is rotating as well as the contact maker, and in perfect "synchronism" with it.

The secondary distributor is made in combination with a commutator, each with as many contacts as the engine has cylinders, and with the moving parts of each attached to the same shaft and revolving. (See Fig. 18).

The battery is connected to the single coil in the usual manner, and a wire is run from the primary terminal of the coil to the commutator, where it is connected to the four segments of the commutator. Thus when the commutator revolves, the current is passed through the one coil every time that contact is made.

If with this arrangement a wire was run from the secondary terminal of the coil to the four spark plugs, sparks would pass in all four cylinders whenever the timer made contact. Instead of this, one secondary wire is run from the secondary terminal to the moving part of the distributor, termed the "distributor brush," or "rotor," and from each contact point, or distributor segment of the distributor to the proper spark plug.

When the commutator makes contact, and the secondary current is formed, it flows to the secondary distributor, which at that instant has made contact with one of its segments, so that that secondary current flows across the contact and to the spark plug that is connected.

The advantage of this system is that there is only one vibrator to keep in adjustment, and only one coil, thus fewer parts. The disadvantage is that the constant action of the vibrator is liable to burn the vibrator points, and destroy them. Electrical lag is also a factor to be considered, as is also a greater consumption of current.

The more modern ignition system uses a distributor for distributing the secondary current to the spark plugs in a similar manner, but instead of using a coil with a magnetic type of vibrator, or interrupter, a coil without a vibrator, termed a "non-vibrating" high-tension double-wound coil, is used, and instead of using a commutator, a timer or "interrupter," which is mechanically operated from the engine, is used. This system will be treated in the next instruction.

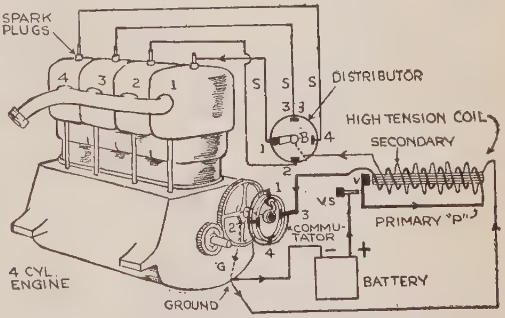

Fig. 17. A simplified illustration showing the principle of a high-tension **distributor or synchronous system** of ignition using a vibrator type of coil. Not in general use. (**P**) primary winding; (**S**) secondary. Note that one end grounds to the engine (usually grounded on the coil). (**VS**) vibrator screw.

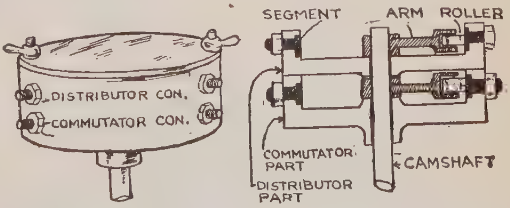

Fig. 18. Simplified illustrations to explain the principle of a **distributor and commutator** in one housing and operated by one drive shaft, used in connection with a vibrator type of coil. This method is obsolete, but a similar principle, of different construction, is the modern method, as will be explained farther on. Note that the distributor and commutator are together. The wiring diagram (Fig. 17) shows the two separated merely to explain the action.

INSTRUCTION No. 19

MODERN BATTERY AND COIL-IGNITION SYSTEMS: High-Tension Coil (Non-Vibrator Type); Open and Closed-Circuit Ignition System; Distributor; Resistance Unit; Safety Gap

THE MODERN BATTERY AND COIL IGNITION SYSTEMS

In order to understand the modern "coil and battery" ignition systems, it was necessary that the reader study the elementary principles of the early forms or methods used for ignition, such as the low-tension coil, the high-tension vibrator coil, the commutator and the distributor, which have all been explained. It ought not therefore to be difficult for the reader to grasp the principle of and the difference between the various modern ignition systems now to be treated.

The battery and coil system is the modern ignition system, such as used on the Atwater-Kent, Delco, Remy, and others which are supplied with a "constant" source of electric supply when used in connection with a storage battery which is kept charged by the generator.

"Constant source of supply" means that the ignition apparatus is not dependent upon a mechanical method of generating current, as in a magneto, but the supply of electric current is constantly supplied by a storage battery and the storage battery is constantly supplied with current (direct) by a generator.

The Non-Vibrator Coil Ignition System

The same underlying principle of operation of a vibrator-type coil, explained on the preceding pages, applies to the non-vibrator coil. The only difference to be noted is that the commutator is dispensed with, and instead of having a "magnetically operated vibrator" or "interrupter" on the coil, a "mechanically operated timer," or "interrupter," is driven from the same shaft as the secondary distributor and is used for exactly the same purpose.

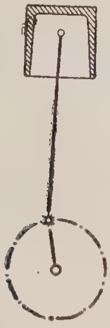

Fig. 1

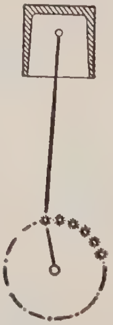

Fig. 2

Fig. 1 represents the **"single spark"**—a hot one at the right time, which causes the gas to ignite quickly without lag, and consumes very little current, as produced by a high-tension coil ignition system of the non-vibrator type.

Fig. 2. Note the **succession of sparks.** This represents the sparks as they occur on the old-style magnetic vibrator coil—several after top of stroke. The hottest one ignites the gas, but usually late.

The non-vibrator coil uses a mechanical interrupter and gives but one "single spark" (see Figs. 3, 4 and 5).

Open and Closed-Circuit Interrupters

The non-vibrator coil system of ignition can be classified as an **open-circuit** system and a **closed-circuit** system. It gives a "single spark."

The open-circuit system consists of a single non-vibrator coil, timer, and distributor (if a multiple-cylinder engine).

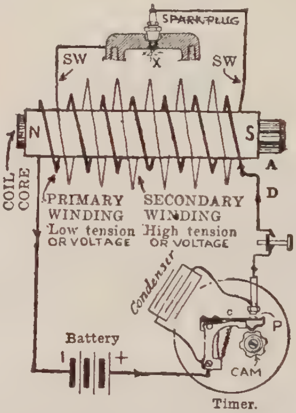
SPARK PLUG
SW
X
SW
N
S
A
D
COIL CORE
PRIMARY WINDING Low tension OR VOLTAGE
SECONDARY WINDING High tension OR VOLTAGE
Condenser
C
P
Battery
CAM
Timer.

Fig. 3. A non-vibrating high-tension coil ignition system, using an open-circuit timer.

The open-circuit timer contact points (Fig. 3), used in connection with this system, are normally **open.** The cam is attached to a shaft, usually driven from the cam shaft, and must therefore be set so that the high point or lobe on the cam will raise the arm (C) so that it will make contact at the proper time. The spark does not occur at the spark plug when the contact is made, but when the contact is opened. This is therefore, a double operation, which causes "electrical and mechanical lag," and this is eliminated by the use of a contact arrangement which is normally **closed.** Thus the improved method (Fig. 4) is termed a "closed-circuit" system, and is the system in general use today.

"Electrical lag" means that the spark will not occur in the same position as regards piston travel at any and all engine speeds. With a very high speed the piston might have a tendency to travel past the point of ignition before the open-circuit timer made and opened contact, whereas with the closed-circuit principle it merely opens the contact.

While all lag factors deal with time in seconds, their effect on the engine is the number of degrees they cause the spark to occur off the point where it should. Consequently a time factor of only one-thousandth of a second means only a variation of 3° at 500 r.p.m., yet means 12° at 2,000 r.p.m., and 18° at 3,000 r.p.m.

Mechanical lag is eliminated much for the same reason, and the quicker and simpler the mechanism to "interrupt" the flow in the primary, the quicker the spark.

Compare the **timer** in Fig. 3 with the **interrupter** in Fig. 4.

Note that in Fig. 3 the cam raises the arm (C) which makes contact at points (P), which are normally open. The strong spark does not occur when contact is made, but when it is opened.

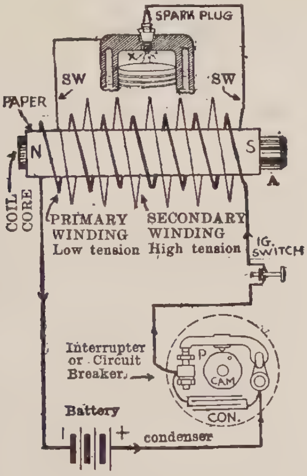
SPARK PLUG
SW
SW
PAPER
N
S
A
COIL CORE
PRIMARY WINDING Low tension
SECONDARY WINDING High tension
IG. SWITCH
Interrupter or Circuit Breaker
P
CAM
CON.
Battery
+
condenser

Fig. 4. A non-vibrating high-tension coil ignition system, using a **closed circuit** interrupter (also called contact-breaker).

Note that in Fig. 4 the contact points (P) are normally **closed**, and the high point on the cam raises the interrupter arm, thus opening the points (P) with one single operation. Thus the closed primary circuit of the coil is interrupted; hence its name "interrupter," or "contact breaker" as it is also often called.

The closed-circuit ignition system using a non-vibrator coil and a closed-circuit "interrupter" in connection with a distributor is more clearly shown in Fig. 5. This represents a modern "battery-and-coil" ignition system.

Note that the distributor shaft, which is driven from the cam shaft of the engine, operates the interrupter cam which opens the interrupter contact points. The same shaft operates the distributor brush which distributes the secondary high-tension current to the spark plugs.

The cam has as many high places, or lobes, as there are cylinders. On the cam in Fig. 5 there are four high places. This would, therefore, be suitable for a four-cylinder engine. It is fastened to a shaft which is driven at cam-shaft speed. It is set or timed so that the high point on the cam pushes the moving contact blade point away from the stationary contact point, thus opening the primary circuit of the coil. By this method the operation of first closing the circuit, then opening it, as on the open-circuit timer is eliminated, and makes the action much quicker.

Circuit of the Modern Closed-Circuit System

The primary circuit of the closed-circuit system (Fig. 5, below), is from (+) of the battery, through the ignition switch, through the resistance, through the primary winding, through the insulated stationary contact point, through the movable interrupter or contact points, through the frame of the interrupter, to which it is grounded, to a ground connection of the frame of the car, to (−) ground of the battery.

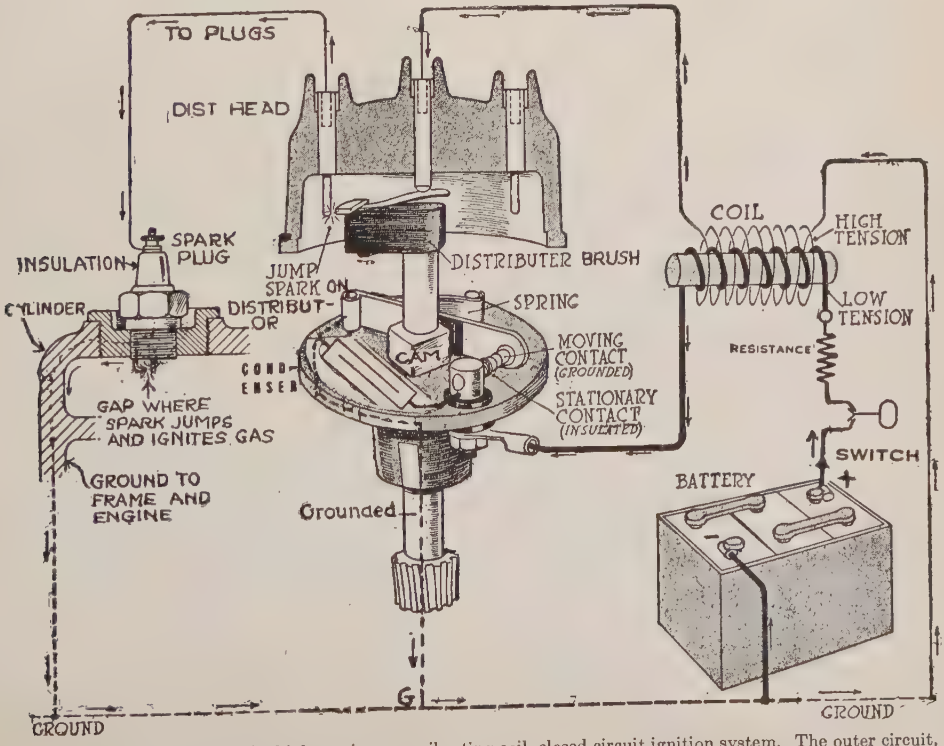

Fig. 5. A simplified illustration of a high-tension non-vibrating coil, closed circuit ignition system. The outer circuit, in light lines, is the secondary; the inner circuit, in heavy lines, is the primary circuit.

The condenser in this instance is placed across the contact points of the interrupter and in the interrupter, one end being connected with the insulated stationary contact and the other end grounded to the frame of the interrupter. The condenser could be in the coil, which it is, in some systems; in such cases it must connect directly across the contact points, as explained on page 189.

The secondary circuit and distributor: One terminal is grounded. The other leads to the center terminal of the distributor, and makes contact with the metal spring on the insulated rotating distributor brush, also called the "rotor."

The other end of the spring on the rotor passes close to, but not touching, the metal distributor terminals of the distributor head (made of insulated material) which leads to the spark plugs (termed the "distributor gap"[1]); thence through the center terminal of the spark plug; it then jumps the gap at the spark-plug points, thence to the shell of the plug to the engine, back to the grounded connection of the secondary.

The distributor rotor, of course, is synchronized or set so that the rotor spring makes contact with the spark plug in the cylinder to be fired; at the same time the interrupter cam opens the circuit.

The ignition switch of course is supposed to be opened when the engine is idle. However, the operator may not always think to open the ignition switch, and therefore an **ignition resistance unit** is placed in series with the primary winding on very nearly all closed-circuit battery and coil-ignition systems, to take care of any possible damage that might occur.

Ignition Resistance Unit

The purpose of the ignition resistance unit is twofold, one being to protect the battery from discharging back through the primary winding and thus overheating the winding and discharging the battery, if the switch is left on and engine is not running.

The ignition resistance is made of iron wire, usually mounted on a porcelain spool on the ignition coil. It turns a cherry red when the primary current flows through it for any length of time. When iron heats it offers resistance; thus the discharge through the primary winding is greatly decreased. If current is left on for a long period of time when the engine is idle, the resistance may burn out and open the circuit and a new resistance unit becomes necessary. This sort of thing happens frequently.

When the engine is running, the circuit is continually opened and closed and thus the heating effect is not as great.

In the instruction on the principle of the ignition coil (page 190), we learned that the coil core is slow in its action of "building up" lines-of-force, or in being magnetized, when the circuit is closed. This being the case, it would appear that at high engine speeds the interruption or opening of the circuit would take place before the iron core of the coil was fully magnetized, thus producing a weak spark. This is quite true and possible.

To overcome this, the coil is wound so that it takes an excess of current, or more than is required in order to compensate for this slow action of magnetizing the core. The question next to arise is, if the excess of current takes care of high speeds, what is the situation in the case of low speeds? At low speeds, the points are closed for a longer period and the excess of current would injure the coil.

The answer is, that the resistance unit heats when the circuit is closed for a longer period of time and offers resistance which cuts down the flow of current to normal. At high speeds it does not heat so much and the resistance is less, and the current is permitted to pass at full value through the winding at high speed, thus assisting in quickly building up magnetism in the core.[1]

High-Tension Safety Gap

Safety gap: The fact that the distributor spring does not make full contact with the distributor terminals leading to the spark plugs brings up the subject of safety gaps.

The safety gap on the ignition coil is always a "shunt" gap placed across the secondary circuit, usually on the coil. If the external secondary circuit is open, the safety gap provides another path to ground (see Fig. 6). It is used more on high-tension magnetos than it is on ignition coils. It is practically a safety valve for the high-tension current. The safety gap is usually set slightly farther apart than the spark-plug gap, or about 5/16″. As long as the wires to the spark plug are connected, the safety gap is inactive, but if the spark-plug wire should come loose, then the safety gap becomes active by a spark jumping across its gap instead of trying to jump from the end of the loose wire to the engine. If this were a greater distance than ½″, which it might well be, it might cause the high-tension current to force a circuit through its own insulated winding to its ground, thus damaging the coil.

CONNECTICUT IGNITION, CLOSED-CIRCUIT SYSTEMS: MODELS 16, 14, AND 15

As an example of an ignition system using a "safety gap" and a "thermostat resistance," the Connecticut ignition system as used on the Dort and also on the "model 89" Willy-Knight six, is shown in Fig. 6. The diagram represents that of the Dort. The Connecticut ignition system using the Connecticut automatic thermostat switch, is clearly shown in this illustration. This ignition system is known as the model "16."

The purpose of the thermostat switch. It must be understood that the timer, or interrupter (Fig. 7) is a closed-circuit type; therefore if the engine is not running and the switch is left "on," a waste of current and heating of the ignition coil results, therefore this automatic switch is used to open the circuit.

There are **two types of Connecticut thermostat switches:** one which is operated by **magnet coils,**

---

[1] The gap between the distributor brush and the spark-plug terminals (Fig. 5) is about .010″. It may vary .003″ or .004″ either way.

The prime advantage of this gap is the fact that no rubbing parts are employed; therefore there is no friction or wear.

The high-voltage secondary current is able to jump the gap, and as soon as the gap is broken down its resistance becomes very low and the secondary discharge passes without noticeable loss.

[1] It is a very easy matter to check the resistance unit, by observing its heating when the ignition button is out and the contacts of the interrupter are closed. If it is shorted out, it will not heat up, and will cause missing at low speeds.

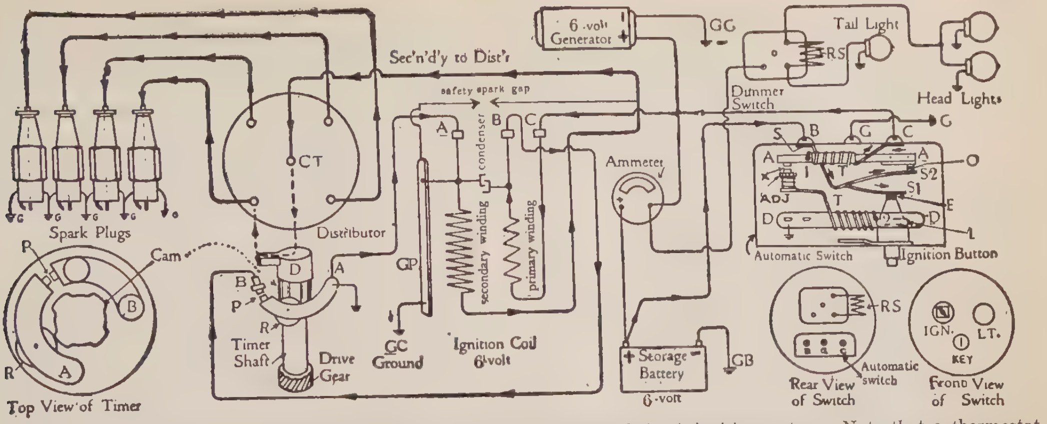

Fig. 6. The Connecticut model "16" high-tension non-vibrating coil closed-circuit ignition system. Note that a thermostat of the **thermal** type, termed "automatic switch," is used to open the circuit if the ignition switch should be left "on." Type "GA" coil is used in this system. Note that the interrupter is grounded at (A).

which is an early type described in Figs. 13 and 14, and a later model where a thermal, or **thermostat blade** (D), (Figs. 6 and 8) takes the place of the magnets. We shall describe the later model, using the thermal blade. "Thermal" refers to heat.

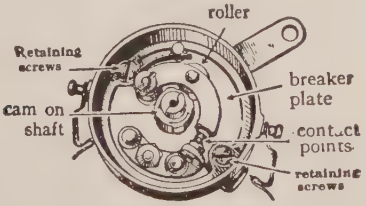

Fig. 7. Top view of Connecticut interrupter or contact-breaker.

Thermostat action (see Figs. 6 and 8). The battery current flows from battery (+), to (B), then through insulated spring (S, Figs. 6 and 8). If the ignition button is pushed in, then an insulated plunger (E) on the switch button presses against spring (S1) causing spring (S2) to close points (O). The current then travels through (A) to (1), through resistance wire ribbon (T) (thermostat wire which is insulated from **A**, except where grounded to **A** at 1), to insulated connection (C), to (C) connection on the coil.

So long as the engine is running, the intermittent opening and closing of timer contact points prevents (T) from heating blade (A).

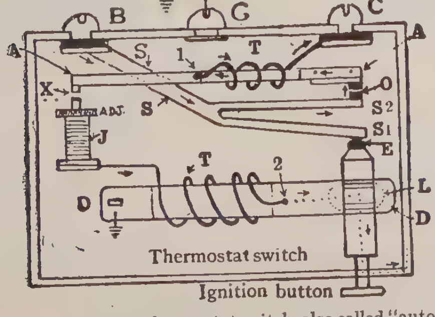

Fig. 8. Connecticut thermostat switch, also called "automatic switch."

If the engine stops with ignition switch "in," then the timer points are closed, and within for 30 or 40 seconds the continuous current passing through resistance wire (T) heats spring blade (A), causing it to bend down, thus making contact with (J) at (X). The current then flows through (J) to (T) on blade (D), through (2) to ground connection of switch box at (G).

Blade (D) then becomes heated and bends up, releasing a wedge-shaped lug (L) which is attached to under part of (D), from a groove in the ignition button shaft. The spring (S1) then easily forces the ignition button "out," thus opening the circuit at (O) and (X).

The primary ignition coil circuit can be traced by starting at (+) of battery (Fig. 6) to thermostat connection (B) through spring (S) to connection (C) (when ignition button is "in"), thence to the primary winding of coil (C), through the coil, out coil terminal (B) to stationary contact (B) on model 16 timer, through points (P) to movable contact (A) (which is grounded), to the grounded terminal of the coil primary winding at (A), through ground plate (GP) to ground (−) of battery (type **GA** coil).

The secondary ignition-coil circuit is from the secondary winding to center terminal (CT) of the distributor, to distributor arm (D) which passes the secondary current as it revolves, to spark plugs, thence through center terminals of spark plugs across spark-plug gaps to the shell of the spark plug to the engine frame, thence back to ground plate (GP) on the coil to the grounded terminal of the secondary winding.

The safety gap is shunted across the secondary circuit of the coil, as shown in Fig. 6, and explained above.

The condenser (Fig. 6) is shunted across the contact points of the timer, but is located in the coil.

The lighting and ignition switch (type K.V.B.) is combined with the Connecticut automatic thermostat ignition switch; a front and rear view is shown in Fig. 6. It has two buttons.

When the button at the left is pushed in, the ignition is "on." **When it is pulled out,** the ignition is "off."

When the button at the right is pushed all the way in, the headlights will burn "dim," as the dimmer resistance (RS) is in series with the circuit. **When pulled all the way out,** the headlights will burn "bright," as the resistance (**RS**) is then cut out of the circuit. When **placed in the center**, the lights are "out."

The fuse for the lights is under the hood on the right side, and a fuse for the horn is on the left side. If all lights fail to burn or the horn fails to operate, see if the fuse is blown. The fuses are 7 volt, 10 ampere enclosed No. 1 type, di. ¼″ x ⅝″ glass tube.

Timing ignition (Dort). Open priming cocks. Turn starting crank until 1 and 4DC (cylinders No. 1 and 4 are on dead center of compression stroke) appears on the flywheel and is in line with the center mark on the crank case; then turn flywheel 1″ past this dead-center line.

Retard the spark lever and loosen the set screw on the distributor shaft.

Push in the ignition-switch button. Disconnect the spark-plug wire on cylinder No. 1, and place it so that the terminal may be about 1/16″ from the metallic part of the spark plug.

Turn the distributor shaft very slowly, in a clockwise direction, till a spark is seen between the spark plug and the wire terminal, and stop.

Screw securely the set screw on the distributor shaft, put the handles of the priming cups in a vertical position, and the spark is correctly timed.

The firing order is 1, 3, 4, 2, and the wires to spark plugs should be attached to the distributor in this order. No. 1 cylinder is the one next to the fan. Spark plug is ⅞–18 thread, and the gap should be .022″ to .025″.

The generator shown in Fig. 6 (which is the electric diagram on the Dort) is the Westinghouse, using a third-brush regulation with a cut-out switch (reverse-current type) contained in the generator. Note that one terminal of the generator is grounded, likewise the (−) terminal of the battery. **When starting,** the ignition current is taken from the battery. **After starting,** and generator gains sufficient speed (8 or 9 miles per hour car speed), and then the generator supplies current for ignition and charges the battery. The generator produces 12 to 15 amperes at 18 miles per hour. At higher speeds the charging rate decreases slightly.

The starting motor (not shown) is located on the left side of the engine, at the rear. It is fitted with a Bendix drive which automatically engages and disengages the fly-wheel gear, as explained in the instruction on starting motors. One terminal of the starting motor is grounded, the other terminal connects with the starter switch, from the starter switch to battery (+), through the battery to ground.

Renewing Interrupter Points

To dissassemble interrupter (timer), model 16: first, unclamp the spring and remove the distributor cover (Fig. 9); second, remove the distributor arm (Fig. 10); third, unscrew the retaining screws (Fig. 11); fourth, lift the breaker-plate, unscrew nut and loosen the primary wire. Install new breaker plate (Fig. 12). After **installing a new breaker-plate, which is always necessary when renewing interrupter points,** reassemble and adjust.

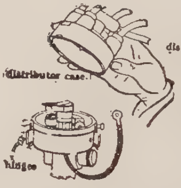

Fig. 9

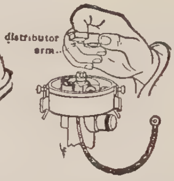

Fig. 10

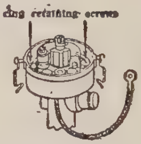

Fig. 11

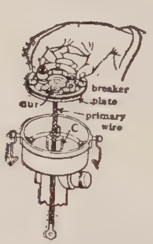

Fig. 12

Interrupter (Timer) Adjustment

The opening of contact-points should be .016″ for a six-cylinder engine, .020″ for a four-cylinder, and .012″ for an eight-cylinder engine. When adjusting, the roller should rest on the point of the cam. Set spark-plug gap .022″ to .025″.

Connecticut Ignition; Models 14 and 15; Closed-Circuit System

This ignition system was used on many of the Overland cars. The thermostat switch was controlled by **magnets** and enclosed in rear of a switch mounted on the dash. In many of the Overland cars this switch, called a "combination switch" box, was placed on the steering column.

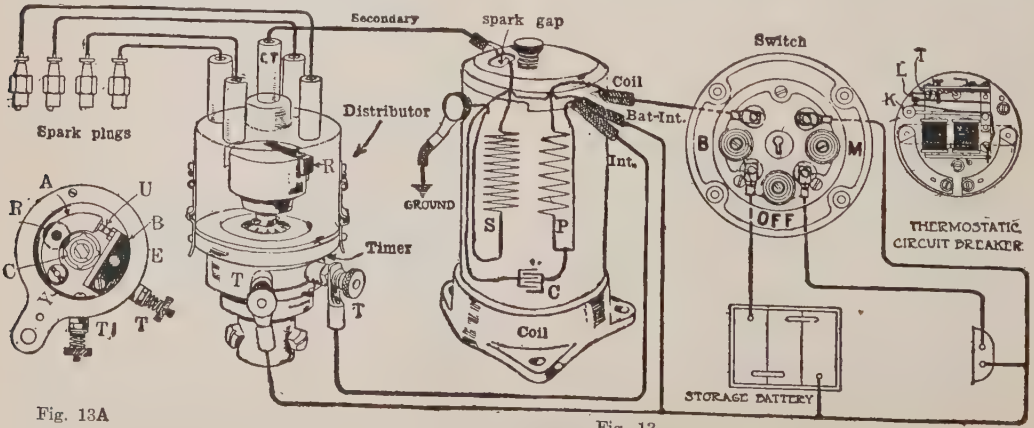

Fig. 13A

Fig. 13

Fig. 13. The Connecticut models "14" and "15," high-tension non-vibrating coil, closed-circuit ignition system, using a magnetic thermostat switch.

Fig. 13A. Top view of the closed-circuit interrupter or contact-breaker. Note that the interrupter is not grounded, as in Fig. 6, but insulated.

The timer or interrupter (Figs. 13 and 13A) is the model 14 and 15, where both contact points (U), one on arm (A), the other on arm (B), are insulated from each other and two wires connect with terminals (T) and T1) from coil, battery, and switch. (R) is a fiber roller and (C) a cam, which turns at one-half the engine speed and has as many lobes as there are cylinders. Both contact-points are normally closed until separated by cam (C). It is thus a closed-circuit type.

The distributor sets above the timer, and the rotor or distributor arm sets on top of the cam shaft and revolves at the same speed as the timer cam. The rotor in models 14 and 15 is of the "brush-type" contact (R), which makes a wiping contact.

The model 16 timer-distributor (Fig. 6) is very similar, except, instead of having two binding-posts to the timer, there is one binding-post and a wire, and the distributor rotor (or arm) is of the "gap-type."

The coil is a non-vibrating type. A safety-gap is provided to protect the coil from liability to a puncture of the winding insulation if the spark plug or secondary wires come loose.

The switch on this system is the model G. When (B) button is pressed, the storage battery supplies current for ignition. When (M) button is pressed, the magneto supplies current for ignition. When the lower button is pressed, it will release either of the above, whichever may be in.

The thermostat, as explained below and also shown at the right in Fig. 13, is contained in the back of the switch. This switch is now seldom used except where magneto ignition is employed. The switch below is the model 41Y ignition and lighting switch with thermostat. Where a generator is on the car, it is connected with a separate cut-out, between battery and switch.

The thermostat consists of blade (T) (see Figs. 13 and 14), which heats when current passes through it for from 30 seconds to 4 minutes without interruption, and causes it to bend to contact with (L).

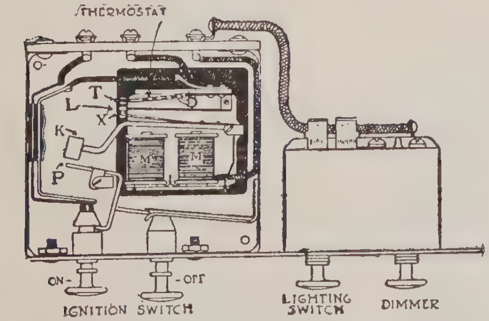

Fig. 14. Connecticut magnetic thermostat switch (early model, as used in Fig. 13). An automatic thermostat in the Connecticut system breaks the circuit in the event that the switch is left in the "on" position with the motor idle. The light switch and dimmer are housed at the right.

This completes an electrical circuit which energizes the magnets (M), causing releasing hammer (K) to operate like the clapper in an electric bell. This arm strikes against a plate (P) which releases whichever of the two ignition switch buttons in switch may be depressed or "on." The thermostat can be set to act from ½ to 4 min.

An adjusting screw (Fig. 13, right illustration) is provided directly over the thermostat spring (T) which regulates the time. If the thermostat was made to disconnect in less than 30 seconds it would probably "kick-off" when putting on ignition, before the engine could be started.

The condenser (C) (Fig. 13) is located in the coil, but by tracing the coil primary circuit it will be observed that it is shunted across the timer contact points.

Example of Timing Connecticut Ignition System

To time the breaker and distributor six-cylinder engine as example): When replacing, if for any cause it becomes necessary to remove the breaker and distributor, crank the engine by hand until the piston of No. 1 cylinder (first from front end of car) comes up on its compression stroke, and stop when the 1-6 mark on the flywheel is on top in a line with the flywheel indicator. At this point the piston is at the uppermost point of the compression stroke or "dead center." You can determine when the piston is coming up on the compression stroke by opening the relief cock on the cylinder and holding your finger over the opening.

Now advance the spark lever on the steering wheel one-quarter of the way. Remove the distributor cap, then set the combination breaker and distributor on the driving shaft with set screws loose; connect the advance lever, turn the hub on the shaft in the direction of rotation (counter-clockwise) until the contact points are just opening, which is the point at which the spark takes place; then tighten the hub set screws.

Now replace the distributor cap, carefully noticing which segment of the distributor brush is opposite, for this is the connection to the spark plug of No. 1 cylinder. Now connect up the balance of the spark plugs in their firing order—1, 5, 3, 6, 2, 4.

The Chevrolet timing: Place the piston on top of the compression stroke. Retard spark, loosen set screw and turn igniter unit until contact points are just opening, which is the point for spark. Tighten the set screw. The firing order is 1, 2, 4, 3. Therefore connect the plug terminals accordingly.

See also Index under "Lexington ignition timing," which is another example of the Connecticut system.

Testing Ignition Circuits and Parts

Testing coil: In order to determine if the coil is operating properly, secure a piece of wire and, holding one end to the frame of the car, engine casting, or other metallic "ground," bring the other end to within one-quarter inch from the point where the high-tension wire (running from the coil to the central terminal of the distributor) leads from the coil, and turn the engine over by hand with the switch on. If a spark occurs at this point and not at the distributor, the trouble is in the high-tension wire which leads from the coil to the distributor. If, however, no spark occurs at either point, see if the safety gap in the top of the coil is wet. In this case dry out the coil for several hours in a warm oven. The safety gap may be observed by removing the cover on the top of the coil.

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[1] To suit individual requirements it may be necessary to advance the ignition slightly when timing, if greater speed is required, or to retard it slightly for very slow running. This is done by loosening set screw and turning timer with rotation of shaft if it is found to be timed early—or against rotation if it is found to be timed late.

The thermostat (or ignition resistance unit in other systems) would cause missing if burned out.

The condenser, if shorted, will cause a weak spark. These subjects are treated farther on.

If this does not correct the trouble and the primary circuit is intact, it is evident that the coil should be replaced or returned for repairs.

It is a good plan regularly to examine the clamping rods holding the coil to the generator, tightening when needed to prevent vibration from loosening the terminals or breaking them.

Test of primary circuit: When testing the primary circuit, there are practically only two things to be taken into consideration, namely, the condition of the contact points in the breaker box and the wiring.

When tracing the primary circuit, first see if any of the fuses have "blown," then trace all the wiring of the ignition circuit.

Testing ignition switch: In order to test the switch and determine if current flows through it, attach a wire to the negative terminal on the storage battery and remove the wire from the terminal on the coil. Then push the ignition button on the left end of the switch in and make and break the circuit with the two wires by touching their free ends together. If a spark occurs, there is a circuit through the switch. If a spark is not obtained, there is doubtless an open circuit in the interior; therefore it should be returned for repairs.

(The address of the Connecticut Tel. and Electric Co. is Meriden, Conn.)

ATWATER KENT OPEN-CIRCUIT IGNITION SYSTEM

As an example of a **coil and battery ignition system, using an open-circuit timer system of ignition,** we will take the Atwater-Kent type K2 open-circuit system. (This concern also manufactures a closed-circuit system, as illustrated on page 205.)

The distributor and timer (called the Unisparker) is illustrated in Figs. 1 to 7. It consists of a timer with its contact breaker, or "maker," which would be more appropriate, mounted on the timer shaft, but independent of each other.

The timer is illustrated in Fig. 3.

The parts consist of: (1) the distributor and timer, which is called the Unisparker; (2) the coil, which consists of a simple primary and secondary winding, sealed in an insulated cylinder; the coil has no vibrators, contacts, or other moving parts; (3) the depolarizer switch; (4) the automatic spark advance.

The function of the Atwater-Kent ignition system is to produce a single hot spark for each power-impulse of the engine, accurately timed to occur at the right instant to produce the greatest possible power and efficiency.

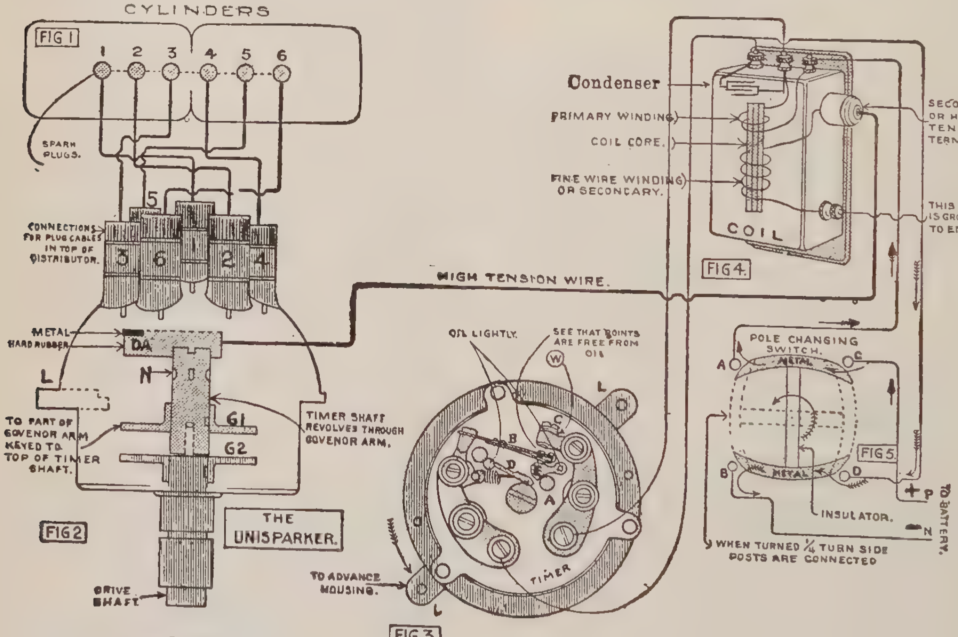

CYLINDERS
FIG 1
1
2
3
4
5
6
SPARK PLUGS.
5
CONNECTIONS FOR PLUG CABLES IN TOP OF DISTRIBUTOR.
3
6
1
2
4
METAL
HARD RUBBER
DA
L
N
TO PART OF GOVENOR ARM KEYED TO TOP OF TIMER SHAFT.
G1
G2
TIMER SHAFT REVOLVES THROUGH GOVENOR ARM.
FIG 2
THE UNISPARKER.
DRIVE SHAFT
HIGH TENSION WIRE.
Condenser
PRIMARY WINDING
COIL CORE.
FINE WIRE WINDING OR SECONDARY.
COIL
FIG 4
SECONDARY OR HIGH TENSION TERMINAL
THIS WIRE IS GROUNDED TO ENGINE.
OIL LIGHTLY.
SEE THAT POINTS ARE FREE FROM OIL
W
L
C
B
D
E
A
TO ADVANCE HOUSING.
L
TIMER
POLE CHANGING SWITCH.
METAL
A
C
B
D
METAL
FIG 5
INSULATOR.
+P
N
TO BATTERY.
WHEN TURNED ¼ TURN SIDE POSTS ARE CONNECTED

FIG 3.

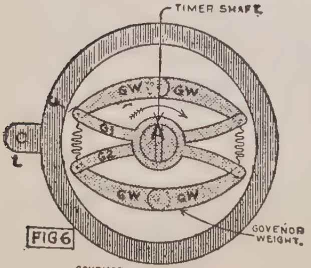


FIG 6

GOVENOR WHEN RUNNING SLOW.

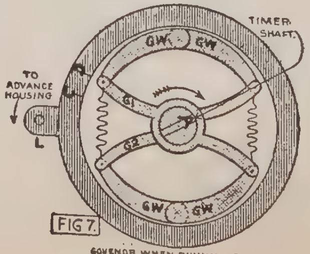


FIG 7.

GOVENOR WHEN RUNNING FAST.

The timer shaft is a half-inch shaft, driven usually from the cam shaft and at cam-shaft speed. It is also quite often mounted on the generator and driven from it, as shown on page 210. It should always be installed in the coolest location available.

The contact points in the timer (Fig. 3) do not touch except during the brief instant of the spark. The ignition circuit is therefore normally open and no current flows, even though the ignition switch be left "closed." This dispenses with the use of a resistance unit, or thermostat.

Where the hand-spark control lever is also used, it should be so proportioned as to give not more than one-quarter to one-half inch of movement for the entire range of the spark lever on the steering-wheel sector.

Range of spark advance: The high-tension distributor is carried on a central shaft, which connects below the governor, so that the distributor block is not moved by the automatic advance mechanism. This permits of a wide range of spark advance without affecting the synchronism. The maximum advance is about 45° of crank-shaft travel, at 2,400 r.p.m.

The source of electric supply for this system, also all other systems of this kind, is from the storage battery. The storage battery, as previously explained, is charged from an electric generator run from the engine.

The current consumption is very small, but the strength or pressure of current as required by the coil is necessary for a single-spark system. Therefore keep the battery fully charged at all times.

In case of an emergency, dry cells can be used connected six in series.

Adjusting A.K. Open-Circuit Timer

Adjustment of the gap between contact-points should be .010″, when the lifter (**D**) (Fig. 3), is in the notch. This adjustment can be made by placing more or less thin shim washers (see **W**), (Fig. 3) on the contact screw.

When taking up this distance between points, arising from natural wear, remove both screws and dress with a very fine file; then replace and shim up to .010″. The points are made of tungsten steel, which is very hard.

Remember that when the points are working properly, small particles of tungsten will be carried from one point to the other, forming a roughness of a dark gray color. This, however, does not in any way affect the working of the points, as the rough surfaces fit each other perfectly. The spark-plug gap should be .025″.

Do not think that the parts of the timer (Figs. 8 to 11) do not work properly because you cannot see their movement. The contact maker of the Unisparker may be likened to a watch, which, because of the small size and extreme accuracy and hardness of its moving parts, is subject to very little wear. Don't change the tension of spring or alter the parts.

Polarity Switch

The polarity switch, also termed a "pole-changing switch" and "depolarizing switch," is intended to prevent the points on (**B**) and (**C**) (Fig. 3) from becoming worn and pitted. "Direct" current is used, which has a tendency to burn and pit the points, whereas an alternating current is much easier on the points. Therefore the purpose and principle of this style of switch is to alternate the flow of current from (**N**) to (**S**) and (**S**) to (**N**), or from positive to negative and negative to positive.

As stated above, "direct" current is used with all battery systems; therefore a steady flow in one direction has a tendency to deposit the metal from one point to the other—but by changing this flow of current occasionally, the deposit will be put back to the other point again. This is similar to electroplating.

Note the action of the polarity switch (Fig. 5): (**C**) to (**A**) is now flowing positive, and (**D**) to (**B**) is flowing negative. By turning the switch one-quarter turn, the poles are changed; (**C**) to (**D**) will become positive and (**A**) to (**B**) will become negative. This change is made occasionally when running, and has a tendency to keep the contact points clean.

Automatic Governor

The governor (Figs. 6 and 7) is mounted directly under the timer. One arm of the governor (**G1**), is attached to the upper part of the timer shaft which is free to advance with the action of the governor. The other arm of the governor automatically advances the time of spark as the speed of the engine increases, by centrifugal action of the governor weights (**GW**), as shown. Note the position of the end of the timer shaft (**A**), at retard (Fig. 6), and advance (Fig. 7). Note that at "retard," the governor arm (**G1**) is at (**C**), whereas at full speed it has advanced to (**D**) (marks shown on left-hand side of housing).

Explanation of the Automatic Advance of Spark

Governor: The Delco, Remy, Atwater Kent, and many other systems employ a mechanical governor for advancing the spark when the engine is speeded. A governor of the centrifugal type is usually employed, but of slightly different construction on different systems. The purpose of the governor is to cause the timer notched shaft to turn in the direction of rotation, causing the contact to make and break earlier as the speed increases.

For instance, refer to Fig. 6, page 202. Assume that the engine is running slow and that the governor is in retarded position. Note the position of the notch (**A**) and the governor weights at the top of the timer shaft. If the engine is speeded up, the governor weights (**GW**) fly outward (Fig. 7), causing the timer shaft to turn a farther advance in the direction of rotation. It is clear that the contact would be made earlier at contact points. The top of the timer shaft is driven through the governor arm—(**G1**) (Fig. 2); thus as weights (**GW**, Fig. 7) are forced outward by centrifugal force, (**G1**) moves the timer shaft (Fig. 2) in the direction of rotation.

The automatic spark control is for the purpose of securing the proper control due to variations in speed alone, and all that is required for normal driving is to secure the proper spark control for slow driving from 10 to 15 miles per hour (set the spark lever about two-thirds advanced), and the automatic feature will give the proper spark position for all higher speeds and for all lower speeds, excepting when the throttle is wide open, at which time the spark lever should be slightly retarded.

The advantage of the automatic spark advance, as further explained is this: With the spark lever set at the running position on the steering wheel, the "automatic" feature gives the proper spark for all speeds excepting a wide-open throttle at low speeds, at which time the spark lever should be slightly retarded. When the ignition is too far advanced, it causes loss of power and a knocking sound within the engine. With too late a spark there is a loss of power (which is usually not noticed excepting by an experienced driver or one very familiar with the car), and heating of the engine and excessive consumption of fuel are the results.

Manual and Hand Advance of Spark

In addition to the governor advance—**the distributor housing can also be advanced by hand,** the two working independent of each other (see Fig. 3). (**L**) is connected with the spark lever on the steering wheel. This is termed "manual control."

The manual or hand control is for the purpose of securing the proper ignition control for carburetor adjusting, slow idling, retard for starting, and variable conditions which cannot be held constant. See explanation below.

The reason for using the manual (**hand**) **control of spark,** where a system is equipped with an automatic advance, is as follows: a heavy charge burns quicker than a light one. For this reason the engine will stand more advance with a half-open throttle than with a wide-open throttle. The hand control is therefore installed in order to secure the proper timing of the ignition due to these variations and to retard the spark for "starting," "idling," and "carburetor adjusting."

The automatic advance mechanism varies slightly in construction on different makes, but almost all are of the centrifugal type.

When starting the engine, where ignition is manual and with automatic advance, the spark lever should be retarded. After starting, move the hand spark lever to a position on the quadrant on top of the steering wheel, known as "driving position." It can then be advanced or retarded as occasion demands.

Operation of [the Atwater Kent Open-Circuit Timer

The operation of the timer: This consists of a pair of contact points, normally open, which are connected in series with a battery and the primary circuit of a simple non-vibrating induction coil.

A hardened steel latch, against which the trigger strikes on its recoil and which in turn operates the contact points, completes the device (see Figs. 8, 9, 10 and 11).

The distributor forms the upper part of the Unisparker; the high-tension current from the coil is conveyed by the rotating distributor block arm (**DA**) (Fig. 2), thence to the spark plugs in their proper order of firing.

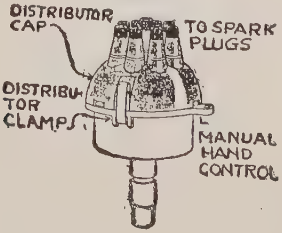


Fig. 7A. Illustrating the distributor and timer unit as shown in Fig. 2. Termed the "Unisparker."

The distributor, which distributes the current to the spark plugs (six, in this instance) in their respective firing order of 1, 4, 2, 6, 3, 5, is mounted on the upper end of the shaft. The distributor arm (**DA**), revolves with the timer shaft and passes the high-tension current to the terminals of the distributor. As six sparks are required per revolution, there are six notches on the timer cam, and the distributor points are spaced 60° apart. Fig. **7A** shows the parts of the distributor. A secondary cable of 5/16″ outside diameter is used for the secondary circuit.

Gap type distributor: The distributor arm (**DA,** Fig. 2) does not touch the contacts above it, but passes close to them (gap .010 in.) as it revolves, and the high-tension current jumps the slight gap. It is therefore termed a "gap-type" distributor.

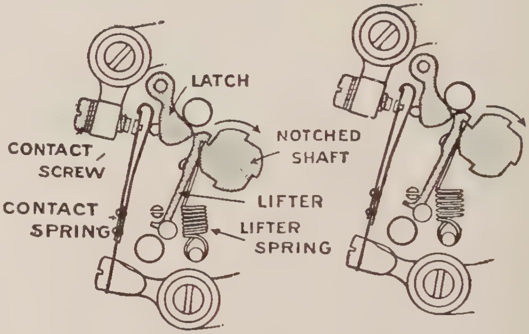


Fig. 8. Contact open. Fig. 9. Contact still open.

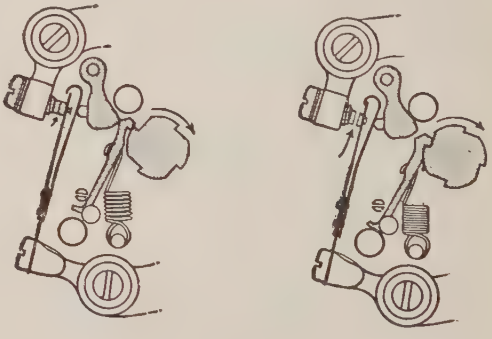


Fig. 10. Contact made. Fig. 11. Contact broken.

Figs. 8, 9, 10, and 11. Atwater Kent open-circuit timer operation.

Figs. 8, 9, 10, and 11 show the operation of the Atwater-Kent open-circuit timer clearly. It will be noted that in Fig. 8, the lifter is being pulled forward by the notched shaft. When pulled forward as far as the shaft will carry it (Fig. 9), the lifter is suddenly pulled back by the recoil of the lifter spring. In returning, it strikes against the latch, throwing this against the contact spring and closing the contact for a very brief instant—far too quickly for the eye to follow the movement (Fig. 10). Note that the circuit is closed only during the instant of the spark.

Fig. 11 shows the lifter ready to be pulled forward by the next notch. There are as many notches in the timer shaft as there are cylinders, and as many leads from the distributor to the spark plugs as there are cylinders.

The ignition coil (Fig. 4) is a box-type coil with a secondary and a primary winding. The primary current (6 volts), coming from the battery or generator, is carried through a pole-changing switch (Fig. 5) through timer contacts, where the current is opened and closed at the proper time by the contact arm (**D**) (Fig. 3) coming in contact with notches (**N**, Fig. 2), which raises latch (**E**), causing contacts (**B** and **C**), which are insulated from each other, to come in contact, thereby closing the primary circuit in the coil. This causes a secondary current to be set up in the secondary winding of high voltage. This secondary current is then distributed to the spark plugs by the distributor. (Cylindrical type coil is now used.)

The condenser in this system, using the box-type coil, is mounted in the coil, as shown in Fig. 4. The condenser is connected or shunted across the timer contact points.

Where a cylindrical type of coil is used, the condenser is mounted on the timer (Fig. 12A), and connects across the timer contact points.

A box-type coil is the type as shown in Fig. 4, page 202.

A cylindrical type coil is the type shown in Fig. 14, this page.

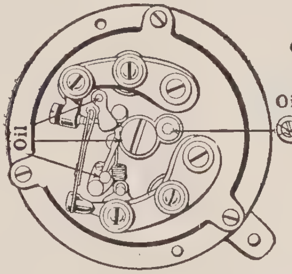


Fig. 12. Atwater Kent open-circuit timer, as shown in Fig. 3. The condenser is in the coil box (Fig. 4).

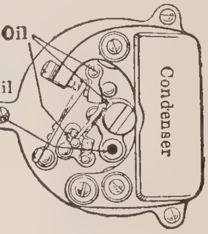


Fig. 12A. "A.K." open-circuit timer with condenser mounted on the timer. In this instance a cylindrical type of coil is used.

THE ATWATER-KENT CLOSED-CIRCUIT IGNITION SYSTEM

The closed-circuit system is similar in many respects to the open-circuit system, except that the timer, or interrupter, is constructed differently. The points are normally closed instead of open. This system is termed the type "CC." When it is equipped with a governor or automatic advance it is termed the type "CA."

When using a closed-circuit timer, it is necessary to use resistance in connection with the primary winding of the coil, else the coil might be damaged if the switch was left on when the engine is not running, as the timer points are normally closed. The resistance unit also protects the coil during variations of speed of the generator, which slightly increases in voltage at high speeds, when the generator supplies current for ignition. At low speeds the battery (6 volts) supplies current for ignition.

At medium and high speeds the generator supplies current for ignition (about 8 or 9 volts).

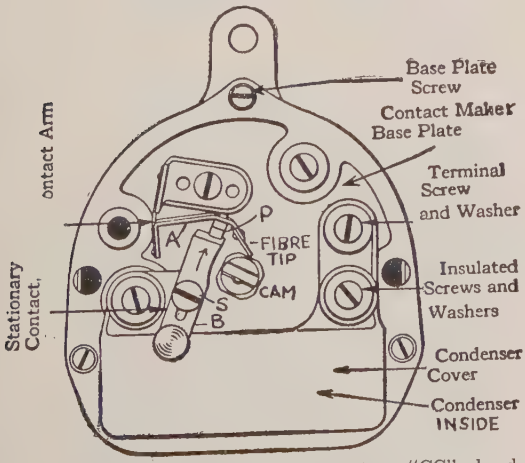


Fig. 13. Top view of Atwater Kent type "CC" closed-circuit timer (also called interrupter and contact-breaker).

The closed-circuit timer (we will term it an "interrupter," because it interrupts the flow of current in the primary winding instead of first closing and then opening) is shown in Fig. 13. Contacts are normally closed by a spring on the contact arm. Rotation of cam brings it in contact with a fibre tip on contact arm (**A**), thus separating contact-points (**P**) and breaking the circuit, at which instant the coil delivers the strongest current).

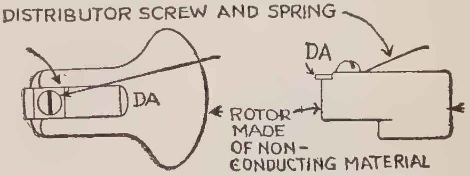

DISTRIBUTOR SCREW AND SPRING
DA
DA
ROTOR MADE OF NON-CONDUCTING MATERIAL

Fig. 13A. Top and side view of the distributor rotor which is placed on the top of the cam (Fig. 13), and serves to distribute the secondary current to the spark plugs in a manner similar to (**DA**) (Fig. 2).

Adjustment of the interrupter points on a closed-circuit system can be made by loosening screw (**S**) (Fig. 13) and moving arm (**B**).

The gap between contact points should be .006″; the spark-plug gap, .025″.

The wiring of the AK closed-circuit system is shown in illustration below (Fig. 14).

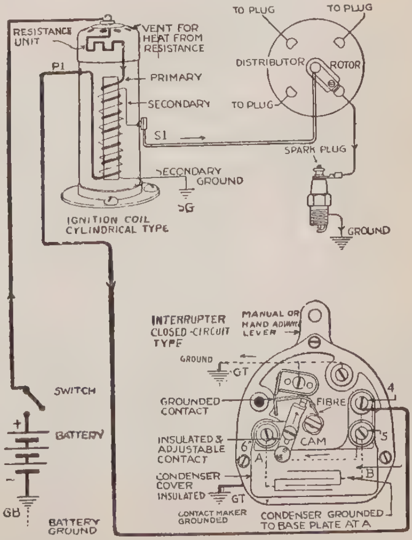

TO PLUG
TO PLUG
RESISTANCE UNIT
VENT FOR HEAT FROM RESISTANCE
P1
PRIMARY
SECONDARY
DISTRIBUTOR
ROTOR
TO PLUG
S1
SPARK PLUG
SECONDARY GROUND
SG
IGNITION COIL CYLINDRICAL TYPE
GROUND
INTERRUPTER CLOSED-CIRCUIT TYPE
MANUAL OR HAND ADVANCE LEVER
GROUND
GT
SWITCH
GROUNDED CONTACT
FIBRE
4
BATTERY
INSULATED & ADJUSTABLE CONTACT
6
CAM
5
A
B
CONDENSER COVER INSULATED
GT
GB
BATTERY GROUND
CONTACT MAKER GROUNDED
CONDENSER GROUNDED TO BASE PLATE AT A

Fig. 14. Wiring of the Atwater Kent closed-circuit ignition system. Note that a cylindrical type of coil is used.

Circuit of the AK closed-circuit interrupter and distributor (Fig. 14): Note one wire from the timer and one wire from the battery is grounded; therefore it is a "single-wire" system. The open or closed-circuit system could also use either a "single" or "two-wire" system.

To trace the primary circuit, start at the switch, follow the black line to the insulated terminal (4), then to the insulated contact point through grounded contact point to grounded terminal, to ground (GT), to ground on battery (GB). (Note that the condenser connects across the contact points.)

To trace the secondary circuit, start at (S1) thence to distributor rotor, through spark plug to ground (SG).

The Atwater Kent Condenser

The condenser on the type "CC" closed-circuit system, instead of being in the coil, is located on the interrupter (Figs. 13 and 14). Note the circuit in Fig. 14. The condenser short-circuits across the timer contact-points for reasons stated on page 190.

To understand how the condenser is connected, see Figs. 14, 15, and 16. A metal cover (Fig. 15) is placed over the condenser to protect it, and to this is attached the insulated contact-point of the interrupter.

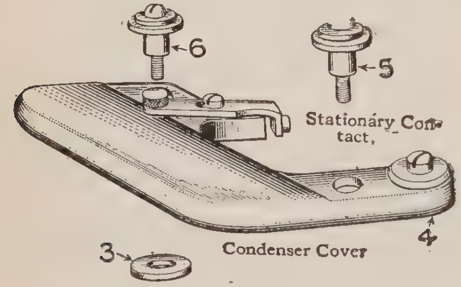


Fig. 15

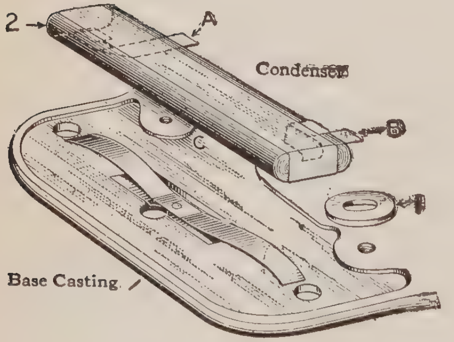


Fig. 16

Figs. 15, 16. Sequence of operations in installing condenser: (1) insulated washer placed in position; (2) condenser placed in pocket; (3) insulated washer laid on top of condenser terminal; (4) condenser cover placed in position; (5 and 6) insulated screws put in; (7) Note that contact adjustment is O.K.

This condenser cover is insulated from the base of the interrupter by screws 5 and 6 which have insulated washers on them.

Note the terminals (A) and (B) of the condenser (Fig. 16). Terminal (A) is grounded to base (C) of the timer below it, then an insulated washer (3) is placed over (A). The other terminal (B) has an insulated washer (1) under it to insulate terminal (B) from the base. Cover (4) is then placed over the condenser and terminal (B) makes contact with the cover. We then have one terminal (A) of the condenser grounded to base (C) and the other terminal (B) connected with cover (4) which is insulated from the base. The circuit would then be as shown in Fig. 14.

It is seldom necessary to remove the condenser, but if ignition fails in case the timer should become water-soaked, feel the coil, with switch on. It should show some heat from current passing through resistance unit in the coil. You will then know that current is passing through the coil all right; therefore open the switch. Then remove the distributor cover and condenser cover and clean all contacts and screws and replace the condenser cover; also wipe water from the other parts and wires. The ignition may also fail by these screws coming loose; however, this seldom happens, but if ignition fails, and you know that current is passing through the coil, and if no spark can be obtained, then this might be investigated.

Oil: Use light machine oil at points shown by the lines on the open-circuit timer (Figs. 12 and 12A). Oil lightly about every 1,000 miles. See that the contact-breaker points are free from oil.

Testing

If the engine misses without regard to speed, test each cylinder separately by short-circuiting the plug with a screw driver, allowing a spark to jump. If all cylinders produce a good, regular spark, the trouble is not with the ignition.

If any one cylinder sparks regularly, this will indicate that the system is in working order, so far as the Unisparker and coil are concerned, and the trouble is probably in the high-tension wiring between the distributor and plugs, or in the plugs themselves. Examine carefully the plugs and wiring. Leaky secondary wiring is frequently the cause of missing and back-firing.

Frequently, when high-tension wires are run from the distributor to the spark plugs through metal or fiber tubing, trouble is experienced with missing and back-firing, which is due to **induction between the various wires in the tube.** This trouble is especially likely to happen if the main secondary wire from the coil to the center of the distributor runs through this tube with the spark-plug wires.

Wherever possible, the **distributor wires should be separated by at least half an inch of space,** and should be supported by brackets or insulators rather than run through a tube. In no case should the main distributor wire be run through a conduit with the other wires.

If irregular sparking is noted at all plugs, examine first the battery and connections therefrom. If the trouble commences suddenly, it is probably due to a loose connection in the wiring. If gradually, the batteries may be weakening or the contact points may require attention. See that contacts are clean and bright, and also that the moving parts are not gummed with oil or rusted.

Timing Atwater Kent Ignition System—Open and Closed-Circuit Type

Open-circuit type when hand-spark control is not used (automatic advance): First, place the piston of No. 1 cylinder on top of the compression stroke. Second, slowly turn the Unisparker backwards until a click is heard, which is the exact instant of the spark. Third, tighten the set screw on the timer shaft which was loosened when starting to time. Be careful not to change position. Fourth, remove the distributor cover and note the position of the distributor block or rotor. It should be on the terminal for No. 1 cylinder. Then see if the wires from the distributor are connected properly, in accordance with the firing order of the cylinders, keeping in mind the direction in which the rotor turns.

The spark set thus, is on top-dead-center retarded, and the governor action will take care of the advance as the speed increases.

The closed-circuit type when the hand-spark control is not used (automatic advance): The timing is the same as above, except that the timer should be turned backwards until the contact-points commence to open. As they open the spark occurs. A good way to test is to have spark plugs on top of the cylinders and current on, so that the spark can be seen at points of plugs. If the timer with automatic advance is used in connection with the regular spark lever on the steering wheel, then do not give over five-eighths or three-quarters of an inch movement of the timer from full retard to full advance.

Open-circuit type with hand-spark control: The setting is the same, except that the position of the spark-advance lever on the steering wheel should be within half an inch of full retard and the lug on the timer should have three-eighths to one-half an inch movement from full retard to full advance. After retarding the spark lever to within one-half an inch full retard, then with the driving member loose, and piston on top of the compression stroke, turn backwards until a click is heard, at which point set the timer. Then see "Fourth" procedure above.

Closed-circuit type with hand-spark control: Same as above, except that the timer is turned backwards until contact points commence to open, at which point set the timer by set screw or clamp, or if driven by a shaft on which the timer cannot be loosened, then the setting can be made with the advance lever shaft or drive gears loosened. The lug on the timer should have seven-eighths to one inch movement from full retard to full advance. (The address of the Atwater-Kent Mfg. Co. is Philadelphia, Pa.)

THE WESTINGHOUSE VERTICAL IGNITION SYSTEM

The Westinghouse battery and coil vertical type ignition system (Fig. 17) is of the closed-circuit type.

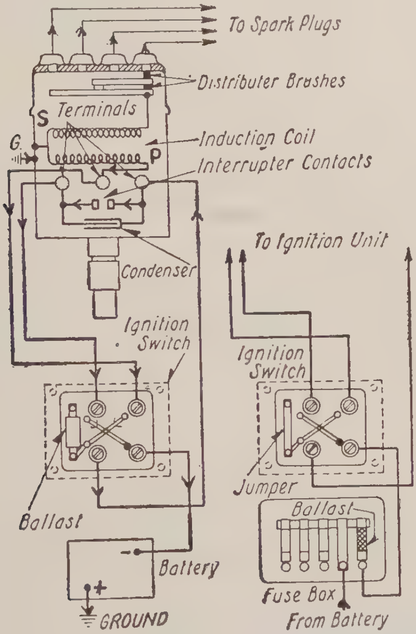


Fig. 17. Westinghouse high-tension non-vibrating coil, closed-circuit ignition system.

The timer-distributor unit is vertically mounted and is operated from the cam shaft or can be attached to the generator, as all other systems of this type can be. Only hand-operated advance is provided.

The condenser is mounted close to the breaker mechanism, being below the coil and distributor. Note the condenser, coil, and contact-breaker are all in one unit.

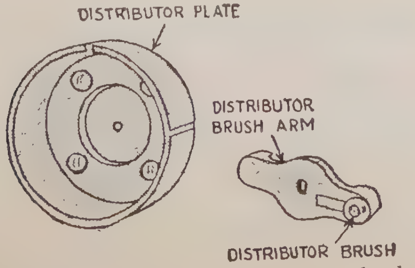


Fig. 17A. Distributor plate and distributor brush.

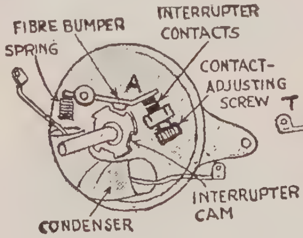
A metal ring can be slipped upward so as to permit of inspection or adjustment of the several contacts.

The distributor (Fig. 17A) is the same as that used in the regular Westinghouse systems in which a circular carbon brush on the distributor brush arm makes contact with terminals embedded in the cover of the distributor plate.

The standard ignition switch is of the snap type and combines the lighting switches in one plate which is mounted flush on the dash. Each time the ignition switch is turned, the polarity of the current is reversed. On this account, it would be termed a polarity or "pole-changing" switch.

In the back of the switch plate there is what is termed a **"ballast coil."** This is a small resistance in series with the final winding, and is intended to protect the winding and prevent excessive drain on the battery, in case the engine should at any time remain idle with the switch in the "on" position. If this "ballast coil" should at any time be accidentally broken the ballast terminals may be temporarily short-circuited with a piece of wire or with a standard 5-amp. fuse, as will be understood by an examination of Fig. 17.

Westinghouse adjustment: In adjusting the breaker the contacts should be dressed with a fine file and should be so adjusted that the maximum opening of the interrupter contact points is .012″, as shown in Fig. 18. The **spark-plug gaps** should be .025″.



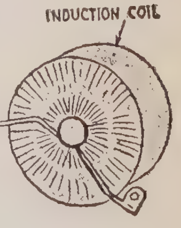


Fig. 18. Contact-breaker or interrupter with condenser.

Fig. 18A (right). The double-wound, high-tension ignition coil winding shown as (S) in Fig. 17.

This **cam** (Fig. 18) has four high points; therefore it is intended for a four-cylinder engine. These high points will raise the contact-breaker arm, or interrupter arm, four times during one revolution of the cam.

We can thus tell that this is a **closed-circuit ignition system** by observing the interrupter points or contacts and the cam—because, normally, the contact points are closed and are opened by the cam, whereas with an open-circuit ignition system, as explained on page 204, the contact points are first closed, then opened.

The Westinghouse Co. makes several different constructions of ignition systems. This is only one example. Manufacturers are Westinghouse Electric Co., Pittsburgh, Pa.

THE BOSCH IGNITION SYSTEM

One type of the Bosch battery and coil ignition system is shown in the illustrations below. The **distributor** and **contact-breaker** are shown in Figs. 19 and 20.

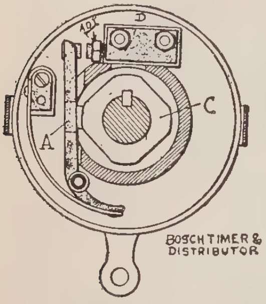


Fig. 19

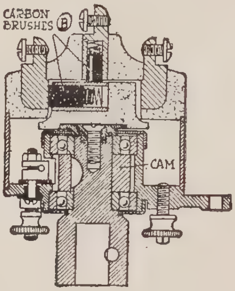


Fig. 20

The contact-breaker (also called "timer" and "interrupter"), is shown in a cross-sectional view in Fig. 20. The distributor is mounted above the interrupter mechanism. In Fig. 19, a top view of the interrupter is shown.

The contact-breaker arm (**A**) (Fig. 19), is actuated by the high points on cam (**C**) pressing against a fiber block on arm (**A**), thus separating the contact points which are normally closed by the tension of the spring. It is thus a closed-circuit type of interrupter.

The distributor is fully as simple and is mounted directly over the breaker, as shown in Fig. 20. Only hand-operated advance of spark is provided.

The switch (Fig. 21), incorporates a vibrator attachment to facilitate starting when the engine is cold or the carburetor is out of adjustment. This mechanism is controlled by the pointed button in the center of the switch plug. Under normal starting conditions, momentary pressure on the button will produce a single spark at the plug. Turning the plug to the right and depressing it makes the necessary connection to provide a continuous stream of sparks at the plug. If desired the button can be locked in this position until the engine has started.

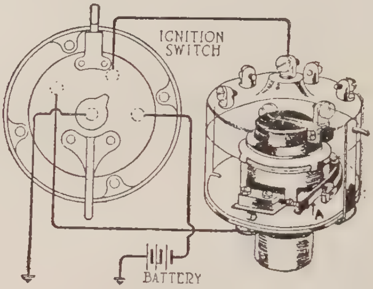


Fig. 21

The switch provides for the use of a magneto, the engine running on the magneto with the switch in one position and on the battery with the switch in the other position.

Adjustment for the gap at the contacts: With the fiber block (Fig. 19) resting on top of the cam, the contacts should be separated about .016″. To alter the adjustment the lock nut must be released first, and carefully secured after the adjustment is made. Occasionally expansion of the fiber bushing prevents the free movement of the lever, and in this case the bore of the bushing can be slightly enlarged with a reamer.

The spark-plug gap should be .020″ to .025″.

The manufacturers are: American Bosch Magneto Corpn., Springfield, Mass.

REMY DISTRIBUTOR, INTERRUPTER, AND IGNITION COILS

The waterproof type of Remy distributor and interrupter, as used on many different cars is shown in Fig. 22. The Remy automatic advance distributor is shown on pages 211 and 212. The systems are of the closed-circuit type.

Parts are as follows: (**A**) Distributor for the center terminal connecting with the secondary terminal of coil; (**B**) one of the spark-plug terminals of the distributor; note that the lower part (**Z**) is not in contact with (**Y**), but 1/64″ from it; (**C**) rotor or segment insulated; (**D**) lock nuts holding interrupter cam in place; (**E**) reference pin; (**F**) interrupter on the contact-breaker cam; (**G**) fiber block on the breaker lever arm; (**H**) spring with a carbon button on the rotor which connects the secondary circuit coming in at (**A**) with the rotor metal plate (**Y**); thus as the rotor (**C**) revolves, the secondary current jumps an air-gap clearance of 1/64″ to the spark-plug terminal (**Z**) and other spark-plug terminals as it revolves; (**K**) end of the shaft above the cam which the distributor rotor fits over; (**L**) pin in cam (**F**) which fits into the under part of the rotor to drive it; (**S**) shaft driven from the engine which drives the interrupter cam (**F**) and rotor (**C**). Note that cam (**F**) is fitted on top of this shaft (**S**) which is tapered; thus lock nuts (**D**) force it down; (**Y**) adjustable metal plate on rotor or segment (**C**).

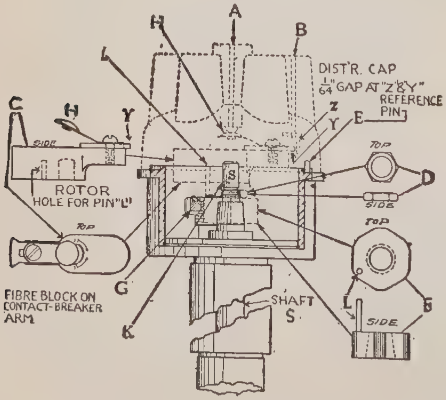


Fig. 22. Remy distributor and interrupter (contact-breaker).

To Check Distributor Settings and How to Time When Putting in New Parts

For distributors with counter-clockwise rotation: In observing Fig. 22A, from the top, the cam appears to be revolving in a clockwise rotation; however, by referring to the standard practice of determining rotation (looking from the drive end), it is seen really to be rotating counter-clockwise.

The spark-control lever (**I**) (Fig. 22A) connects with the lever on the steering wheel and should be in a fully retarded position after having located the

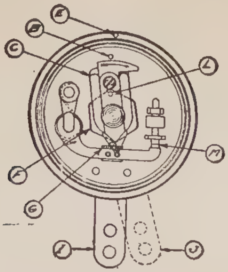


Fig. 22A

Note. "Clockwise rotation" is from right to left, in the same direction as the clock hands rotate. "Counter-clockwise" (or "anti-clockwise") is in an opposite direction to clockwise. When considering the rotation of ignition devices or generators the drive end is the point from which to consider rotation.

cylinder attached to the terminal (B) (Fig. 22) on top of the dead-center compression stroke with the distributor coupling connected up.

(E) is the reference pin (Figs. 22 and 22A) over which the reference slot of the distributor cap is set; (B) is the exact location of the pin in the distributor cap when the distributor cap is installed; therefore, always time by bringing the piston in the cylinder on top of dead-center of the compression stroke, which is attached by high-tension lead to the terminal (B), or to the terminal opposite reference pin (E).

Remove the segment or rotor and cam lock nut (D) (Fig. 22), and lift the cam. Replace the distributor segment (C) in its original position over shaft (K) and cam pin (L) with the cam loose. Then turn cam (F) around (with distributor shaft stationary) in the direction of rotation until the distributor segment (C) is opposite the reference pin (E) with one point of the cam (F) against the fiber block (G), and the breaker points are just ready to separate.

Again remove the segment (C) without disturbing the setting of the cam, install the cam lock-nut (D), tightening it up securely, then install the rotor or segment (C) and the distributor cap, being sure that all high-tension leads are connected to it, in accordance with the direction of rotation and of firing-order.

For counter-clockwise distributors use the instructions just given, transposing the control position so that the segment and cam rotate in the opposite direction.

When installing new high-tension wiring always connect cylinder No. 1 to high-tension terminal (B), connecting the rest of the cylinders in accordance with the direction of rotation, and as per the segments and firing order (unless the distributor cap is marked otherwise).

Spark-plug gaps should be .025″ to .030″.

If the engine misses when idling or at light loads, the gaps at the plugs should be wider. If the engine misses at high speed or when pulling hard, the gaps should be narrower.

The oiler on the shaft should be kept filled with medium cup grease and screwed down two or three turns occasionally. On some instruments a wick oiler is used. In this case use pure vaseline instead of grease.

For adjusting Remy interrupter, see page 211.

Manufacturers are Remy Electric Co., Anderson, Ind.

Remy Ignition Coils

Coils are usually classified as **"two-terminal"** and **"three-terminal"** coils. The designation "two-terminal" or "three-terminal" applies to the top of a cylindrical coil, and not to all of the terminals on a coil.

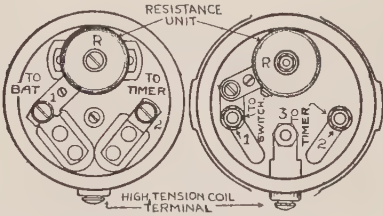


Fig. 23 Fig. 24

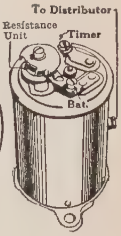


Fig. 25

Fig. 23. Remy two-terminal coil.

Fig. 24. Remy three-terminal coil.

Fig. 25. Side view of Remy ignition coil (cylindrical type).

A two-terminal ignition coil, top view, is shown in Fig. 23, a wiring diagram in Fig. 26, and a top and side view in Fig. 25. This coil is known as model 284B, F, G, and A, and has a condenser in the coil.

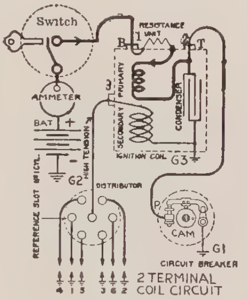


Fig. 26

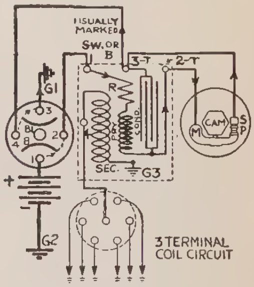


Fig. 27

Fig. 26. Circuit of Remy two-terminal coil (grounded contact-breaker).

Fig. 27. Circuit of Remy three-terminal coil (insulated contact-breaker).

The primary circuit (Fig. 26) would be from (+) of battery, through the ammeter, through the ignition switch, to terminal 1, through the resistance unit, through the primary winding, out terminal 2, to the stationary insulated contact point on the interrupter, through the points, through the movable arm, to ground (G1), to ground of battery (G2), thus completing the primary circuit. (This is termed a "grounded" system.)

The condenser is connected across the contact points, one end being grounded at (G3).

The secondary circuit is from the secondary winding which is wrapped around the same core as the primary, to the center terminal of distributor, to the rotor arm of the distributor, to the spark plugs, through the frame of the engine to ground (G3) of the coil.

Marks on coils vary. Note that terminal 1 is marked "B," meaning to battery, or sometimes "SW," meaning to switch. Terminal 2 is marked "T" or "INT," meaning to timer or interrupter. Where a coil has a mark on the terminal as "MAG," it usually means that it is intended to be used in connection with a magneto.

When testing a coil, by connecting with (B) and (T), the primary circuit can be tested, including the resistance unit.

The resistance unit can be cut out of the test by placing the test point on the screw or terminal (**R**) (Fig. 23).

When testing the condenser, terminal (**T**) and ground (**G3**) would be the circuit across the condenser.

A three-terminal ignition coil is shown in Figs. 24, 27. Many of the three-terminal coils were used with "pole-changing" switches, and "insulated" ignition systems (meaning that the primary circuit is fully insulated, or with two wires to the contact breaker).

The primary circuit (Fig. 27) would be from (+) of battery to 1 on switch, through "pole-changing switch" blade (**B**) which, if turned in one direction, would connect with 1 and 2 of the switch, thence to terminal 1 of the coil, through resistance unit (**R**), through the primary winding, to terminal 2, to movable interrupter-contact arm (**M**), through points (**PS**), back to terminal 3 on coil, thence to 4 on the pole-changing switch, through blade (**B1**) (now disconnected), connecting 4 and 3 together, out 3 to ground (**G1**), to ground terminal (**G2**) of battery (−), thus completing the primary circuit. This is termed an "insulated" system.

If the pole-changing switch was turned in the opposite direction, so that blade (**B**) would connect with 1 and 4, and blade (**B1**) with 3 and 2, the primary circuit would then first go to the stationary contact point (**S**) on the interrupter instead of to the movable arm (**M**). For instance, the primary circuit would then be from (+) of battery to 1 on the switch, through blade (**B**) to 4, to terminal 3 of the coil, to the stationary contact point (**S**), through the points, out movable arm (**M**), to 2 on the coil, through the primary winding, through resistance (**R**), to coil terminal 1, to switch terminal 2, through blade (**B1**) to 3, to ground (**G1**), to ground (**G2**) of battery.

Thus the flow of the primary direct current through contact points could be reversed so that it would flow first in one direction and then in another by moving the switch first one way and then the other. This is termed a "pole-changing switch" or "depolarizing switch," and a three-terminal coil is often used with it. See also Index under "Wiring diagram, Oakland 32," which clearly shows a pole-changing switch.

The purpose of a pole-changing or depolarizing switch is explained on page 203.

The pole-changing switch is not used very much at the present time, because tungsten metal is now used for points. It is very hard and does not have the electrolytic[1] effect to such an extent as the silver points which were formerly used. Note that the condenser is connected across the points with either direction of the flow of the current.

DRIVING THE INTERRUPTER AND DISTRIBUTOR

One modern method of driving the timer (interrupter, also called "contact breaker") and distributor, is from the generator shaft, as shown in Fig. 8.

The generator shaft is driven by gears or by a silent chain, encased. The timer shaft is driven from the generator shaft by a spiral gear, and is geared so that it will run the distributor and timer usually at one-half the speed of the crank shaft.

Quite often the timer and distributor shaft are operated from the cam shaft. In fact, there are various methods employed, but in most every instance it runs at cam-shaft speed (one-half the speed of the crank shaft).

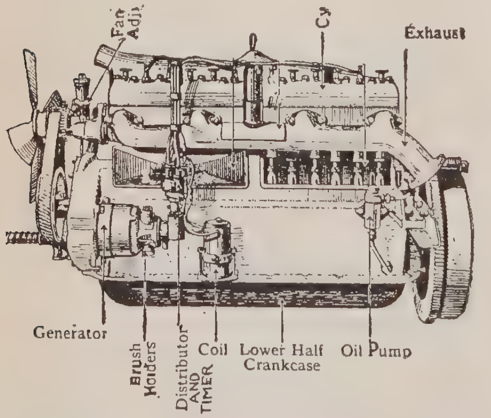


Fig. 8. Modern method of driving the timer and distributor through the generator shaft.

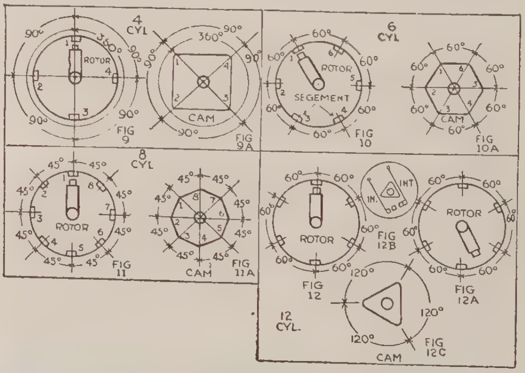
On the Packard double distributor, explained farther on, the cam operating the double set of interrupter contact breakers is driven at crank-shaft speed, but a three-lobe cam is used.

Relation of Speed of Distributor-Rotor, and Interrupter Cam to Crank Shaft of Engine

The crank shaft of the engine must make two revolutions (720°), to complete its four-cycle revolution.

The distributor rotor always revolves at cam-shaft speed, or half the crank-shaft speed.

The interrupter cam in all instances except one, as on the Packard twelve, revolves at cam-shaft speed, or half crank-shaft speed.



Four cylinder engine: When the engine crank shaft makes 2 revolutions—

The interrupter cam (4-lobe) makes 1 revolution and makes 4 interruptions of the primary low-tension current, 90° apart, or 180° of fly-wheel movement. (See Fig. 9.)

The distributor rotor makes 1 revolution and makes 4 high-tension contacts, 90° apart, or 4 sparks.

---

[1] Electrolytic (electrolysis) refers to the depositing of metal from one point to another, as in electro-plating.

Six-cylinder engine: When the engine crank shaft makes 2 revolutions—

The interrupter cam (6-lobe) makes 1 revolution and makes 6 low-tension interruptions, 60° apart, or 120° of fly-wheel movement. (See Fig. 10.)

The distributor rotor makes 1 revolution and makes 6 high-tension contacts, 60° apart, or 6 sparks.

Eight-cylinder engine of the "V" type: When the engine crank shaft makes 2 revolutions—

The interrupter cam (8-lobe) makes 1 revolution and makes 8 low-tension interruptions, 45° apart, or 90° of fly-wheel movement. (See Fig. 11.)

The distributor rotor makes 1 revolution and makes 8 high-tension contacts, 45° apart, or 6 sparks.

Twelve-cylinder engine of "V" type: When the engine crank shaft makes 2 revolutions, or 720°—

The interrupter cam (3-lobe) makes 2 revolutions (720°), or revolves at crank-shaft speed instead of cam-shaft speed; therefore it makes 6 interruptions of the low-tension primary circuit 60° apart. There being two contact-breaker arms instead of one, connected with two separate primary coils, then each breaker arm would make 6 interruptions, or 12 interruptions 30° apart, or 60° of fly-wheel rotation, during 2 revolutions of the 3-lobe cam. (See Fig. 12.)

Distributor rotor: Note that there are two distributors driven at half the speed of the crank shaft; therefore each rotor would make one revolution, or 360°, while the crank shaft made two revolutions. Distributor segments are 60° apart, therefore each distributor rotor would make six high-tension contacts during one revolution, or twelve sparks during one revolution with both distributors, during which time the crank shaft makes two revolutions.

With these explanations we have dealt with single distributors and single contact breakers, with the exception of the twelve-cylinder engine, as explained above.

Attention is called to the Delco double distributors and double interrupters, as explained under "Delco ignition coils, distributors and interrupters."

REMY IGNITION ON STUDEBAKER "LIGHT SIX"

As an example of a modern method of driving the generator and ignition system, the Studebaker "Light Six," model "EJ" engine is used.

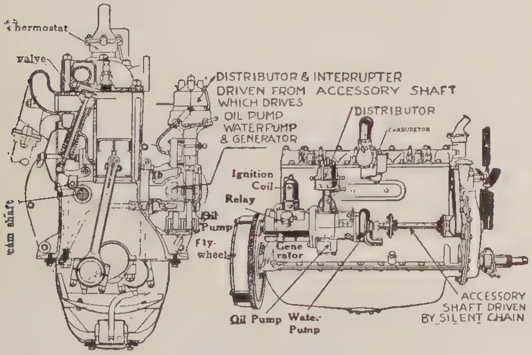

Thermostat
valve
cam shaft
DISTRIBUTOR & INTERRUPTER DRIVEN FROM ACCESSORY SHAFT WHICH DRIVES OIL PUMP WATERPUMP & GENERATOR
DISTRIBUTOR
CARBURETOR
Ignition Coil
Relay
Oil Pump
Fly-wheel
Generator
Oil Pump
Water Pump
ACCESSORY SHAFT DRIVEN BY SILENT CHAIN

Fig. 1. Cross-section. Fig. 1A. Right side view.

Figs. 1 and 1A. Studebaker Light-six method of driving ignition system.

The Remy distributor and closed-circuit interrupter are connected with a vertical shaft which is driven from a shaft called the "accessory shaft." The accessory shaft is driven by a silent chain (see page 51), which also drives a water-circulating pump and generator.

The speed of the distributor shaft is 1 revolution to 2 of the crank shaft of the engine, or at cam-shaft speed.

There are six high points or lobes on the interrupter cam, and six terminals on the distributor (Figs. 2 and 3); therefore, there are six sparks, one for each cylinder during two revolutions of the crank shaft.

The distributor and interrupter (Figs. 2 and 3) are advanced by a manual control connecting from the spark-control lever to the spark lever on the steering wheel. An automatic advance is also provided.

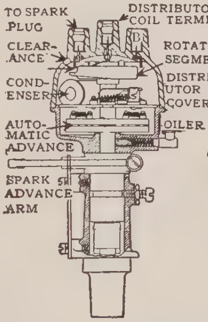


Fig. 2. Section of Remy distributor.

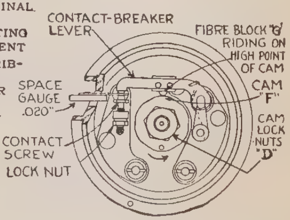


Fig. 3

The interrupter is of the closed-circuit type. See page 208 for construction of the Remy distributor and interrupter.

Adjustment of Remy Interrupter Points

To check the opening of the breaker points on the interrupter, remove the distributor cover, then turn the crank shaft over by hand-crank until the contact-breaker lever (Fig. 3) rides on one of the high points of the cam, then slip a thickness gauge through the space between the points. If the opening is greater than .025″, loosen the cam lock nuts and turn the contact screw until adjustment is not less than .020″ nor more than .025″. Be sure to tighten the lock nut.

Contact points should always be flat, and make good contact with each other. When they have a frosty appearance all over their surface, it indicates good contact. If they are not making good contact, the surfaces can be smoothed up with a fine file or with No. 00 sandpaper and can then be readjusted.

See also pages 221 and 224 under the subject of "contact-point surface and removal" and "dressing and testing platinum points."

By referring to the Index under "Wiring diagrams," the wiring diagram of the Studebaker Light-Six car will be found. This diagram clearly shows the ignition circuit.

REMY SEMI-AUTOMATIC IGNITION SYSTEM

This is a recent development of Remy ignition, and is similar in many respects to the Remy system used on the Studebaker "Light-Six."

In the design of the Remy semi-automatic distributor there is nothing radically different from the manual type that has served so well on the many Remy-equipped cars and trucks.

The condenser mounted on the breaker plate, a slight change in the **breaker lever,** and the addition of an automatic control mechanism as illustrated, are the only distinguishing features.

The type of advance used is known to the trade as semi-automatic, which means that part of the advance is performed automatically and part is taken care of manually. Under all ordinary driving conditions the advance mechanism adjusts the spark position to the engine requirements. The hand advance need be used only when a wide-open throttle at very low speed, or at maximum speed, is desired.

The automatic advance mechanism is simple. Three centrifugal weights advance the cam as the speed increases. The cam shaft carries a star-shaped punching against which rest the tangs on the weights, and as the weights fly outward, due to increase in speed, the cam is advanced.

From normal retard position the weights move easily and the spark starts to advance at very low speeds.

The primary circuit is from the battery (+) grounded battery terminal, to the grounded contact lever or arm, through the points, to the ignition-coil terminal marked "Timer," through the primary winding, through the resistance unit "IGN" on the switch, to the battery (−) terminal. Note that this is a two-terminal ignition coil, and the condenser is mounted on the breaker plate, placed across the points, one end being grounded. The cam which raises the breaker contact lever, or arm, has six high points; therefore the one shown in this illustration would be for a six-cylinder engine.

The secondary circuit is from the ignition coil of the secondary winding, to the distributor rotor, to the spark-plug terminals (note that the gap between rotor and terminals in the distributor cap leading to the spark plugs is 1/64"). Note that there are six terminal leads from the distributor cap to the spark plugs; therefore it would be for a six-cylinder engine.

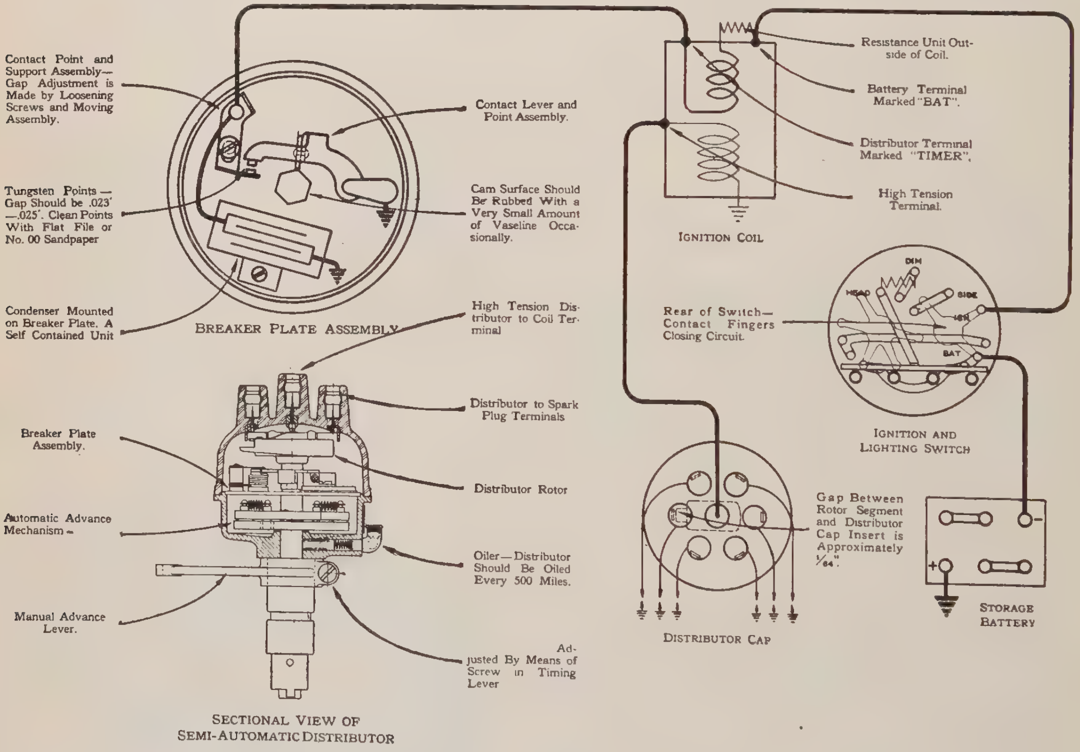

Contact Point and Support Assembly—Gap Adjustment is Made by Loosening Screws and Moving Assembly.
Contact Lever and Point Assembly.
Tungsten Points—Gap Should be .023"—.025". Clean Points With Flat File or No. 00 Sandpaper
Cam Surface Should Be Rubbed With a Very Small Amount of Vaseline Occasionally.
Condenser Mounted on Breaker Plate. A Self Contained Unit
BREAKER PLATE ASSEMBLY
High Tension Distributor to Coil Terminal
Breaker Plate Assembly.
Distributor to Spark Plug Terminals
Distributor Rotor
Automatic Advance Mechanism
Oiler—Distributor Should Be Oiled Every 500 Miles.
Manual Advance Lever.
Adjusted By Means of Screw in Timing Lever
SECTIONAL VIEW OF SEMI-AUTOMATIC DISTRIBUTOR
Resistance Unit Outside of Coil.
Battery Terminal Marked "BAT".
Distributor Terminal Marked "TIMER".
High Tension Terminal.
IGNITION COIL
DIM
HEAD
SIDE
IGN
BAT
Rear of Switch—Contact Fingers Closing Circuit.
IGNITION AND LIGHTING SWITCH
Gap Between Rotor Segment and Distributor Cap Insert is Approximately 1/64".
DISTRIBUTOR CAP
+
−
STORAGE BATTERY

Fig. 4. Descriptive wiring chart of the Remy semi-automatic ignition, together with names of parts and adjustment data.

INSTRUCTION No. 20

DELCO IGNITION: Coils; Distributors and Interrupters

The Delco distributor might be classified in three ways:

1. **Single distributor, with one set of timing contact** points on the interrupter, using one ignition coil.
2. **Single distributor, with two sets of timing contact** points on the interrupter (connected in parallel), using one ignition coil.
3. **Double distributor, with two sets of timing contacts,** using two ignition coils.

The following explanations will serve to make the foregoing classification clear.

Delco Ignition Coils

Four general types of non-vibrating, single-spark ignition coils have been used. They are:

1. **Round type with straw-colored shell.** This type does not incorporate either the resistance unit or the condenser.
2. **Round type with black shell.** This type does not incorporate the condenser, but the resistance unit is mounted on the outside of the coil shell.
3. **D-type with bakelite shell.** Certain of the coils carry the resistance unit mounted upon the end of the shell. This type does not incorporate the condenser.
4. **D-type with black shell.** This type incorporates the condenser within the shell and the resistance unit on the end of the shell.

Figs. 1 and 2 show the internal circuits in typical coils. Note in Fig. 1, that the resistance unit is mounted on the right end of the coil and in Fig. 2, it is on top at the right end.

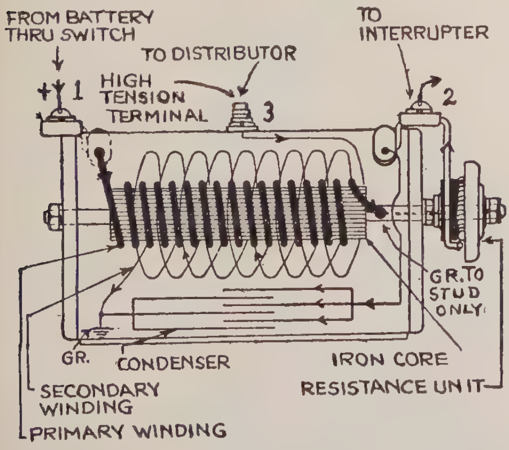


Fig. 1. Delco model "2158," ignition coil with condenser in coil.

In Fig. 1, note the condenser in the coil which is connected across the interrupter points, one end of the condenser being connected to terminal 2, and the other end grounded. The primary-circuit terminals are numbered 1 and 2; the secondary terminal is No. 3.

Fig. 1A illustrates a grounded ignition circuit using a condenser in the coil and a single distributor and interrupter.

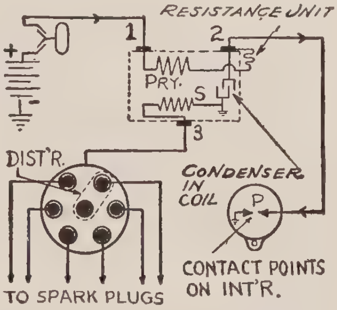


Fig. 1A. Circuit when using coil shown in Fig. 1.

The primary circuit (Fig. 1A) runs from (+) of battery, to ignition switch to terminal (1) of the coil, through primary winding, through "resistance unit," to coil terminal (2), to the insulated interrupter contact point, across contact points (**P**), to grounded interrupter contact, to grounded (−) terminal of the battery, thus completing the primary low-tension circuit.

The secondary circuit runs from the secondary terminal (3) on the coil to the center terminal of the distributor, through the rotor, to the spark-plug terminals of the distributor, to the spark plug, through the spark-plug gap, to the spark-plug shell grounded to the engine, through the ground of the engine and frame, to the grounded terminal of the secondary in-coil, thus completing the secondary high-tension circuit.

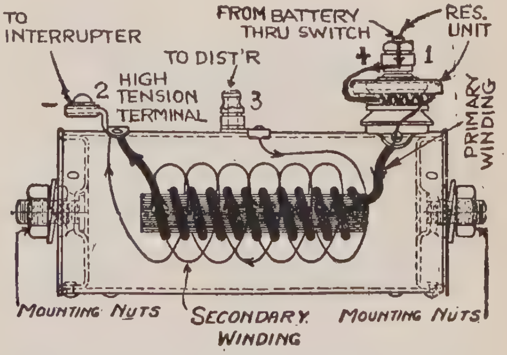


Fig. 2. Delco model "2159," ignition coil. Condenser is not in coil.

In Fig. 2, the condenser is not in this coil. It is located in the interrupter housing, either inside or outside, and is connected across the interrupter points (**P**). (This is the coil used on the Buick.)

The primary circuit (Fig. 2A) runs from (+) of battery, to the ignition switch, to the resistance unit (1), through the primary winding (**P**), to the terminal

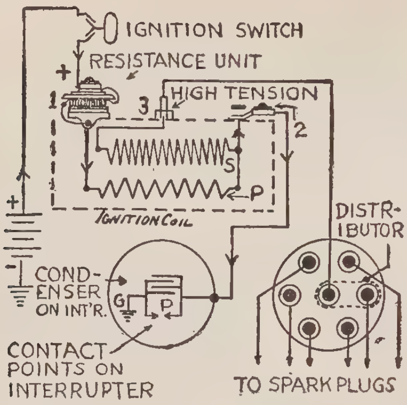


Fig. 2A. Circuit when using coil shown in Fig. 2.

(2), to the interrupter points (P), to ground, to (—) ground of battery, thus completing the primary low-tension circuit.

The secondary circuit: runs from the secondary terminal (3) to the center terminal of the distributor, to the spark plugs, to ground on engine and frame, to the battery ground (—), through battery (or generator, if generator is supplying current instead of battery), to the terminal (1) of the coil (+), through the primary winding (P), to the secondary connection to the primary winding at (S), thus completing the high-tension secondary circuit.

Delco Interrupter with a Single Contact-Breaker Using One Coil

The top view of a Delco closed-circuit interrupter with a single contact breaker is shown in Fig. 3. The cam in this instance, has 8 high points or lobes and revolves at cam-shaft speed; thus 8 interruptions, or 8 sparks occur during two revolutions of the crank shaft of the engine. One spark plug per cylinder is used.

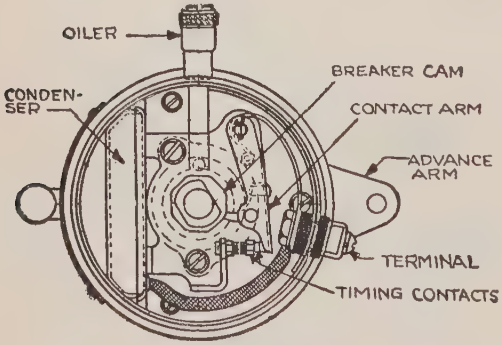


Fig. 3

Delco Interrupter with Two Contact-Breakers Connected in Parallel, Using One Coil

In Figs. 4, 5, 6, and 6A, note that the closed-circuit type interrupters have two interrupters or contact breakers operated by one cam.

One spark plug per cylinder is used and also one coil, but two contact points are connected in parallel, both of which open at one time. The primary ignition current which could otherwise flow through only one set of points is divided between the two sets, and the resultant wear upon the points is less and an additional factor of safety is provided. The Marmon, Cadillac, and Cole use this principle.

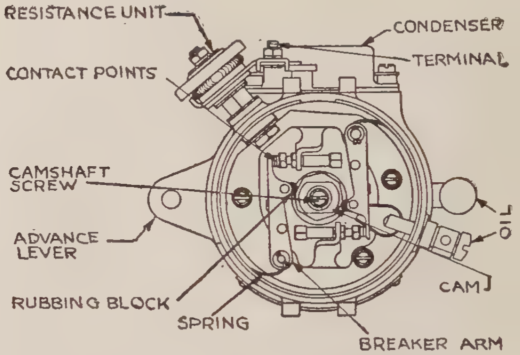


Fig. 4. Delco interrupter with two contact-breakers in parallel (top view).

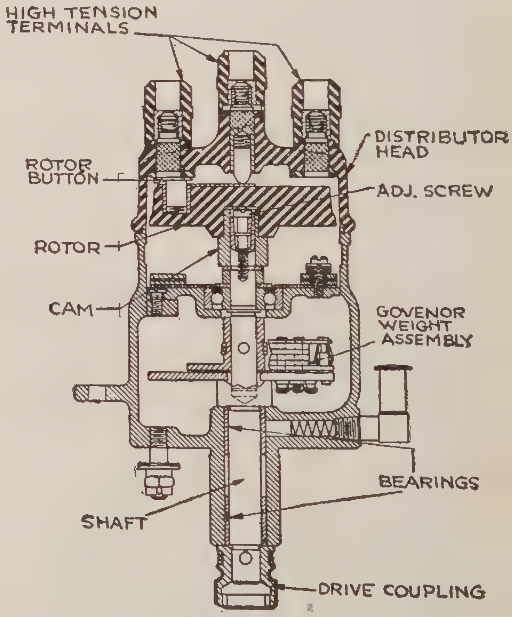


Fig. 5. Sectional side view of Delco ignition unit, a top view of which is shown in Fig. 4.

The distributor, interrupter, automatic spark advance mechanism and the ignition drive shaft are shown in Fig. 5. Manual advance of the spark, as shown in Fig. 5. Manual advance of the spark, controlled by a lever, as well as by an automatic advance, are provided for.

Delco-Cadillac Distributor and Timer

The Cadillac electric system consists of a Delco starting motor and generator in one unit, which is explained in the later discussion of electric systems. **The wiring** is a "single wire" or grounded return system. See Index under "Cadillac wiring diagram."

Ignition: The distributor and timer are carried on the fan-shaft housing, and are driven through a set of spiral gears attached to the fan shaft. The distributor consists of a cap or head of insulating

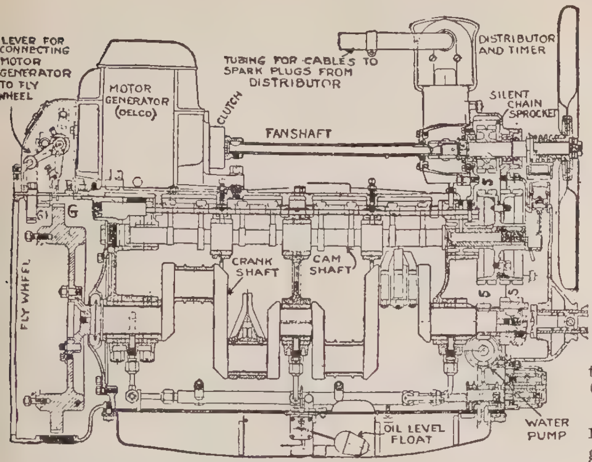


Fig. 5A—Location of the distributor and timer, and of the motor-generator on the Cadillac.

material, carrying one contact in the center with eight additional contacts placed at equal distances about the center and a rotor which maintains constant communication with the center contact.

The rotor carries a contact button which serves to close the secondary circuit to the spark plug in the proper cylinder.

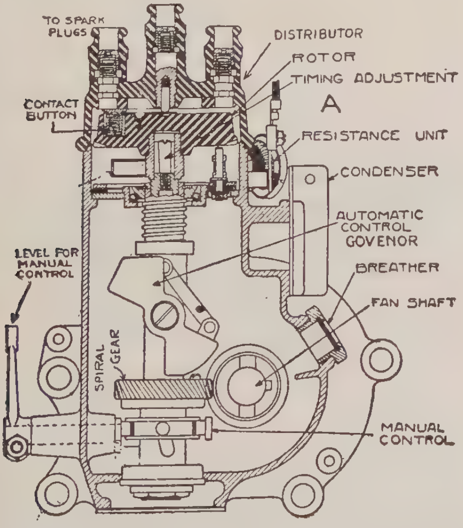


Fig. 6. The Delco distributor and timer. The Delco electric system as used on the Cadillac.

Beneath the distributor head and rotor is the timer. The timer cam is provided with a lock screw in the center of the shaft. (See Figs. 6 and 6A.)

A manual spark control is provided in addition to the automatic spark control. The manual spark control is for the purpose of securing the proper ignition control for variable conditions, such as starting, differences in gasoline, weather conditions, and amount of carbon in the engine. The automatic control is for the purpose of securing the proper ignition control necessary for the variation due to engine speed alone.

The timer, more properly termed an interrupter, is shown in Fig. 6A. It is of the closed-circuit type. Note that there are two contact-breaker, or interrupter points. The object for using two contact-breaker points, is to distribute over two sets of points the current which would otherwise pass through one. This greatly lessens wear and burning of the points.

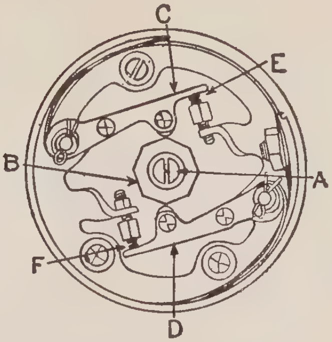


Fig. 6A. Delco-Cadillac timer (interrupter) with two contact-breakers. (A) is the adjusting screw; (B) cam; (C) and (D) contact-breaker arms; (E) and (F) breaker points.

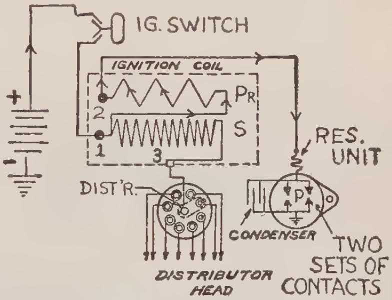


Fig. 6B. Illustration showing circuit where two sets of contact-breakers (connected in parallel) are used.

The primary circuit (Fig. 6B) runs from battery (+), to switch, to (1), through the primary winding (P), to (2), to the ignition resistance unit mounted on the interrupter housing, to the interrupter points (P) connected in parallel, to ground, to (—) ground of battery. Note that the condenser is shunted across the two contact points.

Note. Cadillac and Marmon have the positive (+) of the battery grounded.

The secondary circuit runs from terminal (3), to the distributor, to the spark plugs, to ground of engine, to (—) ground of battery, to (1) on coil.

Delco-Cadillac Distributor Connections

Distributor connections on the Cadillac—Delco ignition system are shown in Fig. 6C. The cables lead from connections on the distributor to the cylinders in the order which they fire.

Note that the brush (**B**) makes contact consecutively, but cables from the distributor are connected to the plugs in their respective firing order.

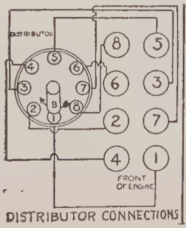


Fig. 6C

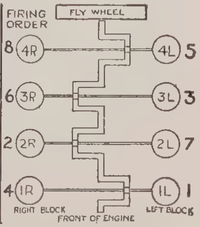
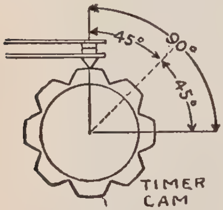
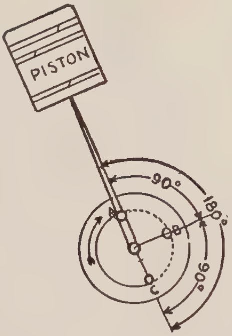


Fig. 6D

The firing order is shown in Fig. 6**D**. The cylinder marked (1L) fires first, then 2R, 3L, 1R, 4L, 3R, 2L, 4R. Follow the black figures on the side of the cylinders which show consecutively how the cylinders fire.





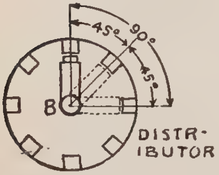


Fig. 7 (upper). Fig. 7B (right).
Fig. 7A (lower).

The relative movement of timer cam, distributor, rotor, and piston is shown in Figs. 7, 7**A**, 7**B**. The movement is shown in degrees. There is an impulse or firing spark at every 90° movement of the crank shaft, which is approximately one-half of a stroke of the piston, or one-quarter of a revolution of the crank.

When the crank shown in Fig. 7**B** travels 90° (**A** to **B**) the timer or distributor brush (**B**, Fig. 7**A**) being run at cam-shaft speed, or one-half crank-shaft speed, it then moves 45°, as does also the timer cam (Fig. 7).

When the crank makes two revolutions, or 720°, the timer cam and distributor brush (**B**) move 360° or one revolution. Therefore there are 8 sparks to two revolutions of the crank.

Delco-Cadillac Ignition Timing

The timer contact points are set as follows: Turn the engine over until the contact arms (**D**) and (**C**), Fig. 6**A** are directly on top of the lobes of the cam (**B**): (Note that there are eight lobes or high points on the cam.) Then adjust the contact points at (**E**) and (**F**) so that they stand .020″ (twenty-one-thousandths of an inch) apart. Both sets of contact points should be adjusted alike.

To time the ignition proceed as follows: Move the spark lever to the extreme left on the sector; open the compression release cocks on the cylinder blocks, and crank the engine by hand until the piston in No. 1 cylinder is on firing center. (No. 1 cylinder is the one nearest the radiator in the left-hand block of cylinders.)

Next remove the distributor cover, also the rotor, and loosen the lock screw (**A**) just enough to allow the cam (**B**) to be turned by hand after the rotor is fitted. (The lock screw should not be loosened enough to allow the cam to turn on the shaft when the engine is cranked by hand.)

Then replace the rotor and turn it by hand until the distributor brush in the rotor is directly under the terminal marked No. 1 on the distributor cover. Replace the distributor cover, and move the spark lever to the extreme right on the sector.

Then switch on the ignition; hold the high-tension wire to the spark plug in No. 1 cylinder about one-eighth of an inch away from the cylinder casting, and turn the engine slowly by hand in the direction in which it runs. Stop turning immediately a spark occurs between the wire and the casting. (It will be necessary to turn the engine nearly two complete revolutions before the spark occurs.)

If the cam (**B**) is properly set, a spark will occur when a point on the fly wheel 1 21/32″ (one and twenty-one thirty-seconds of an inch) in advance of the center line for No. 1 cylinder is directly under the pointer or "trammel" attached to the crank case of the engine. This point for each cylinder is marked on the fly wheel by the letters "IG/A."

If the spark occurs before this, rotate the cam (**B**) slightly in a counter-clockwise direction to correct the adjustment. If a spark occurs later than this, rotate the cam slightly in a clockwise direction.

After the adjustment has been properly made, lock the cam securely to the distributor shaft by the lock screw (**A**).

After locking the adjustment, it is a good plan to check the timing by fully retarding the spark lever; in other words, by moving it to the extreme left on the sector, holding the high tension wire to the spark plug, in No. 1 cylinder about one-eighth of an inch away from the cylinder casting, and again turning the engine slowly by hand in the direction in which it runs, stopping immediately when a spark occurs.

If the ignition is properly set, the spark will occur under these conditions when the center line on the fly wheel for No. 1 cylinder is directly under the pointer attached to the crank case, or has passed the pointer.

Caution: Do not set the ignition so that the spark occurs before center with the spark lever at the extreme left on the sector.

Resistance unit and ignition coil are explained in the discussion of the subject "Ignition."

Note. See Index under "Synchronizing two sets of interrupter points." Type 1 connection under this heading applies to the Cadillac.

Delco Double Distributors Using Two Distributors, Two Contact-Breakers, and Two Ignition Coils and Two Sets of Spark Plugs

Figs. 8 and 9 illustrate the Delco distributor used on the six-cylinder Pierce-Arrow "38–48" models. It is termed a "double ignition system" and consists of double distributors, double contact breakers (closed-circuit type) and a double set of spark plugs. Two coils are used. Automatic and hand (manual) advance of spark is provided. There are two distributor heads: one contains the two contact breakers and the other the condensers. There is a distributor head for each set of spark plugs. One single six-lobe cam, driven at cam-shaft speed, is used. Either the "single" or "double" ignition system may be used.

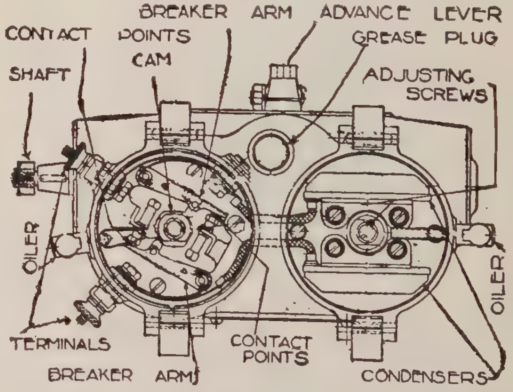


Fig. 8. Top view of Delco-Pierce-Arrow double distributors.

Two sparks occur at slightly different times in each cylinder; one coil furnishes high-voltage current to the plugs over the intake valves, while the other coil supplies the plugs over the exhaust valves. The Stutz uses a Delco distributor which is similar, except that interrupter points open simultaneously.

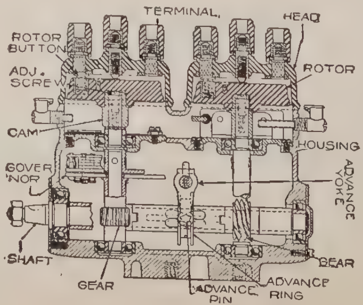


Fig. 9. Side view of Fig. 8.

Attention is called to the method of adjusting the relative time of separation of the timing contacts in the No. 5216 Pierce-Arrow double distributor. The left-hand set of contacts, viewed from the driving end of the distributor, and operating with the ignition of the plugs on the exhaust side of the engine, must be adjusted to separate 3° (flywheel) or 1½° (distributor) ahead of the other set of contacts. To make the adjustment accurately and easily, a method must be used very similar to that described on page 221 for the use of testing lamps. The firing order is 1, 5, 3, 6, 2, 4.

See Index for "Pierce-Arrow wiring diagram."

Delco-Packard (Twin-Six) Ignition

Figs. 10 and 11 are top and vertical sections of the Delco-Packard ignition distributors and interrupters of the closed-circuit type (Twin-six models "3-25" and "3-35").

The interrupter contact-breaker mechanism consists of a separate set of timing contacts for each low-tension circuit. These are operated by a single three-lobed cam mounted on the top of a vertical shaft which is driven at crank-shaft speed. Thus each low-tension circuit is broken three times during each revolution of the crank shaft.

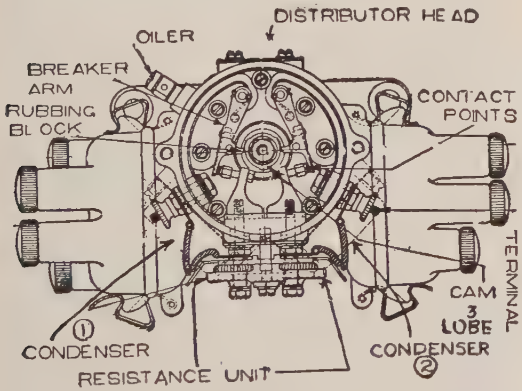


Fig. 10. Top view of Delco-Packard ("Twin-Six") distributor.

The distributor is equipped with the automatic spark advance. There are two coils used for engine ignition and one coil for fuelizer ignition.

A feature on the ignition unit used on the twelve-cylinder Packard models is the **auxiliary breaker mechanism** mounted on the top of the distributor and used in connection with a separate ignition coil to operate the spark plug in the "fuelizer." See Index for Packard "Fuelizer" and Packard "Wiring diagram." The wiring diagram will more clearly explain the principle.

It should be observed that the 5220 and 5238 distributors use a 15249 auxiliary breaker, while 5161 and 5220 distributors use a 14805 auxiliary breaker.

Note that in the system described above a three-lobe cam is used which revolves at crank-shaft speed, whereas with most all other systems it revolves at cam-shaft speed.

The fact that twelve interruptions, or sparks, can take place in the two six-cylinder blocks of cylinders during two revolutions of the single three-lobe cam is explained by the fact that there are two interrupter arms with separate contact points operating against opposite sides of a three-lobe cam. Note that the **cam is triangular** in form, with the sharp corners rounded off; thus the lobes are 120° apart. Therefore when one contact arm is raised at the highest point on one of the lobes of the cam (which is the wide-open position of the contact points), the interrupter arm on the opposite side of the cam will be exactly between the two lobes (which is the closed position of the contact points).

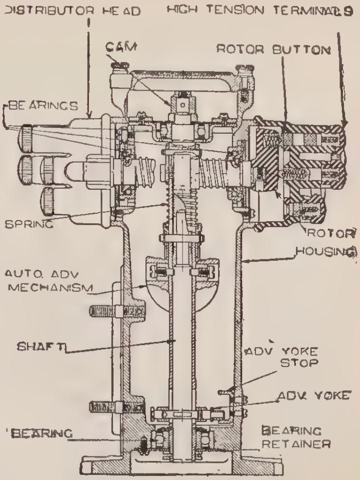


Fig. 11. Side sectional view of Delco-Packard ("Twin-Six") distributor.

Because there are three lobes 120° apart, three sparks would be produced per revolution of 360° for each set of contact points, or six sparks during one revolution for both interrupter contact points. Since the cam travels at the same speed as the crank shaft, then for two revolutions of the cam, there would be twelve sparks.

The high-tension distributor, like all distributors, revolves at cam-shaft speed, or one revolution to two revolutions of the crank shaft, and distributor terminals on the two distributor heads, each with six segments, leading to the twelve spark plugs, have the segments 60° apart.

Separate high-tension distributor heads are provided for each cylinder block. These are mounted on either side of the ignition apparatus housing and are operated by rotors on a cross-shaft driven from the vertical timer shaft.

The firing order in each block is: 1, 4, 2, 6, 3, 5. The impulses alternate between the two blocks. If we number the cylinders in succession, beginning with number one at the front of the right block, the firing order would be: 1R, 6L, 4R, 3L, 2R, 5L, 6R, 1L, 3R, 4L, 5R, 2L, the R and L designating the right and left cylinder blocks.

Arcing across the contact points when they are separating is minimized by the use of **separate condensers** for each set of breaker points, located in the rear side of the ignition timer and distributor housing. Indirectly these condensers also serve to intensify the high-tension current wave.

Resistance units in both low-tension circuits, and located on either side of the common ground return terminal on the timer housing, serve to keep the low-tension current down to the proper rate of flow at various car speeds. These also prevent excessive discharge from the battery when the ignition switch is left on and the engine is not running.

See Index for "Packard wiring diagram."

The Delco-Lincoln Ignition System

Figs. 12, 13, 14 show the **interrupter and distributor** used on the Lincoln. The vertical shaft viewed from the top turns counter-clockwise at one-half engine speed, and carries the manual spark advance mechanism, governor assembly controlling the automatic spark advance, the four-lobe breaker cam, and the rotor. The four-lobe cam produces eight sparks during one revolution of the cam, due to the two interrupters.

Each of the two sets of contacts are connected with the primary circuit of a separate ignition coil. In this manner the right-hand set of contacts (when viewed from the driver's seat) connected with the right-hand ignition coil, controls the ignition in the right bank of four cylinders. Likewise the left-hand set of contacts connected with the left-hand ignition coil controls the ignition in the left-hand bank of cylinders.

A rotor (Fig. 15), carried on upper end of distributor shaft, carries two steel rotor brushes, both electrically connected. One of them connects with the small carbon brush, which makes contact with the slip-ring in the distributor head. The other rotor brush connects with the center plunger contact in the distributor head.

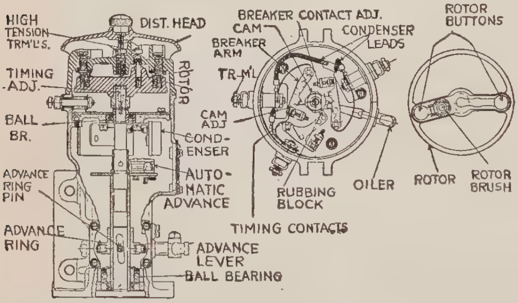


Fig. 12 Fig. 13

Figs. 12 and 13. Side and top view of Delco-Lincoln distributor.

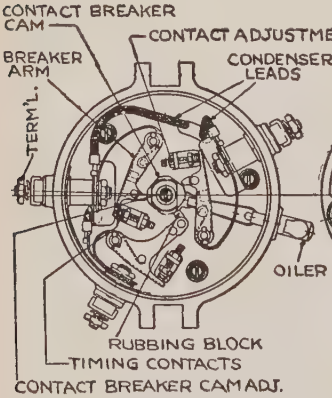


Fig. 14

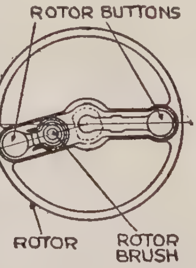


Fig. 15

Fig. 14. Clearer top view of Lincoln. On the interrupter, owing to the fact that the cylinders are 60° apart, they are not placed opposite to each other.

Leads from each of the eight equally spaced terminals around the distributor head should be connected to spark plugs in the cylinders which carry a corresponding number.

The high-tension lead from the right-hand ignition coil is connected to the center terminal (the long screw) of the distributor head. Current from this coil takes care of ignition in the right bank of cylinders Nos. 1, 3, 7, and 5, through the rotor brush connected with the center plunger contact in the head.

The left-hand bank of cylinders Nos. 6, 8, 4, and 2, receive ignition current from the left-hand ignition coil whose high-tension lead is connected to the terminal (the short screw) near the center of the distributor head. This current passes through the rotor brush connected with the carbon brush.

Care must be taken to see that the leads from both primary and secondary terminals of the ignition coils connect to their correct terminals on the distributor.

The distances between the contact points when opened by the cam are adjustable by means of the contact screws which carry the stationary contact points. They should be adjusted so that they are .020″ apart when the fiber rubbing block of the contact arm rests directly on top of the cam lobes. Due to the slight wear of the fiber block during the first 2,000 miles driving, it may be necessary to make one or two adjustments of the points, after which practically no attention is necessary other than to note occasionally that the adjustment conforms to specifications.

The thickness of the gauge on the distributor wrench provided in the tool equipment should be used in adjusting the points.

When a slight readjustment of the contact points will not affect the timing noticeably, it is recommended that the ignition timing be checked, and if necessary corrected after each adjustment of the contact points.

After assembly of the parts of a repaired Lincoln distributor it will be necessary correctly to adjust the two sets of timing contacts, so that they separate at intervals of exactly 30° and 60° of distributor-shaft travel.

These values correspond to 60° and 120° on the flywheel, which are the intervals of crank-shaft travel between cylinder firings.

To obtain the correct setting, first adjust each of the two sets of contacts to the correct maximum dimension of .020″. Then shift slightly the position of the contact-point mounting plate until a setting has been found which will cause the contacts to open exactly at 30° and 60° intervals. This plate may be shifted within small limits after loosening the three screws securing it to the distributor housing, and allowing the plate to pivot on the screw nearest the oiler.

In order to measure accurately the 30° and 60° intervals, the mechanic should connect a small lamp in series with each set of contacts similar to the test set in Fig. 20, page 221, to indicate the instant the points separate. An ordinary protractor, or similar measuring device calibrated in degrees and approximately 4″ in diameter, must be used to measure the number of degrees of interval between the separation of the contacts. Small scratches may then be made on the distributor housing opposite a previously made scratch or mark at any point on the edge of the rotor, indicating the actual intervals between the separation of the two sets of contacts. These angular distances may then be measured with the protractor, and if not correct, the contact mounting plate may again be slightly shifted.

If during the shifting of the plate, the adjustment of the contacts is appreciably changed, their adjustment should be corrected, after which a re-check should be made with the protractor and lamps of the intervals between the separation of the two sets of contacts. It would be advisable to check up the adjustment of the contacts once or twice during the first 2,000 miles driving, so that any necessary correction might be made.

Lubrication of the upper ball bearing is taken care of by placing in the oiler three or four drops of engine oil every 500 miles. The lower ball bearing of the distributor shaft and the advance ring of the manual-spark control mechanism receive their lubrication from the light cup grease carried in the lower part of the distributor housing. This section of the housing should be kept filled with light cup grease to a level just above the advance ring. Lubricant may be placed in the housing by removing the cover plate near the spark-advance lever on the forward side of the housing.

A very small amount of light grease or vaseline should be applied to the surface of the breaker cam each 500 miles. The rubber track containing the eight inserts or contacts should receive a very small amount of vaseline applied occasionally during the first 1,500 miles driving. The track will then become glazed, and no further lubrication will be required. It is then only necessary to wipe out the distributor head occasionally with a clean cloth. No lubricant is required on the slip ring in the distributor head, against which the carbon brush rests. The center plunger contact in the distributor should always make contact with the rotor, and the carbon brush in the rotor should always make contact against the slip ring.

A slight blackening of the surface of the distributor head inserts has no effect whatever upon the perfect performance of the ignition system.

Delco-Lafayette Distributor

Figs. 16 and 16A show the top and side cross-section views of **the interrupter and the distributor** used on the Lafayette model, which is similar to that shown in Fig. 4, page 214. The vertical shaft, turning at one-half engine speed, carries the manual advance mechanism, governor assembly controlling the automatic spark advance, the eight-lobe breaker cam, and the rotor.

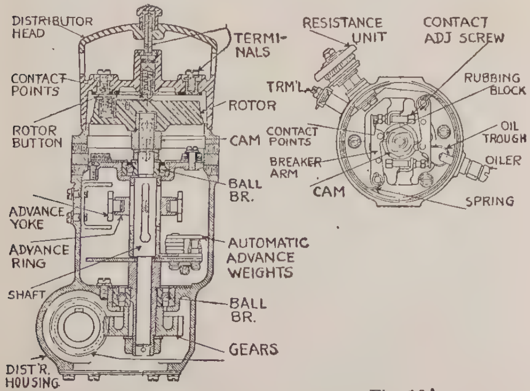


Fig. 16 Fig. 16A

Figs. 16 and 16A. Side and top view of Delco-Lafayette distributor.

Two sets of timing contacts are provided, the object being to distribute over two sets of points the current which would otherwise pass through one set. Both sets of points separate, and therefore are arranged to separate at the same instant.

See Index for "Wiring diagram."

Delco-Packard (Six-Cylinder) Distributor

Fig. 17 shows the general construction of the **interrupter and distributor** used on the six-cylinder **Packard** models.

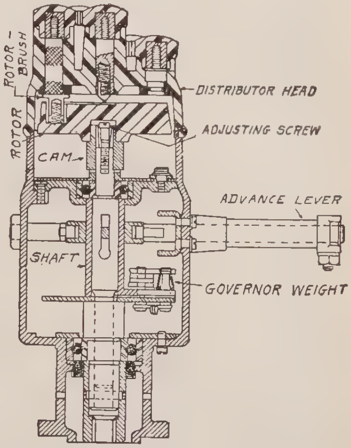


Fig. 17

Two sets of interrupter contacts are provided, each set being connected in series with a separate ignition coil. One of these coils provides ignition for the engine cylinders, while the other coil supplies ignition at the fuelizer spark plug. Electrical connections of this system are shown clearly in the circuit diagram. See Index for "Wiring diagram."

Delco-Buick Distributor

Figs. 18 and 19 show the top and sectional views of the Delco distributor and interrupter used on the 1921 **Buick models.** The design of the present **Buick distributor** is such that advance and retard of the ignition is accomplished through an **advance ring** (see Fig. 18) within the distributor instead of by an oscillating movement of the distributor head changing the angular position of the timing contacts with the distributor cam.

A condenser, mounted in former models inside the ignition coil, is now contained in a moisture-proof metal case within the distributor housing, next to the interrupter. Delco coil (1921) is Delco No. 2159 (Fig. 2, page 213).

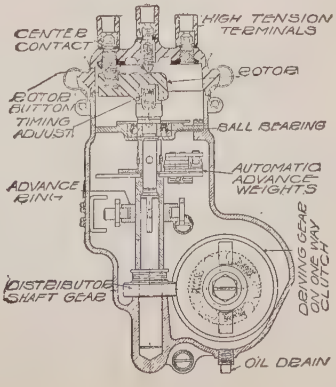


Fig. 18. Side view of Delco-Buick distributor.

The distributor consists of parts as shown in Fig. 18. The rotor revolves at cam-shaft speed, or one-half the speed of the crank shaft. The shaft is driven from the generator shaft which, through a one-way clutch, drives the generator (see Index for "Buick generator" and "Buick wiring diagram").

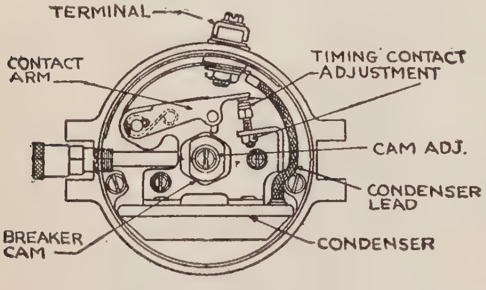


Fig. 19. Top view of Fig. 18.

Timing the Buick-Six Ignition

1. Place the spark lever on the steering wheel in the fully retarded position.
2. Turn the engine to the seven-degree mark (which is approximately one inch after dead center), with the No. 1 cylinder on the firing stroke.
3. Loosen the timing-adjustment screw in the center of the distributor shaft and contact-breaker cam. Turn the cam so that the rotor button will be in position under No. 1 high-tension terminal when the distributor head is properly located. Locate the contact-breaker cam carefully in this position so that when the backlash in the distributor gears is rocked forward the contact points will be opened, and when the backlash in the gears is rocked backward the contacts will just close. The distributor shaft turns clockwise when viewed from the top.
4. Tighten the adjustment screw securely and replace the rotor and distributor head. **The cylinders fire** in the following order: 1, 4, 2, 6, 3, 5.

The proper spark-plug gap should be thirty-thousandths of an inch (.030″). **The contact-breaker points** should separate .020″ when they are separated the maximum distance by the cam.

On account of the wearing to a seat of the fiber rubbing block on the contact arm, one or two adjustments may possibly be necessary during the first 2,000 miles of driving, after which practically no attention is necessary other than to note occasionally that the adjustment of the contacts conforms to specifications.

A **frosted appearance of the contacts** indicates that they are making **good contact** with one another, and should not be disturbed as long as proper operation is maintained. The contact points are made of tungsten. This metal is too hard to file. Should it be necessary to dress them, an oil stone should be used. Care should be taken that they seat properly against each other and are correctly adjusted after being replaced.

It is a good plan after adjusting the timing contacts to check the ignition timing. See instructions under "Timing the Ignition."

DELCO IGNITION TIMING

Adjusting Timing Contacts

See also the instruction on "Ignition Timing," which explains the advance and retard of the spark, etc.

The timing contacts should be adjusted so that when they are separated by the breaker cam they are apart by the following thickness: All Delco distributors for four and six-cylinder engines should have their contacts adjusted to .020″ to .0275″; all distributors used on eight-cylinder cars, except Cadillac, should be adjusted to .015″ to .0225″; Cadillac should be .015″ to .020″; Packard should be .020″ to .025″.

On those distributors, except the Packard and Pierce-Arrow, having two sets of timing contacts, the separation of the contacts, where there are two sets, should be as nearly simultaneous as possible. Both are intended to separate at the same time, and the maximum contact separation of each set of contacts should be held to the specifications. Should difficulty be encountered in obtaining the adjustment to synchronize the operation of the points, the contact-breaker plate on which the contacts are mounted may be shifted within certain limits after loosening the three screws holding it in place. These screws should be carefully tightened after the necessary adjustments have been made.

On account of wearing to a seat of the fiber rubbing block on the breaker arms, the points will require one or two adjustments during the first season's driving, after which practically no attention is required.

Interrupter contact points are made of pure tungsten metal, which is very hard and of long life. Should the contacts require cleaning or redressing, rub the points lightly over an oil stone—the tungsten metal is too hard to file. The contact arms may be removed by lifting them from the posts on which they are pivoted, after taking out the cotter-pins and loosening any clamping nuts holding the ends of the steel springs.

Timing the Delco Ignition

The breaker cam is secured to the distributor shaft with the cam adjustment screw, as in Fig. 4, page 214, in the majority of distributors; in others, by the timing adjustment screws. The adjusting screw permits the cam to be placed in any angular position for timing.

The manufacturer of the car should be consulted for the exact directions for timing the engine. However, the following directions will give an approximate timing which will prove satisfactory under ordinary conditions:

1. Place the spark lever on the steering wheel in a position one-third advanced.
2. Turn the engine by hand until the piston in No. 1 cylinder is just on top dead center on the compression stroke.
3. Loosen the timing adjustment screw in the center of the cam, and locate the proper lobe of the cam by turning the rotor until the rotor button comes under the high tension terminal of the distributor head connected to the No. 1 cylinder.
4. Locate this lobe of the cam so that when the back-lash in the distributor gears is rocked forward the timing contacts will be opened and when the back-lash is rocked backward the timing contacts will just close. The distributor shaft usually rotates in a clockwise direction when viewed from the top. Tighten the adjusting screw and replace the rotor and distributor head.

Note. The Lincoln distributor rotates counter-clockwise.

In the Stutz double distributor (similar to the Pierce-Arrow, Fig. 9, page 216), the distributor cam and collar, which carry the two rotors, are keyed in position, and are not adjustable. Timing is accomplished through an adjustable coupling through which the distributor is driven.

Adjusting Spark Plugs for Delco Ignition

The adjustment should be .030″. On spark plugs having more than one gap, all but one gap should be made wide, and closest gap adjusted to .030″.

An exceptionally wide adjustment may be the cause of missing at the higher speeds. **Too close an adjustment** will cause the ignition to be poor at very low speeds when idling.

Synchronizing Two Sets of Interrupter Contact Points (Delco)

Fig. 20 shows a simple device which is of material assistance in synchronizing the operation of two sets of timing contacts. This handy test set consists of a small block of wood upon which are mounted two small 6-volt lamps provided with the leads (**C**), (**D**), and (**E**). Terminals (**A**) and (**B**) are each made of a thin piece of fiber 1½″ by 1″, one side being covered by a thin piece of brass or copper to serve as a contact.

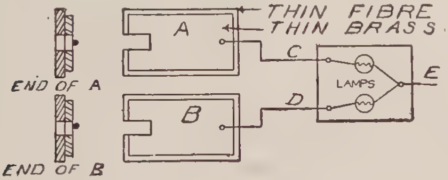


Fig. 20. Device for synchronizing interrupters.

Distributors with which this set is used are divided into two types: type 1 (Fig. 21) has two sets of timing contacts connected in parallel; in type 2 (Fig. 22) the double distributors have two sets of contacts, each of which is connected to a separate primary ignition circuit, as in the Pierce-Arrow and Stutz distributors.

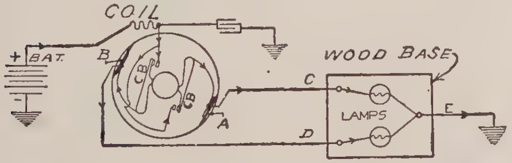


Fig. 21. Type 1 connection for synchronizing two interrupter contact-breakers (CB) connected in parallel.

When used with distributors in type 1 (Fig. 21), each of the terminals (**A**) and (**B**) are slipped between the contact-arm spring, and the distributor housing with the metal side of the terminal in contact with the spring. Connect lead (**E**) to "ground." Current is obtained from the storage battery on the car by placing the ignition switch lever in "on" position.

During this operation it will be well to place a piece of cardboard beneath one of the generator brushes on those generators not equipped with a cut-out relay, in order to prevent a flow of current through the generator windings.

In this type of distributor which is supplied with two sets of contacts the primary ignition current is divided between the two sets, which reduces the amount of burning and offers an additional factor of safety to the system.

The separation of each set of timing contacts will be indicated by the lamp in the circuit, and when both lamps go out at practically the same instant the contacts are properly synchronized.

When used with type 2 distributor (Fig. 22), the notches in the ends of the terminals (**A**) and (**B**) permit them to be readily connected to the two terminals on the distributor as shown.

In the Pierce-Arrow (page 216) and Stutz double distributors there are two sets of timing contacts. In these cases each set of contacts interrupt a separate primary ignition circuit, giving double ignition. One circuit supplies high-tension current to the plugs over the intake valves, while the other circuit takes care of plugs over exhaust valves.

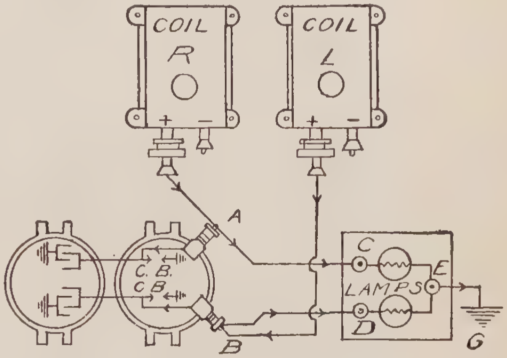


Fig. 22. Type 2 connections for synchronizing two interrupter contact-breakers used on double ignition.

By examining the connections as shown in Fig. 22, it will be noted that as each set of contact-breakers separate, the lamp in its circuit lights. When contact-breakers are closed, a short-circuit will be formed around lamps, causing them to go out.

In setting the Stutz contacts, both lamps should light at the same time; that is the timing contacts should be synchronized.

Pierce-Arrow interrupter contacts are not synchronized. By referring to the Pierce-Arrow wiring diagram, page 403, and to Fig. 8, page 216, it will be noted that one contact-point is for the ignition system on the exhaust side of the engine and the other is for the ignition system on the intake side.

The contact points for the exhaust side are set ahead of the intake, as mentioned below, the degrees referred to being flywheel degree movement.

Models 31 and 51: exhaust set to open 3° before inlet.
Models 32 and 33: exhaust set to open 3° to 7° before inlet.
Models X-5-W-2: exhaust set to open 0 to 3° before inlet.
Models R-10: exhaust set to open 0 to 3° before inlet.

For example, with models 32 and 33, the lamp connected in the circuit (Fig. 22) with the contact-points for the exhaust side should light 3 to 7 flywheel degrees before the one connected in the circuit with the contact-points for the intake side.

Contact-Point Surfaces and Removal

The contact-point surfaces often have a frosted appearance. This is not an indication of trouble, as is often believed, but shows that the contacts are making good contact with one another, and they should not be disturbed as long as proper operation is maintained. The contact points are made of tungsten. This metal is too hard to file. Should it be necessary to dress them an oilstone should be used. Care should be taken that they seat equally against each other after being replaced.

The contact arms may be removed by lifting them from the posts on which they are pivoted, after taking out the cotter-pins and loosening any clamping nuts holding the ends of the steel springs.

See Index for "Delco motor-generators and wiring diagrams."

INSTRUCTION No. 21

TESTS AND ADJUSTMENTS OF THE VIBRATOR TYPE OF HIGH TENSION COIL: Ford Ignition Coil

This instruction deals only with vibrator-type coil adjustments and tests. The next instruction will deal with the non-vibrator type.

Adjusting Vibrators of an Ignition Coil

The usual method of adjusting a coil trembler or vibrator is the rather rule-of-thumb method of screwing down the trembler screw till there is a sharp musical "buzz" obtained, and, as near as it is possible to determine, to adjust the screws so as to obtain the same note from each trembler.

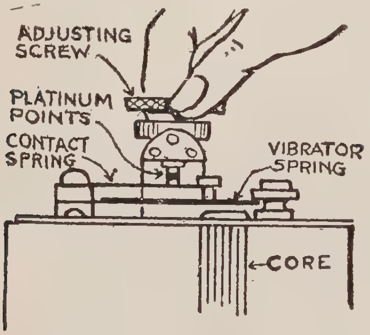


Fig. 1

Current consumption of the coil depends largely on how close the vibrator contacts are set. Very often it happens that a good deal of current is wasted in having too close contact, and at the same time the platinum points on both the vibrator and the adjusting screw are soon "pitted" and worn out from the excessive sparking.

There is a further serious disadvantage, inasmuch as the firing point cannot be synchronized for each cylinder, the closely-set trembler firing the charge earlier than the lightly-set one, and thus it happens that an engine rarely gives off the full amount of power. Perfect synchronization is required in obtaining full power. This explains why some engines often give more power on the magneto. The fault lies in bad setting of the coil and sticking vibrators.

Instructions for Adjusting the Ford Vibrator Coil (K.W. Ignition Co.'s Make)

There are four vibrator-type coil units (Fig. 2) contained in the Ford coil box.

The primary winding starts at the bottom of the coil unit, which consists of a metal disk which makes contact with a spring inside of coil box and which is connected with electric current, either from the battery, the generator, or the magneto (see Index under "Ford wiring diagram").

The primary current passes through the primary winding, through vibrator blade (**VS**), through points (**P**), to the contact spring, to the primary contact to the timer, to the contact on the timer or commutator.

The secondary winding is shown in Fig. 2. See also Index, for "Ford wiring diagram."

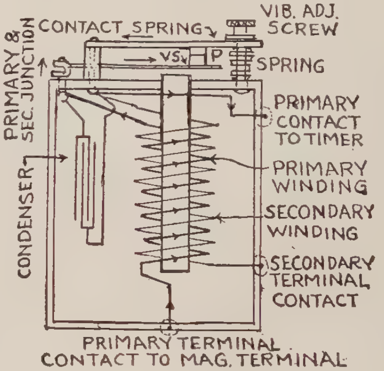


Fig. 2. Ford vibrator coil unit (K.W.)

Adjustment of vibrator: The K.W. coil unit shown in the illustration is designed to operate on a current consumption in the primary winding of 1 1/10 to 1 2/10 amperes at a voltage of 6 to 8 volts.

When the vibrator tension on a coil is increased, or more vibrations are produced in a given time by screwing down on the vibrator adjusting screw, the secondary voltage is increased and the primary will draw more current.

Therefore the proper adjustment of this adjusting screw for certain current values is necessary in order to prevent the building up of too high a voltage, which is liable to puncture the insulation of the secondary winding.

A Ford coil unit (K.W., Fig. 2), when tested on a 6-volt circuit with a low-reading ammeter in series with the primary circuit, should register 1 1/10 to 1 2/10 amperes.

When the vibrator spring is pressed down against the iron core, the air-gap clearance between points (**P**) should be 1/32″ apart. It is very essential that this vibrator spring have the proper tension, inasmuch as on this depends the amount of current that the primary winding consumes, as well as the effectiveness of operation.

The tension, or number of vibrations, can be adjusted by the vibrator adjusting screw. First, however, in order to adjust properly, the vibrator spring itself should be tested for proper tension as follows:

Remove the top bridge. If "tungsten" contact points are used, the vibrator spring should stand exactly ¼″ above the iron core. If K.W. "sparkite" springs and contact points are used, the spring tension is less, owing to the low-surface resistance of this metal; therefore the vibrator spring should be 5/32″ above the iron core.

It is important that the vibrator-spring tension be correct, as just stated, before attempting to adjust the tension of the vibrator spring with the adjustment screw.

The condenser is located in each coil unit, and is connected or shunted across the vibrator contact points.

Hard starting, due to vibrator adjustment: If there is **too much tension** on the vibrator springs, the weak current generated by the magneto at cranking speeds will not be sufficient to cause the vibrators to buzz, and it will be difficult to start the engine. **Too little tension** will not let the vibrators respond quickly, and the engine will run unevenly.

A defective coil unit can be detected by noticing if the vibrator buzzes without producing a spark at the plug. Then the suspected unit can be exchanged with another unit to make sure that the trouble is actually in the coil unit. A defective or punctured condenser is indicated by a heavy spark at the vibrators and a weak spark at the spark plug.

If the engine has a tendency to miss when driving over rough roads, this may be due to the coil units not fitting tightly in the coil box. The bouncing of the car makes the coil units touch the metal cover of the box and causes misfiring. Coil units in the Ford coil box depend upon spring tension for contact.

Sometimes, misfiring is due to the wooden lining of the metal coil box being damp and allowing the electric current to leak across from one terminal to another.

The spark plug: On the Ford and some magnetos where there is a volume of spark, a spark plug recommended by the manufacturer should be used, as the points usually have metal of slightly high resistance to prevent pitting and burning of points, due to the excess of current supply. **The spark-plug gaps** are 1/32″ apart on Ford plugs.

Vibrator Coil Cause of Missing

In rare instances one of the coil sections will become short-circuited or the insulation may become punctured on the secondary winding. This is commonly caused by using too many batteries or too high a voltage. In this case the plug would not spark at all, therefore it would be advisable to try changing positions of the coil units in the box. If the plug sparks properly on one of the other coil sections, then you may know that that particular coil unit is defective. Therefore, inspect the platinum points on the vibrators and contact points, as they may be partially burned away or badly pitted. If this coil section still fails to give a spark, then it is evident it is burnt out inside.

In some instances a coil may have its insulation short-circuited for only half its length of winding and would give a spark. If a short circuit was near the beginning of the winding, it would not spark at all.

Testing the Coil

If a multiple-cylinder engine, test each unit separately until it is determined which coil is missing. After assuring yourself the missing is not caused by a spark plug, weak batteries, carburetion, or other causes, then test the coil itself.

Vibrator Coil Tester

A very serviceable device for testing Ford coil units, single and double contact lamps, as well as spark plugs, is the B.W. Tester[1] illustrated above.

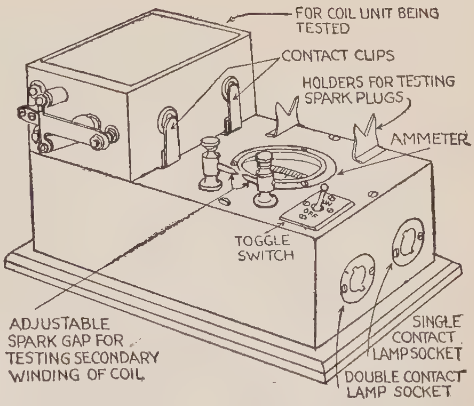

FOR COIL UNIT BEING TESTED
CONTACT CLIPS
HOLDERS FOR TESTING SPARK PLUGS
AMMETER
TOGGLE SWITCH
ADJUSTABLE SPARK GAP FOR TESTING SECONDARY WINDING OF COIL
SINGLE CONTACT LAMP SOCKET
DOUBLE CONTACT LAMP SOCKET

Fig. 3. The "B W" tester. Designed for testing Ford coil units, spark plugs, and lamp bulbs.

To test a Ford coil: The coil to be tested is slipped into place so that the contact springs touch the proper contacts. A 6-volt battery is attached by means of cord and test clips. The ammeter on the Tester has zero (0) center, and it is proper for it to read in either direction. The adjustable spark gap should now be set with one-quarter inch (¼″) gap. This may be measured by gauging the gap with one-quarter inch (¼″) drill or rod. This gap is much greater than the gap in the spark plug, due to the fact that a spark takes place in the open air, while in the case of the spark plug, the sparking takes place in a highly compressed charge in the cylinder which requires the spark gap to be considerably smaller.

The switch is now closed, and the ammeter should give a fairly steady reading of about 1½ amperes. While this current is flowing, a continuous flow of sparks should follow across the spark gap. If the flow of sparks is not constant, this indicates that the vibrator contacts of the coil have probably become pitted; they should be removed and smoothed with a fine file. The adjusting screws on the coil should be turned one way and another until the stream of sparks appears the hottest.

If at this point of adjustment the current is lower than 1.2 amperes, then the vibrator spring on the coil is weak and should be strengthened as follows: Remove the cross-piece that carries the adjustable contact. Now note the distance that the vibrator spring stands away from the coil head. Increase this distance slightly by bending the vibrator spring away from the coil head; then replace the adjusting cross-head, and the current will have increased as well as the stream of sparks. If the current is higher than 1.8 amperes, then the vibrator spring is too strong and stands away too far from the head of the coil. In this case the vibrator springs should be bent inward.

If the ammeter pointer flies over to the end of the scale, then this indicates that the vibrator contacts are stuck together. If in this case they are worn out and cannot be smoothed with a file, they should be replaced.

If it is impossible to get a reading of 1½ amperes and a continuous hot spark across ¼″ spark gap, after making all the adjustments named above, the coil is no longer serviceable and should be replaced.

To test a spark plug with the tester shown above: Connect the Tester to a source of power, as instructed above. Place a Ford coil into the coil guides in the same manner as in testing the coil. Now open the spark gap to at least ½″, then place the spark plug into the rack provided on the Tester and close the switch. Where it is possible, it is a good idea to open the spark gap of the spark plug to about ¼″, so as to get the same condition in the open as with the small gap in the highly compressed cylinder.

If the spark plug is only foul from carbon deposit on the porcelain, the carbon will be immediately burned off. If there is a cracked procelain, the spark will short-circuit through this crack and no spark will flow at the spark-plug gap, and the plug is no longer serviceable.

To test lamp bulbs: Both the single and double-contact sockets provided for testing lamps are directly connected to the transformer, and all that is necessary to test lamps is to connect to source of power as instructed above and push the lamp into the proper socket.

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[1] This can be secured of A. L. Dyke, Electrical Department, Granite Bldg., St. Louis, Mo., price $11.65.

Causes of Spark Plug Missing

The usual cause of missing of explosion is that the spark plug becomes fouled by carbon, or soot is deposited on the porcelain insulation, causing the plug to become short-circuited. It is generally caused by using a poor grade of oil or loose piston rings, which permits the oil to pass too freely into the head of the cylinder.

Other causes are sticking vibrator points, a defective commutator, or a weak battery.

When mis-firing occurs, particularly when running at high speeds, it would be advisable to inspect the commutator, as the fiber may be worn so that the roller touches only the high spots, or it may be that the roller has worn out of round and consequently forms imperfect contact on all of the points.

At slow speeds, mis-firing is apt to be the result of improperly seated valves or air-leak in the carburetor or cylinder-head gaskets.

A weakness in compression may be detected by lifting the starting crank slowly the length of its stroke for each cylinder in turn. In rare instances an exhaust valve may become warped by the engine becoming overheated, in which case the valve seat will have to be reground or the valve replaced.

When starting to test for the trouble, first determine if the missing occurs when running slow or when running fast, or if at all times. Also be sure the carburetion is right.

Testing for Miss with Vibrators

We will assume the engine is a four-cylinder engine.

To ascertain which, if any, of the four plugs are fouled with oil, short-circuit with carbon, or inoperative from some other cause, open the throttle two or three notches to speed up the engine; now hold your two fingers on two outside vibrators so that they cannot buzz. The evenness of the exhaust will show that the other two are working correctly and that the trouble is not there; or an uneven exhaust will indicate that it is between the two that are free.

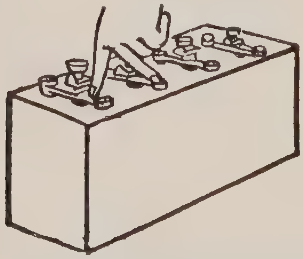


Fig. 4. Testing for missing with vibrators on the coil.

If the two cylinders fire evenly, change the fingers to the two inside vibrators and again listen to the exhaust. Having ascertained in which pair the trouble is, hold down three fingers at a time until you find the one which does not fire.

Cylinder No. 1, we will say, is the front cylinder, and they number in rotation 1, 2, 3, 4. No. 1 coil unit would be the one farthest from the steering post (left-side drive), and they number 2, 3, 4 to the left.

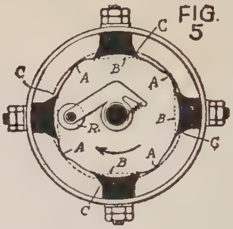


FIG. 5

Causes of commutator troubles (Fig. 5): (1) worn metal segments (C) often cause missing by not making good con act. (2) The commutator may also become loose on the shaft and get out of time. (3) Spring weak. (4) Loose connections at binding posts. (5) Depressions worn on face of fiber on which the roller (**R**) travels, resulting in the roller jumping (at high speeds) almost over the metal contacts (**C**). The roller (**R**) and pin of the revolving part will also probably be found in bad shape. To repair, turn down in a lathe or replace with a new one. (6) Grease will coat the insulated fiber ring (**C**) from one segment to another, and cause a short circuit. Too much oil will also cause a glazed surface over the segments (**B**), and good contact cannot be made between roller (**R**) and these metal segments.

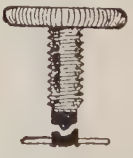
Dressing Platinum Points

Every time the contact separates, a minute quantity of platinum is transferred from one contact to the other. If the current is reversed by means of a reversing switch, the lost platinum will be transferred back to some extent. This is called depolarizing. Therefore, when using "direct" current for vibrator-coil ignition, it is a good idea occasionally to change the connection on the battery. The current flowing in one continuous direction causes this pitting of points. Where "alternating" current is used, as with a magneto, the points do not pit as much, because the current is changing its direction of flow.

On the Ford, the magneto generates "alternating" current. Therefore the pitting of points is not so bad, but when the car is run continuously at high speed, naturally the magneto generates a higher voltage, hence pitted platinum points.

Testing Platinum Contact Points

Imitation platinum will also cause "pitting." You can test to see if genuine platinum has been used by putting nitric acid on it. If it eats into the metal, it is not genuine platinum. A jeweler's stone can also be used for this test. Ask any jeweler.



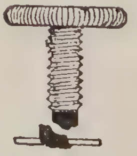


Fig. 6 (left). Shows pitting, and is the state to which a properly set contact-point finally arrives.

Fig. 7 (right) is the result of a badly set contact which is worn unevenly. The platinum would have to be filed away right down to the steel, and the spark would then soon eat the rivet hole and cause serious mis-firing.

Dressing Ignition Contact Points

To dress the platinum points, remember that the main requirements are to remove only as small an amount of the valuable metal as possible and to trim the surface dead level and smooth. In making the final adjustment of the screw, do not set the platinums closer than necessary to give a good, steady buzz of the vibrator.

For dressing the points (also magneto points), suitable small jeweler's files are sold at accessory shops. These are very thin and finely cut files.

If the surfaces are merely blackened, insert a strip of 00 emery paper between the two points, and pull the paper through them a few times.

An oil stone is excellent for dressing points, especially Tungsten points, which are too hard to file. An example of dressing the tungsten contact points on an oil stone is shown in Fig. 8.

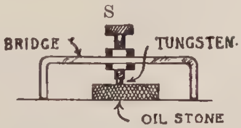


Fig. 8. The coil point screw (S) is clamped, by means of two nuts, to the center of the metal strip. The strip is moved forward and backward over the oilstone, thus securing a true surface on the tungsten point, which makes it last much longer without grinding.

Platinum and Tungsten Contact Points

Procure **genuine platinum points** when purchasing new screws or vibrator springs, if possible. Platinum-iridium and Tungsten metal points are both used. Imitation points will "pit" and burn together and cause missing.

Platinum-iridium alloy, which consists of 80 per cent platinum and 20 per cent iridium, should be used on all magneto contact-breaker points. Pure platinum would hammer under action of the interrupter, therefore iridium, which is harder, is used with it.

Tungsten points are quite often used on coil and battery systems because of the extreme hardness and infusibility of this metal, but its disadvantages for magneto use are oxidation of points when heavy currents are carried. The oxidation results in a high resistance oxide which makes it difficult to start, and the arcing makes it very difficult to distinguish when a condenser is defective. When platinum-iridium contacts are used, extreme arcing is always an indication of a defective condenser. Tungsten points therefore require a greater condenser capacity to overcome arcing than platinum does.

Platinum-iridium is best for all contact points, but, as stated, tungsten can be used on coil and battery systems. See also Index for "Platinum points for magneto contact breakers."

The foregoing applies to contact points on vibrator coil screws and springs.

Spark Plug Gap Suggestions

Do not set spark plug gaps over 1/32″ apart. A longer gap will likely cause a mis-fire.

When testing the spark, by removing the wire from the plug, do not separate the terminal wire from the plug or engine frame more than 3/8″, as it will strain the coil and break down the insulation.

INSTRUCTION No. 22

TESTING IGNITION COILS OF NON-VIBRATOR TYPE: Condenser Tests; Resistance-Unit Tests

As an example of the procedure for testing an ignition coil of the non-vibrator type, the North East Ignition system as used on the Dodge car will be used.[1]

See Index for "Dodge wiring diagram" for the internal circuit of this system, and study it carefully.

LOCATING IGNITION TROUBLE: N. E. IGNITION SYSTEM (MODEL "O")

1. Whenever it is determined that trouble has been located in the ignition mechanism or in the coil windings, and that it is not in the spark plug or loose connections, or due to a run-down battery, then turn off the ignition switch and remove the distributor head in order to expose the interior of the breaker box. Crank the engine slowly until it is seen that the breaker cams come together.

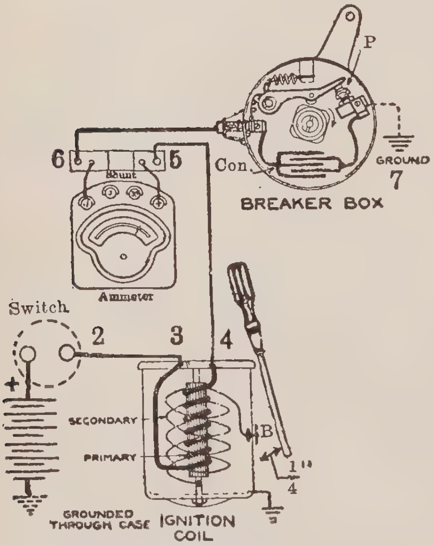


Fig. 1. Testing the North East ignition coil as used on the Dodge.

2. Disconnect the wire at the contact breaker leading from the switch to the contact breaker, and insert a low-reading ammeter in the circuit, as shown in Fig. 1. (The ammeter shown is the model "280" Weston.)

Note. The use of a screwdriver is not resorted to in this test. Fig. 1 is used to illustrate several different tests.

3. Turn on the ignition switch and note the amount of current through the primary circuit. With a battery voltage of 12 volts, the normal amount of current consumed by the coil with the engine idle and breaker contacts (**P**) closed, is approximately 2.5 amperes. This will determine if the primary circuit of the coil is in proper shape.

Note. It is best to use first the 30-amp. shunt, if a Weston model 280 instrument is used, because, if there is a short circuit it will read far more than 2.5 and burn out the meter. If a low reading is thus obtained, then connect the 3-ampere shunt and use the lower reading scale, which is more accurate for low readings.

To Test the Secondary Winding

a) **A ground** in the secondary from the secondary winding to the coil box cannot be tested with an ordinary test lead, because the inner end of the secondary coil is normally grounded to the core. A ground from the coil to the core can usually be indicated by burning of the insulation appearing on the outside of the coil where the spark has punctured it.

b) The simplest method of **testing for a short circuit of the secondary winding** is to substitute another coil temporarily for the suspected one, and to compare their behavior under similar operating conditions.

c) **To test for an open circuit in the secondary winding:** Remove the high-tension terminal bushing (**B**) (Fig. 1) on the side of the coil, and then run the distributor unit at a moderate speed with ignition switch on, while a screwdriver is held against the housing with its tip about ¼" from the high-tension contact button (**B**) on the ignition coil. If no spark jumps, the winding is probably open-circuited. Before accepting this as final, however, be sure the primary coil winding is in proper shape, because the induced current comes from the primary coil.

If the primary winding test shows abnormal ammeter readings, either more or less when the meter is inserted between switch, coil, and breaker box, as in Fig. 1, or if there is an open circuit, then other portions of the circuit should be tested as follows:

1. **Test the wiring from coil to switch** by placing one lamp test point on 2, and one on 3, then from switch to ammeter (2 to 5), and ammeter to breaker (6 to 7), to see if these are open circuits, grounds, short circuits, or loose connections. Also examine the switch and coil connections. The 110 or 220-volt direct-current test lamp and leads (Fig. 3 can be used for this, but be sure no current is passed through the ammeter and that the ignition switch is open.

2. **Test the battery:** If the battery shows 2.6 volts across each cell, it is fully charged. If it shows 1.8 volts or less per cell, it is discharged. However, voltmeter readings are not accurate, for if a battery is sulphated, unreliable high-voltage readings will result when tested while on charge. Therefore a battery should be tested on discharge also. See Index for "Testing a storage battery on discharge."

3. **Examine switch, ammeter,** and also the **storage battery connections** for loose or poor connections or grounds. Quite often poor or loose connections on

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[1] Through the courtesy of N.E. Electric Co.

the battery or switch will cause lack of proper current supply, as a loose connection not only causes missing, but offers resistance and cuts down the current supply.

To Test the Condenser[1]

The condenser in the N.E. Dodge, Model "O" interrupter is in the contact breaker housing, and connects across the points of the contact breaker. One point of the contact breaker in this system, is grounded, and so also is one end of the condenser (see Fig. 2). The purpose of the condenser is explained on page 191. On some ignition systems the condenser is placed on the coil.

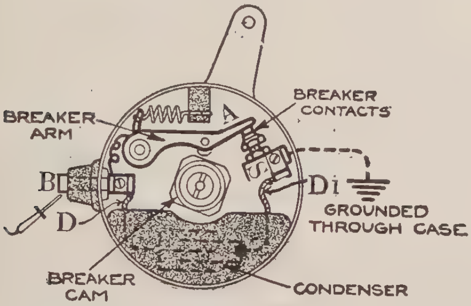

Fig. 2. Testing condenser on N. E. (Dodge) model "O" interrupter or contact-breaker.

To test condenser for a ground: Disconnect condenser leads (**D, D1**) from the contact breaker mechanism (Fig. 2). Hold one test lead (110 or 220-volt direct-current lamp and leads) against the condenser case, and touch the two condenser leads (**D, D1**), one at a time with the other lead. The test lamp will light if there is a ground; if the condenser is in proper shape, the lamp will not light.

To test condenser for a short circuit: Separate breaker contact points. Place a test lead on each of the condenser terminals (D, D1). If the condenser is short-circuited the lamp will light; if nothing is wrong, it will not light.

To test condenser for an open circuit: This test should be made with a test lamp from alternating current. Separate the contact breaker points. Hold one test lead on one terminal (D) of the condenser and touch the other condenser terminal (D1) lightly with the other test point. If the condenser is in proper condition, a slight spark will occur every time the test lead is applied. If the condenser is open-circuited, no spark at all will occur. In either case the test lamp will not light, because even with a normal condenser, the current permitted to flow through the test lamp is so small that no visible effect will be produced.

To Test Contact Breaker

To test contact breaker for a ground: Disconnect the wire to the contact breaker binding post at (B), (Fig. 2). Separate the contact points. Touch one test lead to the shell of the contact-breaker box and the other to breaker arm (**A**). The lamp should not light if everything is correct. If the breaker is grounded it will light. The condenser should be tested first, as a short-circuited condenser would cause the lamp to light, since it would be in the circuit.

Note. If the contact breaker has two binding posts and has an insulated return instead of a grounded return, the test should be made with breaker points closed in order to include the stationary contact point (S), as well as the rest of the breaker mechanism.

To test contact breaker for short circuit: Disconnect wire at (B) (Fig. 2) to contact breaker. Separate points. Place one test lead on the terminal (B), and the other on the stationary contact (S). If the lamp lights there is a short circuit. Be sure the condenser is in good order, for the reasons given in the test immediately preceding. If the lamp does not light it is without defect.

To test contact breaker for open circuit: Make the same test, except that the contact points should be closed instead of being separated. If the test lamp fails to light when the breaker contact points are closed, an open circuit is indicated.

To Test Primary Winding

To test primary winding of ignition coil for ground: Remove the coil-housing cover and disconnect the coil leads from the terminal block on the cover (Fig. 3). Hold one test lead against rod (6) in the center of the coil and touch the lead to the primary winding terminal (3), then (4). The test lamp will light if there is a ground.

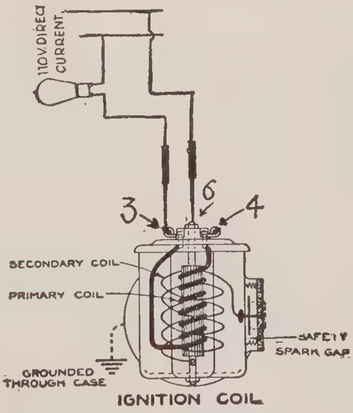

Fig. 3. Testing primary winding of ignition coil.

To test primary winding for an open circuit: Place one test lead on (3) and the other on (4). If the lamp does not light there is an open circuit.

To test primary winding for a short circuit: See paragraphs 2 and 3 under "Locating Ignition Trouble." If the ammeter reads more than 2.5 with switch closed, points together, and engine idle, it indicates a short circuit either in the primary winding or elsewhere in the circuit.

Operating Test: Bench Running Test of N.E. Ignition System (Model "O")

The N.E. ignition test[1] is made on a special test bench (Fig. 4) with apparatus designed for the purpose.

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[1] A method where many coils are tested is to have an interrupter connected with a drive system of some sort. See Fig. 12, page 230.

[1] Through the courtesy and with the permission of the North East Electric Co., Rochester, N.Y.

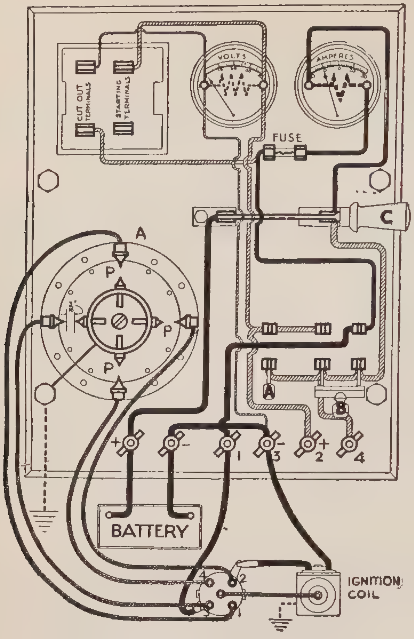

Fig. 4. N. E. ignition test-board for testing the ignition system, generator, and cut-out.

The ignition unit is placed on the test-bench and connected to a motor which drives the ignition unit under conditions as nearly like those encountered in service as practical, and is carried out with a range of speeds equal to that of the engine. The test-board shown in Fig. 4 is the N.E. testing outfit for testing the ignition system, generator, cut-out, etc.

The ignition unit, consisting of distributor, interrupter, and coil, all in one unit (see Index for "Dodge ignition unit"), is connected with a motor which drives it at various speeds as stated above. The distributor is connected with an adjustable spark device (Fig. 4), with the points (**P**) adjusted to ¼" gap. The unit is first driven at 1,200 r.p.m., and switch (**C**) is closed. High-tension sparks are at once produced at points (**P**). The speed is varied from 1,200 to 2,000 r.p.m. A low-reading ammeter is inserted in the primary circuit as shown.

At 500 r.p.m. with a 12-volt fully charged battery, the consumption should be nearly 1 ampere; at 1,200 r.p.m. approximately 0.8 ampere; and at 2,000 r.p.m., 0.6 ampere.

The black wires show the primary circuit of the coil connected with battery, switch, and ammeter. For instance, the primary circuit is from battery to (+) terminal, to switch, to ammeter, to fuse, to terminal of switchboard 1, to contact breaker, through points, to primary coil, from other end of coil primary to (−) terminal (3) on switchboard, to (−) terminal of battery.

The secondary circuit of the coil is from the secondary terminal of the coil to the center of the distributor, thence from terminals on distributor to points (**P**) on spark tester (**A**), through points to ground, to ground of coil.

A coil on a test should jump ¼" in the open air without missing. If it will not jump this gap continuously, then it is certain not to jump the spark-plug gap inside the engine which is under compression and thus shows greater resistance.

For timing the N.E. ignition system on the Dodge, see Index under "Dodge ignition timing."

REMY NON-VIBRATING COIL AND CONDENSER CONNECTIONS

The condenser is always connected or "shunted" across the interrupter points (**P**) of all high-tension coil primary circuits and magnetos. It can be placed **on the coil,** as shown in Fig. 5, or **on the interrupter,** as in Fig. 6.

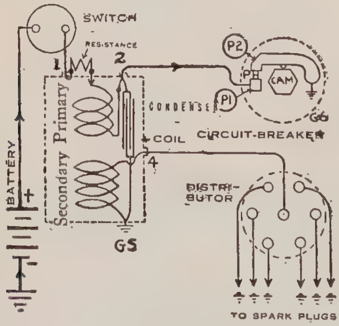

Fig. 5. Remy grounded ignition system using a non-vibrating cylindrical type, two-terminal coil with condenser in coil. Note that the condenser is across the contact-breaker points (P).

The primary circuit (Fig. 5): From (+) of battery, to switch, to coil terminal 1, through resistance unit, through primary winding to coil terminal 2, to interrupter stationary contact (P1), through movable contact (P2), to ground, to (−) ground of battery.

Note that the condenser in the coil is connected across interrupter points (P).

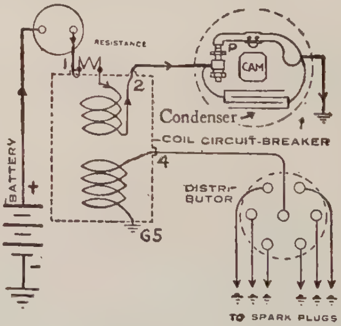

Fig. 6. The same ignition principle as shown in Fig. 5, but with the condenser in the interrupter housing. The condenser is shunted across the contact-breaker points (P), as in Fig. 5.

The primary circuit (Fig. 6): From (+) of battery, to switch, to 1, through resistance unit, through primary winding to 2, through points (P) on interrupter, to ground, to (−) ground of battery.

Note that the condenser in the interrupter housing is connected across the interrupter points (P).

In order to explain the importance of connecting the proper wires to a coil where a condenser is in the coil, the diagram (Fig. 7) is used to show how the condenser can be cut out of action to a great extent, thus reducing the efficiency of the coil and causing sparking at the interrupter points.

Primary circuit (Fig. 7) (connected wrong): From (+) battery to 2, through primary winding, through resistance unit, through points (P), to ground, to (−) ground of battery.

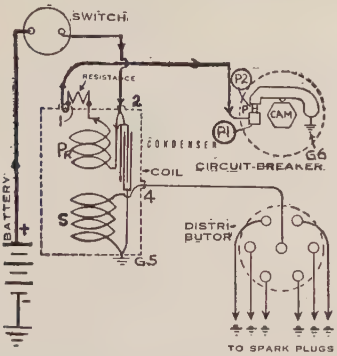

Fig. 7. The same ignition system as in Fig. 5 with leads to and from the ignition coil **connected wrong**, thus disconnecting the condenser from across the contact-breaker points where it is required.

Note that the condenser is not directly across the interrupter points (P); the primary winding and resistance unit are between one end of condenser (2) and (P1) of interrupter. The proper connection is shown in Fig. 5. Coils are usually marked (B) for battery, and (T) for timer. Thus the terminal from the battery leading to the switch and from the switch, should connect with (B) or (1) on the coil. See page 209, explaining Remy 2 and 3 terminal coils; see also page 213, for Delco coils.

Remy Condenser Instructions and Tests

Condenser trouble will usually be distinguished by severe arcing at breaker contacts.

Test for shorted condenser: Disconnect the condenser, or, if condenser is inside of coil, disconnect coil. Connect terminals leading to the condenser, across 110 volts A.C. or D.C. with a lamp in series. If lamp lights, the condenser is short-circuited or broken down between layers. Test points from lamps are indicated as (T) (T1) (Figs. 8, 9).

On systems using grounded ignition, that is, grounded primary winding in ignition coils (Fig. 8), connect test point (T) to post (2), to which the lead from the breaker is attached, marked "Timer," and to base of coil with test point (T1), for this test.

Note. If primary winding has become grounded in this type of coil, the lamp in this test will be lighted the same as if the condenser is shorted. However, if the breaker points are badly and are burned, it can be assumed to be condenser trouble.

On systems using insulated ignition (primary winding not grounded), (Fig. 9), connect test point (T) to center post (2), marked "timer-switch" and connect (T1) to outside post (3) which has not the resistance unit connected to it.

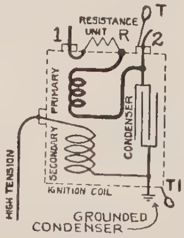

Fig. 8

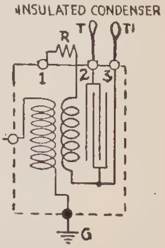

Fig. 9

Fig. 8. Remy ignition coil (two-terminal type) with condenser grounded.

Fig. 9. Remy ignition coil (three-terminal type) with both terminals of condenser insulated.

Open condenser: An open condenser may be one which is disconnected inside of the box or coil tube, or one which has opened up between layers so that its capacity is very low. With an open condenser or one which has no capacity from any cause, very severe arcing will occur at contacts as stated above.

Capacity test: In case 110 volts D. C. is available, a capacity test can be made by connecting across the condenser with the test lamp in series, then disconnect the test lamp and bring the condenser terminals together. If a good spark is obtained, the condenser is all right. A. C. current is not as dependable for this test as D.C. current, although with proper care fair results can be obtained. In using A.C. current a good spark will not be obtained every time the condenser leads are touched together, but only occasionally.

Ignition coil test: In all battery ignition systems a good spark should be obtained at maximum engine speed. For testing a coil in the open through ordinary spark-gap points, which are well cleaned, a good coil will jump a gap of not less than 5/16″ when the coil is connected up in the regular way at 3,600 or less sparks per minute with breaker points opening at a point between .020″ and .025″. Test coil for at least one hour until well heated up, according to the instructions given above, before mounting on the car. A coil which cuts out or misses under these conditions should be taken out of service.

DELCO INSTRUCTIONS RELATIVE TO TESTS OF RESISTANCE UNIT AND CONDENSER

Delco ignition coils, interrupters, and distributors, as well as adjusting Delco timing contacts are explained on pages 213–221. In the present discussion we deal with the Delco ignition resistance unit and condenser tests.

Resistance Unit Tests

Resistance units sometimes break down or burn into, with the result that there is no spark at all, or a very weak one.

Connect the coil so that the resistance is cut out and note if the spark is improved. See pages 213, 214, showing resistance on coils.

A resistance unit, if short-circuited, will permit excessive current to pass through the contact-points, and this will cause them to be burned or pitted excessively, although the ignition may appear to be very good and without a miss.

If the resistance unit is connected properly, it will heat up; if it does not heat up it will indicate that the resistance unit is not in the circuit. See page 198, explaining the purpose of a resistance unit. Also refer to page 231, relative to the resistance unit becoming thin, owing to heat, thus weakening the spark.

Condenser

If the condenser is not in good condition, the contacts will burn and pit rapidly, owing to the excessive arcing when they are separated, but the ignition will be rather bad if, indeed, it will operate the engine at all, so that the burning of the contacts, due to a bad condenser, can, as a rule, be distinguished from burned contacts due to a high voltage or to a short-circuited resistance unit.

A good test for the condenser, by which to show whether it is in good condition or not, is to connect it up in accordance with the circuit diagram shown in Fig. 10. For this test a 110 or 220-volt source of direct current is necessary, a lamp of the same nominal voltage as the circuit, and the wiring shown. The lamp is connected in series with the line and the condenser across the line.

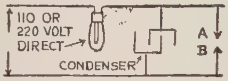

Fig. 10

If the terminals (A) and (B) are connected together, a very faint spark, which has a snapping sound similar to the sound made when leads from a storage battery are attached, should occur. If the condenser be disconnected from the circuit, a much different arcing will be observed, somewhat longer and yellower, and without the distinct snapping sound mentioned previously.

If a condenser, known to be good, is tested in this manner once, it will enable the observer to distinguish very readily between the sparks at the points (A) and (B) obtained with a good condenser and a bad condenser, as a bad condenser will give the same quality of spark as if no condenser at all were in the circuit. This test is a mere qualitative test, but this is about the only satisfactory test which can be found which does not require expensive apparatus.

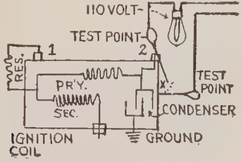

Fig. 11

If a condenser is in coil, it can be tested in the same manner as shown in Fig. 10, by placing the test points (Fig. 11) so that the same effect can be had. One end of the condenser is usually grounded.

Condenser and Coil Test Suggestions

Possibly the most common test is to disconnect the doubtful condenser and substitute one that is known to be correct. The results obtained when using the good condenser will show up the action of the original condenser.

For instance, if an excessive amount of sparking is at the contact points, it is probably due to a defective condenser. Therefore if a good condenser is connected right across and over the condenser to be tested, and if the sparking stops, then you may know the trouble is with the old condenser.

Where there are many coils and condensers to test, it is a good idea to rig up a contact breaker on the bench (Fig. 12), so that it can be driven at various speeds, and then to have a good condenser across its points which can be connected and disconnected by a switch (SW). Then when a coil is tested it can be connected with the contact breaker. If it has a condenser in the coil, disconnect the condenser on the contact breaker; then watch if it sparks at points (P). If it does, cut in the good condenser.

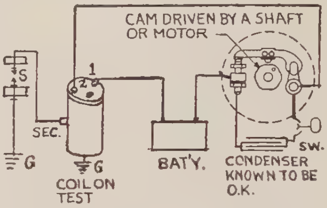

Fig. 12

Also **watch the spark at secondary test points** (S). It should spark for at least ¼″ to 5/16″ without missing for, say, 50 or 60 sparks. Be sure the coil is well warmed up when making the test.

If the condenser of the system being tested is in the contact breaker, it can be tested without removing, by connecting a good condenser so that it will be across the points of the contact breaker and noting results.

Home-Made Tester for a High-Tension, Non-Vibrating Coil and Condenser

This device (Fig. 13) consists of a sheet copper plate about 6″ wide, by 8″ long, by ⅛″ thick to serve as a base.

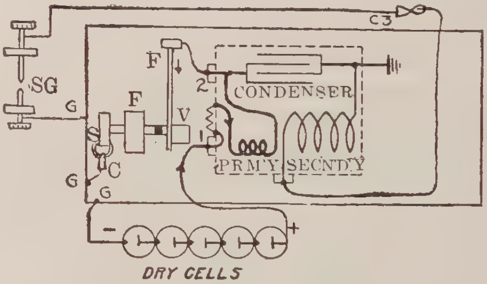

Fig. 13

A magnetic vibrator (V), similar to a vibrator on a high-tension vibrator coil, is mounted on the plate with fiber blocks (F), as shown.

The purpose of the device is to produce a vibrating action on the end of a coil, thus producing the same effect as a vibrator coil. By this method the strength or intensity and the constant steady spark of the secondary can be tested.

When testing a coil (Fig. 13), it does not make much difference which end is used; furthermore, the magnetic effect is so great that the vibrator will vibrate directly on the metal shell. It is best, however, to have the vibrator knob (V) vibrate against the end of the coil if possible. Either end could be used.

Fig. 13 illustrates a **Remy two-terminal coil** with a condenser in the coil. With coils where the condenser is in the contact breaker, they should be tested separately with a 110-volt test light, as previously explained.

The primary circuit through the coil is from (+) of battery to (1), through primary winding to (2), through vibrator blade (V), through points, to vibrator screw, through clamp (C), to ground of plate (G), to ground on plate, to (−) of battery. The condenser on the test outfit is across the points of the vibrator. By adjusting the vibrator screw (S) the vibrator blade (V) will vibrate, causing a spark at secondary spark gap (SG).

The secondary circuit is from the secondary winding to a clamp (C3), thence to a spark gap tester (SG), which can be made of two finely pointed brass rods through a fiber support. The gap of the points should be adjusted to ¼″ or 5/16″.

Condenser Test

When making the condenser tests, the object is to see if there is excessive sparking at the vibrator points. If so, it is probably due to a defective condenser and it should then be tested separately with test points as described in page 227.

A good plan is to **have another condenser known to be in good** condition. If there is excessive sparking, place the terminals of the good condenser across the vibrator points, by placing one terminal at (2) and one on screw (S). If the sparking then ceases, it is clear that the condenser in the coil is defective. A Delco No. 13057 (Packard) condenser which has two leads would be a suitable condenser for use in this manner. See Index under "Testing a magneto condenser," which shows a similar method of using a device as herein described.

The quality of the spark should be closely observed when testing the condenser. If the spark at the tester gap (SG) is fiery, showing glints of purple or purplish-red flame, the coil is normal. If the spark is thin, thread-like, and whitish or very light blue, and there is a snappy spark at the breaker points, the indication is that the condenser is punctured. This can then be checked by placing an extra condenser, known to be in good condition, as described above. If the coil will deliver a good spark when connected to a known normal condenser and will not give a spark when the condenser is disconnected, the proof is conclusive that the coil condenser is defective.

A great deal of stress is laid on the condenser test. This is advisable for the reason that condenser failure causes about 90 per cent of coil failures; therefore, when testing coils the condenser is always suspected. While open and short circuits in the coil windings do sometimes occur, they are comparatively rare and need hardly be considered.

Coil Test

Operate coil and see if it will produce a spark continuously at gap (SG) for at least one hundred steady sparks without missing with gap $\frac{5}{16}$″. If there is a safety gap on the coil being tested, the gap (SG) should be slightly less than the gap of the safety gap on the coil.

A high-tension coil when in operation at normal speed should draw about 2 amperes.

Resistance Unit Test

In testing a coil such as the Delco or Remy with a resistance unit in it, test with the resistance in circuit and with the resistance out of circuit. This can be done by making connection on the opposite side of it from 1 (Fig. 13) thus cutting it out.

This may be the cause of a weak spark, because the resistance burns out at times, and, if not burned into, may be thin (owing to heat), and thus reduce the quantity of current going through it, consequently weakening the spark. By cutting it in and out of circuit, the intensity of the spark at gap (SG) can be observed.

Many coils are equipped with resistance units. If current cannot be passed to the coil through the regular terminals, it may be suspected that the resistance unit is burned out. This can be determined by touching a test wire to the central nut which holds the unit in position. This has the effect of cutting the unit out completely and sending the current directly to the primary windings. If current does not flow, the indication is that there is a break between the resistance-unit screw and the end of the coil winding inside the cartridge.

If a coil is defective, in that the secondary spark is weak or misses, or if the condenser permits excessive sparking at contact points, thus causing a weak spark, then the chances are that it would cost more to repair the coil than it would be worth.

In some instances the condenser ground comes loose in the coil where it is soldered. This can be remedied by soldering.

Ignition resistance units can easily be fitted if burned out, or condensers can be replaced when in contact breakers, but if the coil is defective otherwise, do not attempt to repair it. Send it to A. L. Dyke, Elect. Dept., St. Louis, Mo., or to the manufacturer, and obtain a new one.[1]

Parts: Contact-breaker arms and screws, ignition resistance units, condensers, etc., can be carried in stock for different ignition systems most in use in any particular vicinity. Such parts can be secured of the manufacturer or of A. L. Dyke, Elect. Dept., St. Louis, Mo.

The United Motor Service, Detroit, Michigan, supplies parts for Remy and Delco apparatus, and issues a catalog of parts.

Clamps for connecting wires, such as shown in the illustration, are very handy for all testing purposes. They can be obtained of A. L. Dyke, Elect. Dept., St. Louis, Mo. The size is No. 8, trade No. 90239, price 30 cents each.

Spark-Plug and Lamp-Bulb Portable Testing Outfit and Test Board

A spark plug and lamp testing portable outfit illustrated in Fig. 14, is handy for carrying from one part of the shop to another, for testing on different cars. Several dry cells are placed in a long, narrow

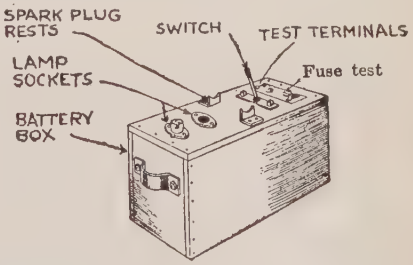

Fig. 14. Spark plug and lamp testing portable outfit.

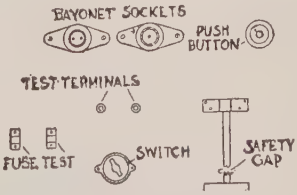

Fig. 14A. Showing parts as mounted on the top of the testing outfit shown in Fig. 14.

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[1] To find the make of ignition system used on different makes of cars, see Index under "Specifications of Leading Cars."

box, and connected through a switch to the testing terminals. The switch throws the two types of lamp sockets (single and double contact) into the circuit, and the push button connects the batteries through the spark coil to the plug-testing rests. This unit is compact enough to be taken directly to the job.

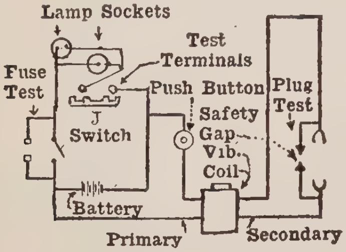


Fig. 15. Wiring of a test board for testing bulbs, fuses, spark plugs, and horns. This can also be used as a guide in connecting the portable outfit shown above.

A test board, which can easily be constructed, for testing spark plugs, coils, lamp bulbs, fuses and circuits, is shown in Fig. 15. Quite often a lamp does not burn. It may be due to the lamp being burned out, or to an open circuit in the wiring. In order first to determine if it is due to the lamp bulb, it can be quickly tested. If it is in proper condition, then the trouble is in the wiring. This also applies to the fuse. When the test terminals are not being used to test a circuit, connect jumper (J) across them to permit testing of lamps and fuses.

Testing an Electric Horn

The electric horn can be tested by placing an ammeter with the 30-ampere shunt in the circuit, as shown in Fig. 16. Then adjust to take the least possible current. The average horn draws from 3 to 8 amperes, according to its size; see Index under "Electric horns." The ammeter can also be used to test the horn for short circuit or open circuit.

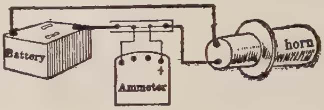


Fig. 16

Test Lamps and Test Points

This subject is treated farther on. See Index.

Manufacturers of Ignition Devices

Bosch: American Bosch Magneto Corp., Springfield, Mass.
Delco: Dayton Engineering Laboratories Co., 329 First St., Dayton, Ohio.
N.E.: North-East Electric Co., Rochester, N.Y.
Wagner: Wagner Electric Mfg. Co., 6400 Plymouth Ave., St. Louis, Mo.
Berling: Ericsson Mfg. Co., 1125 Military Road, Buffalo, N.Y.
Connecticut: Connecticut Telephone & Electric Co., 61 Britannia St., Meriden, Conn.
Simms: Simms Magneto Company, 278 N. Arlington Ave., East Orange, N.J.
Westinghouse: Westinghouse Electric & Mfg. Co., 82 Worthington St., Springfield, Mass.
Remy: Remy Electric Div. of General Motors Corp., 1623 E Grand Blvd., Detroit, Mich.
Splitdorf: Splitdorf Electrical Co., 98 Warren St., Newark, N.J.

INSTRUCTION No. 23

SPARK PLUGS: The Missing Spark; Spark Intensifier

Spark Plugs

The purpose of spark plugs is explained on page 188. There is usually one spark plug for each cylinder.

Location of spark plug in cylinder: The spark plug can be placed in the cylinder as follows: over the center of the piston, over the exhaust valve, or over the inlet valve. The first position is not the best, as it is found that it too easily becomes fouled. If screwed above the exhaust, it will likely miss fire; this is on account of the dead gases surrounding it. The correct position is **over the inlet valves,** as it will be kept cool by the inrush of fresh gas, and it is in an atmosphere perfectly suited for explosion directly the spark appears, as this is the more perfectly scavenged part of the cylinder, i.e., in the direct path of the fresh gas.

The plug is usually placed over the inlet valve on "T" or "L"-head cylinders. In the overhead valve type, the plug is placed in the top center or in the side of the cylinder. It is exposed to the full heat of the explosion when overhead, directly in the center of the bore; consequently in a high-compression engine, a well-made plug, gas-tight and free of electrical leaks, must be used.

Double ignition: On the Stutz and Pierce-Arrow engines, there are two spark plugs in each cylinder, which is an advantage, in that a very hot spark is produced which ignites all of the gas more quickly, thus saving in gasoline consumption. One spark plug is placed on the exhaust side of the cylinder and the other spark plug on the inlet side. See Index for "Pierce-Arrow ignition and wiring diagram."

As previously stated, where one spark plug per cylinder is used, the usual location is in the neighborhood of the inlet valve, as it should be surrounded by fresh gas that enters during the inlet stroke. If it is located on the exhaust side, dead gas will collect about the plug electrodes and cause missing, and also heat.

It is also desirable to have the plug where the water jacket surrounds it, as in Fig. 4, to avoid overheating, else the plug electrodes are liable to be overheated and become incandescent and to cause pre-ignition.

Fig. 1

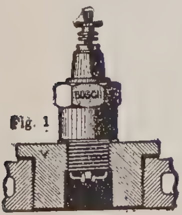


Fig. 2

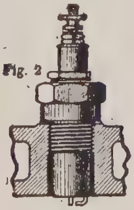


Fig. 1. Valve cap too thick; out of the path of the gas.

Fig. 2. Recess around the plug shell retains heat.

A poor location is shown in Fig. 1. When set in a thick valve cap (V) with short threads, dead gas accumulates in the recess and causes missing at slow speeds. Fig. 2 shows another poor method. The recess accumulates heat, and metal extension is liable to result in a plug becoming red hot and warping electrodes, altering the size of the gap.

Fig. 3

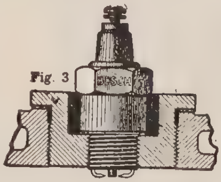


Fig. 4

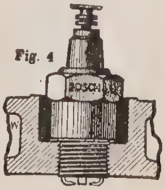


Fig. 5

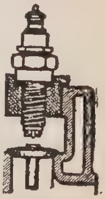


Fig. 3. Correct position of plug in valve cap.

Fig. 4. Correct position of plug when set in water jacket.

Fig. 5. Plug reach too long.

A good location is where spark-plug points or electrodes just reach the combustion chamber, where cool fresh gas will come in contact with them and flame will spread with maximum rapidity, as in Figs. 3 and 4.

When the plug extends too far in the combustion chamber, there is danger of the valve head striking it (Fig. 5).

For spark-plug lengths, see page 235.

Spark-Plug Construction

Construction: There are two types in general use: the "separable" type plug, where the insulation or core can be removed, as shown in Fig. 6, and the "integral," or one-piece plug, shown in Figs. 10 and 11.

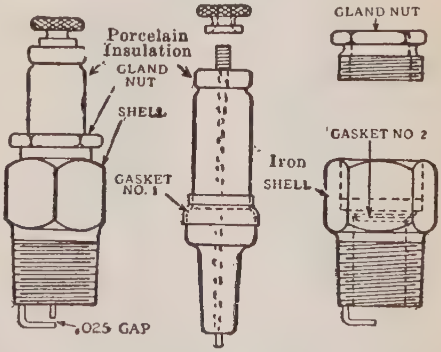


Fig. 6. Parts of a porcelain insulated spark plug—separable type.

The parts of the plug are: the iron shell or body which screws into the cylinder (see Fig. 6); the insulation which is held in the shell by the bushing or a gland nut; the electrode which passes through the insulation. Washers or gaskets are used as a gas-tight packing (Fig. 6).

The insulation is sometimes made of mica (Fig. 7), but owing to the construction, which is usually with washers, it leaks or permits current to pass to the electrode, especially when oily. The insulation in general use is porcelain, and this, unless of the best grade (not porous) will also leak, thereby weakening the spark. It is difficult to secure spark plugs which will not absorb oil and cause leakage.

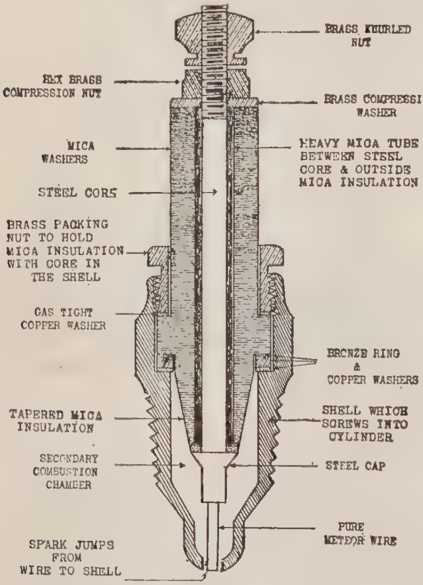

BRASS KNURLED NUT
HEX BRASS COMPRESSION NUT
BRASS COMPRESSION WASHER
MICA WASHERS
HEAVY MICA TUBE BETWEEN STEEL CORE & OUTSIDE MICA INSULATION
STEEL CORE
BRASS PACKING NUT TO HOLD MICA INSULATION WITH CORE IN THE SHELL
GAS TIGHT COPPER WASHER
BRONZE RING & COPPER WASHERS
TAPERED MICA INSULATION
SHELL WHICH SCREWS INTO CYLINDER
SECONDARY COMBUSTION CHAMBER
STEEL CAP
PURE METEOR WIRE
SPARK JUMPS FROM WIRE TO SHELL

Fig. 7. Parts of a mica insulated spark plug—separable type.

Spark plugs for aeronautic use: Mica is used extensively on plugs for aeronautic engines (Figs. 8 and 9). They are used but a brief time, and new ones are substituted.

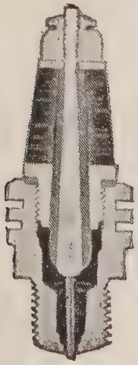


Fig. 8

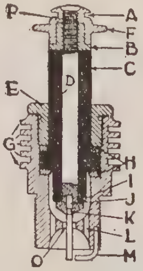


Fig. 9

The aeronautic type of spark plug is designed for great heat and high compression. The spark plug shown in Figs. 8 and 9 is made of mica and is very costly to construct. Note the heat radiation flanges on the shell; also the baffle plate (O) which tends to keep oil from the mica; stem (P) made of brass or copper for heat conductivity; electrode (J) is swedged at bottom of stem (K). The core is of mica washer sections (I), with a mica insulation tube at (D). The usual gap opening is .015″ to .018″. They are subjected to a pressure of 90 to 110 lbs. The life of a plug of this type is 25 to 100 hours.

The parts of the Splitdorf mica aeronautical spark plug (Fig. 8) are as follows: brass terminal, mica washers, lateral wound mica, steel center rod, 98 per cent pure nickel electrode point, carbon steel from brass terminal to electrode, and carbon steel shell.

The AC Titan, one-piece porcelain spark plug is used on the Liberty 12-cylinder engine. There are two spark plugs per cylinder to the Liberty 12 engine.

Separable Spark Plugs

Separable spark plugs are those in which a gland nut or bushing holds the porcelain or mica in place, as shown in Figs. 6 and 7. Plugs of this type have a tendency to leak and cause missing, especially at low speeds and hard pulls, or on high-compression engines. The integral plug appears to gain a point in its favor here.

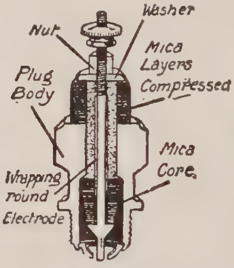


Fig. 10

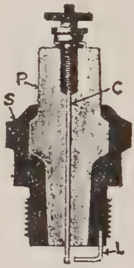


Fig. 11

Fig. 10. Integral type of spark plug with mica insulation. This plug is not separable.

Fig. 11. Integral type of spark plug with porcelain (P) or composition insulation. This plug is not separable.

The electrode (C) should be made of manganese nickel alloy. If not properly made it will expand under intense heat and break the porcelain. Spark-plug electrodes, or wires are approximately .050″ or .060″ diameter. Best results are obtained with .050″.

Cement is placed around the electrode. As it dries, it becomes porous, and porosity means electrical leaks.

Thus, it will be clear that "leakage of gas" and "leakage of electricity" are the troubles to be overcome in spark-plug construction. Leakage of gas causes "leakage of compression," and leakage of electricity causes a "weak spark."

Poor throttling, poor pick-up, missing on hard pulls and high speeds, are frequently caused by using a poor grade of plug. Of course there are other conditions which will cause this, such as carbonized insulators, or too close or too wide a gap at the plug points, or improper carburetion adjustment, but assuming that these troubles are corrected, the

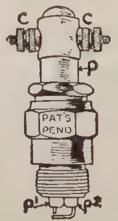


Fig. 12. Double spark plug—shell is not grounded. P1 and P2 are separate porcelain insulators.

leakage of gas and electricity are two of the fundamental troubles seldom noticed.

Therefore, the highest priced plug is often the cheapest. Likewise, a poor grade of ignition coil, when hot, will lose its efficiency.

Spark-Plug Sizes and Threads

Different threads and different lengths of spark plugs are used, illustrated in Fig. 13.

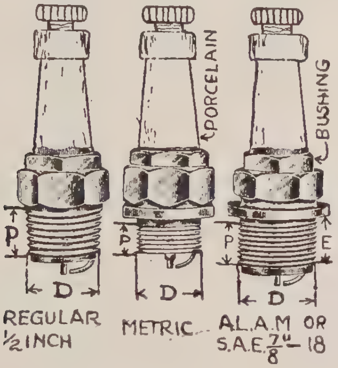


Fig. 13. Regular length of ½″, metric, and ⅞″ spark plugs.

Spark plugs are made with three standard threads (see Fig. 13): the ½″ pipe thread; metric; and ⅞″–18 S.A.E.

The half-inch size is a thread which is a standard ½″ iron pipe size, and has a slight taper.

The seven-eighths inch 18-size is the size which was adopted as a standard by the Society of Automotive Engineers for automobile use. It was formerly known as the A.L.A.M. The thread is ⅞″ in diameter, with 18 threads to the inch. It is used on a majority of the cars today.

The metric size is smaller than either of the others. Its diameter is 18 millimeters, or approximately 11/16″. This is the size of thread for spark plugs, adopted by the Society of Automotive Engineers for aeronautic engines. It is also used on some makes of automobiles and motorcycles. It is used extensively abroad.

S. A. E. Spark-Plug Shell Sizes

Figs. 14 and 15 show the two S.A.E. spark-plug shells. It will be noticed that the diameter of the hexagon part of shells differs. The "small hex." measures ⅞″ across the flat, and has a round gasket flange. The "large hex." measures 1⅛″.

S.A.E. spark plugs are all ⅞″–18, meaning that the outside diameter is ⅞″, and that there are 18 threads to the inch.

Gaskets used with the S.A.E. spark plugs of ⅞″ size measure ⅞″ inside diameter and 1⅛″ outside diameter. The "S.A.E. Reg." measures 13/16″ from shoulder to firing point, and the "S.A.E. Long" measures 1 1/16″.

The ⅞″ S.A.E. plug requires a special tap cutting of 18 threads, whereas the standard ⅞″ thread is 14 threads to the inch.

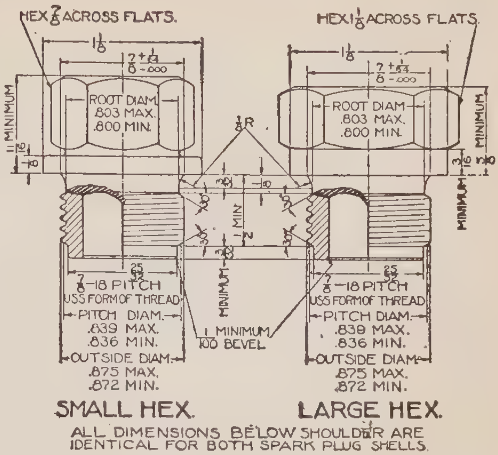

HEX ⅞ ACROSS FLATS.
HEX 1⅛ ACROSS FLATS.
1⅛
1⅛
ROOT DIAM. .803 MAX. .800 MIN.
ROOT DIAM. .803 MAX. .800 MIN.
MINIMUM
MINIMUM
MINIMUM
MINIMUM
R
⅞–18 PITCH USS FORM OF THREAD
PITCH DIAM. .839 MAX. .836 MIN.
OUTSIDE DIAM. .875 MAX. .872 MIN.
MINIMUM 1/100 BEVEL
⅞–18 PITCH USS FORM OF THREAD
PITCH DIAM. .839 MAX. .836 MIN.
OUTSIDE DIAM. .875 MAX. .872 MIN.
SMALL HEX.
LARGE HEX.
ALL DIMENSIONS BELOW SHOULDER ARE IDENTICAL FOR BOTH SPARK PLUG SHELLS.

Fig. 14 Fig. 15

Spark-Plug Lengths

The length of a spark plug depends upon the engine. If the valve cap is deeply recessed as in Fig. 16, a **long body** plug is required, otherwise the wrench could not reach the hex. If it is not recessed, a **long thread** is required. If, however, the valve-cap plug should not screw well down into the combustion chamber, an extension of the spark plug is required, for it is important that the points of the plug extend to the combustion chamber.

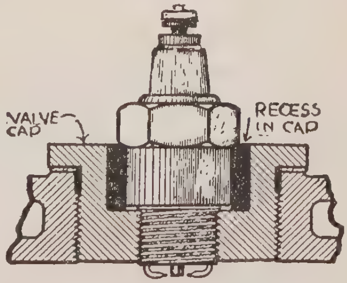


Fig. 16. Note the long body for raising the hexagon part of the plug above the recess in the valve cap so that a wrench can be applied. Different kinds of valve caps require different lengths of plugs. This plug is of the integral type.

Note that the plug points must not extend too far (see Fig. 5). This extension depends upon the distance the plug is to extend; therefore they are made with ½″ and 1″ extension. Figs. 17 to 19 will make this clear.

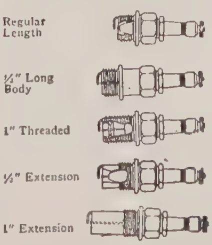


Fig. 17

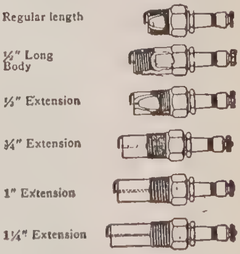


Fig. 18

Fig. 17. ⅞″–18 (threads per inch) S. A. E. thread spark plugs with different length of body or shell.

Fig. 18. ½″ pipe-thread spark plugs showing the different lengths of body.

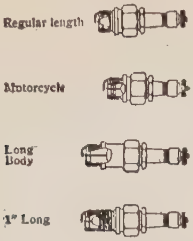


Fig. 19. The metric thread (18 m.m.) spark plug which is also made with different body lengths as shown.

Spark-Plug Sizes and Lengths Used on Leading Cars

Practically all cars, with the exception of the following, use the ⅞″ size spark plug with 18 threads per inch and of the "regular" type, as shown in Fig. 17.

Essex, A: metric, regular, Fig. 19.
Ford, T: ½″ pipe size; regular, Fig. 18.
Jordan, M: ⅞″–18, extension, Fig. 17.
Locomobile, M–48: ⅞″–18, special.
Nash: ⅞″–18, extension, Fig. 17.
Nelson: metric, regular, Fig. 19.
Olympian, 45: ⅞″–18, extension, Fig. 17.
Overland, 4: ½″ pipe size, extension, Fig. 18.
Porter, 46: metric, regular, Fig. 19.
Scripps-Booth, B–39: ⅞″–18, extension, Fig. 17.
Stephens, 80: ⅞″–18, extension, Fig. 17.
Studebaker: ½″ pipe size, regular, Fig. 18.
Willys-Knight, 20: ⅞″–18, special.

Gaskets for Spark Plugs

Copper, asbestos-lined gaskets are used between bushing and shell on all "separable" plugs, to make them leak-proof. They are also used on ⅞″ and metric plugs between the shell and where they screw into the cylinder—but not on the ½″ plug, because it has a taper thread and no shoulder on the shell.

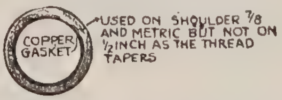
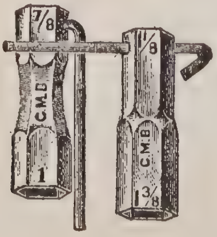

COPPER GASKET
USED ON SHOULDER ⅞ AND METRIC BUT NOT ON ½ INCH AS THE THREAD TAPERS

Fig. 20. Spark plug copper gaskets. Measurements of gaskets are as follows: S. A. E.: ⅞″ (inside di. ⅞″; outside di. 1⅛″); Half-inch: (inside di. 27/32″; outside di. 1 3/32″); Metric: (inside di. 23/32″; outside di. 63/64″).

Spark-Plug Wrench

No. 1. The ⅞″ end of this wrench fits all standard spark plugs, such as the Spitfire, Reliance, Rajah, Red Head, and many others; the 1″ end fits the Sootless, Reliance; the ⅞″ fits the Herz, Bosch, and others.



No. 1 No. 2

Fig. 21. Spark-plug socket wrenches.

No. 2. The 1⅛″ end fits all standard spark plugs of the large "hex." type, such as the Champion, De Luxe, and others. See also Index under "Spark-plug wrenches."

Spark-Plug Gap

The gap is the distance between the points on the plug shell and electrode. It is important that this distance be exact.

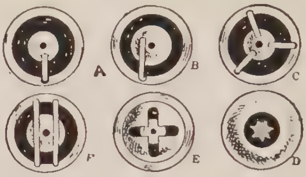


Fig. 22. Different kinds of plug points or gaps.

A spark plug used with magneto ignition should not have too wide a gap, because, when the engine is running slow, the current is weaker.

Relation of spark-plug gap to engine compression: Assume that we have a four-cylinder magneto, the "safety gap" of which is set at ⅜″, corresponding to 8,000 volts, which also corresponds to the voltage required to fire a spark plug having a gap .025″ under a pressure of 65 lbs. If this magneto was required to fire an engine where there was a higher compression of 85 to 90 lbs., even if the mixture represented slightly lower resistance, it would probably fail to fire and, instead, would jump across at the safety gap. However, a slight reduction of the distance between the spark-plug points would lower the effective pressure, so that it would operate in the proper manner. On the other hand, if the engine had low compression, the spark-plug points should be opened up, but if too wide, this would immediately place a greater strain on the spark-plug insulation and if the plug carbonized badly it would be likely to flash over.

Spark-plug gap and compression: For high-compression engines (75 to 80 lbs.) set gap .020″; for medium-compression engines (65 lbs.) set gap .025″; for low-compression engines (55 lbs.) set gap .030″. See Index for "Compression."

It does not always hold true, however, that spark-plug gaps should be set according to compression, because on some engines of high compression the gap is not made less, but the coil is wound for a stronger current to take care of the extra high resistance.

Greater resistance at spark-plug gaps in high-compression engines is due to the fact that air offers less resistance than does gas under pressure. A spark plug in the open air will jump a greater distance than when under pressure. The higher the pressure, the greater the resistance at the gap.

The space between the spark points must be considered an insulator, and it must be remembered that the compressed charge in the cylinder through which the spark is required to jump is a better insulator than uncompressed air.

A spark that will jump the point or gap of a spark plug when the plug is out of the cylinder may not have strength enough to jump when the plug is screwed in the cylinder and under compression. So the spark must be especially strong, and should be able to punch a hole through a visiting card held between the points.

It is essential that the battery be kept charged so that it will deliver its proper voltage with a "single-spark" system—as it is quick and must have pressure enough behind the coil to cause a hot spark.

If points are too close, it will be impossible to run slowly, for the actual area of the flame will be too small.

If the gap is too wide, misfiring (on a high-compression engine) is likely to take place, especially when one tries to accelerate suddenly, after going slow. The effect of opening the throttle and admitting a full charge is to increase compression, and it is a well-known law that resistance increases with pressure.

The coil will operate up to 1/32", but bear in mind that the greater this distance, the more strain on the coil and the "leaner" the spark.

Therefore the gap depends upon: (1) the kind of ignition system; (2) the amount of compression of the engine.

Where a vibrator coil is used, the usual distance is about 1/32". With a "single-spark" system, however, such as the Atwater-Kent, where the spark is very quick, the gap must be very small, about .025". In fact, this is the average distance.

On 4, 6, and 12-cylinder engines, the spark-plug gap is .025" and on 8-cylinder engines .020". The spark-plug gap where a Bosch NU4 magneto is used is .016".

To experiment, try setting the plug point on, say, one cylinder until it misses on a hard pull up hill with throttle closed or as much closed as it will pull up the hill comfortably. Then slightly close the gap and try the hill again, and continue experimenting in this way until the missing stops. When the correct distance is found, then set the other plugs accordingly.

Where spark plugs are used on magneto ignition, and also on the Ford, the metal electrode of the plug is carefully figured out as to its resistance capacity, as a very heavy voluminous spark requires an electrode of somewhat higher resistance metal, to prevent burning and pitting. **Therefore always use a spark plug that is recommended by the manufacturer.**

To Clean Spark Plug

To clean a spark plug: Unscrew the bushing which holds the porcelain in the shell, remove the porcelain (or mica) and soak the shell and porcelain in kerosene or gasoline. Clean all carbon off each. **Don't scrape porcelain,** as it will roughen the glazed part and cause it to retain carbon, and will also cause "porosity," which causes electrical leaks. If the oil is burned on the porcelain, muriatic acid will remove it. In placing the porcelain back into the shell, be sure that the copper washer is placed back and that the bushing screwed tight so as to prevent leaking. Alcohol is also used for cleaning spark plugs.

SPARK INTENSIFIER

This device consists of an insulated base and screws for adjusting (Fig. 23).

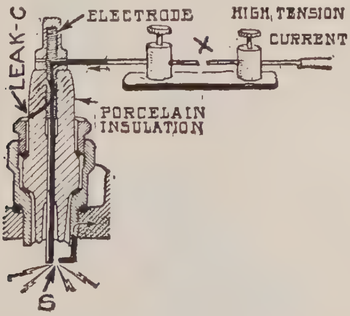


Fig. 23. Spark intensifier.

The purpose is to provide a gap (**X**) in series with the high-tension circuit for the spark to jump before it reaches the plug. It is claimed that this will intensify or raise the voltage of the high-tension circuit to such an extent that it will jump across a carbonized plug in spite of its fouled condition.

The extra gap throws an additional load on the coil. Naturally, if it is not well made, the high voltage will be very likely to break down the insulation. Furthermore, a fat voluminous spark is hotter and will ignite the gas quicker than a thin, lean spark. Although the intensified spark will jump across the fouled part of a plug, the spark is thin, and it is best to use good clean plugs. It is a question whether or not the intensifier will add anything to the efficiency or performance of a clean-running engine; if so, the gap at the spark-plug points might be widened. This, of course, would be impractical as the gap under compression offers more resistance to a jump than in the open air; but at that, if the gap in the cylinder was widened in proportion, this cylinder would likely miss fire.

One theory is that the intensifier is beneficial where a plug has a tendency to collect drops of oil on the points, and that by increasing the intensity the spark will jump through the oil. There is one thing certain, and that is that any electric current is going to follow the path of least resistance.

The action is this: In order to cause the spark to jump the gap (S) at the spark plug in the cylinder, 5,000 or more volts are required. Suppose, however, that the spark plug has an accumulation of carbon from the porcelain insulation to the plug shell, or a crack in the porcelain which fills up with carbon, oil, and dirt, as at (C) to the electrode (Fig. 23). Although this path is longer than the spark-plug gap, it is not under compression and thus it offers less resistance than does the gap (S), or, in other words, it requires less voltage to go over the carbonized path. There is then a leak of voltage at the carbonized path which prevents 5,000 volts reaching the plug-gap (S). This explains the reason for its missing.

If the intensifier gap (**X**) is provided, this temporarily acts as a dam to the flow of current, and, like flowing water, it will pile up against the dam and thus establish a greater force when released. After the breakdown of the dam, the current comes with such a rush that it cannot all pass through the carbon path, and as its voltage is now sufficient, it will also jump the spark-plug gap.

THE MISSING SPARK

If the engine misses explosion, the trouble may be due to carburetion being at fault (see "Digest of troubles" and "Carburetion"). If the trouble is not with carburetion[1], then the chances are the spark plug is missing through being fouled. The spark plug causes more trouble in this respect than any other part of the ignition system.

The cause of spark-plug sooting and pre-ignition: A poor grade of oil or too much oil will turn to carbon (soot), and will deposit on the end and inside of the spark plug, and "short-circuit" the plug, so that the spark will not occur at the point, consequently causing missing of explosion.

Poor oil or too much oil will also leave carbon or soot deposit on the end of the piston and inside of the combustion chamber. This deposit hardens, and sharp points of it will project. This projection will become white hot, causing the gas to ignite before it is time. This is called premature or "pre-ignition."

Spark-plug troubles are therefore usually as follows: short circuit from carbon, cracked porcelains, electrodes burned away, spark plugs not pressure tight, moisture condensing on insulator.

There are several general causes for ignition missing, or for a failure to ignite the gas, as follows:

1. **Lack of current** from the battery.
2. **Loose connections.**
3. **Burned out or thin resistance unit** occasioned by excessive heating, thus permitting only a small amount of current to pass through.
4. **Improperly set interrupter** points.
5. **Defective condenser,** causing sparking at the interrupter points and weakening the spark.
6. **Defective primary winding.**
7. **Spark-plug crack** on that part of the plug which is not in the cylinder under compression. This crack fills up with oil and dirt, and while the crack is longer than the spark-plug gap, it is not under compression. The result is, usually, missing at low speeds and hard pulls, but hitting on high speeds.

   The reason for this is because at low speeds and on hard pulls the throttle is wide open and the low piston speed greatly increases the degree of compression. Compression offers greater resistance; therefore the spark takes the easiest path, through the carbon.

   At high speeds, the cylinders do not have time to fill up with gas and, the piston speed being greater, the degree of compression is not so great in comparison; thus there is sufficient voltage to jump the gap.
8. **Carbonized spark plugs,** of course, will cause missing at low or high speeds.
9. **Burned points,** due to excessive current. For instance, the Ford spark plug, unless of the proper quality of metal in the electrode, will burn the points badly due to the excess of current. This coil should be adjusted according to instructions on page 222, and only high-grade Ford plugs should be used.
10. **Moisture on the outside of the porcelain** at high voltages will cause the current to leak over the surface of the shell as in Fig. 24 (10).

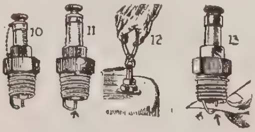


Fig. 24. Spark-plug troubles.

11. **Points may have come together** as in Fig. 24 (11), when they were screwed into the cylinder.
12. **Wire may be loose** on the terminal (Fig. 24) (12).

To adjust the gap, use a thickness gauge or paper (Fig. 24) (13). Adjust to $\frac{1}{32}$″ for vibrator coil ignition; to .025″ for non-vibrator coil ignition, and to about $\frac{1}{64}$″ or .015 to .020″ for magneto ignition.

To Find Cause of Missing

First, check the ignition circuit, and also find the cylinder which is missing by loosening the spark-plug wire from one plug at the time and holding it about 3/16″ away from the spark-plug shell (Fig. 25). With the engine running slow, the sparks should be counted for at least 50 without missing. It is safe then to assume that the ignition is doing its part.

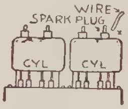


Fig. 25. Testing the ignition system by observing the steadiness and intensity of the spark.

If there is missing and the spark is not hitting regularly, then clean the interrupter points and see if they are properly adjusted; look for loose connections; see if the current from the battery is of proper strength; try another coil, if results are not obtained otherwise.

Second, check the spark plugs. It is useless to check these until you first know that your ignition system is in perfect order. If good sparks have been obtained on the first test, then proceed to test each spark plug with the engine running and the ignition switch "on," as follows:

Place the point of a screwdriver (Fig. 26) on top of the plug terminal, and hold the metal part of the screwdriver on the metal part of the engine, thus killing the spark in this cylinder.

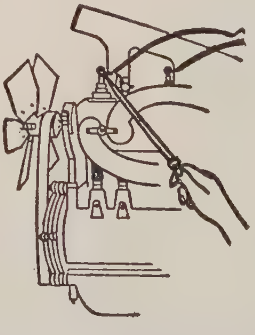


Fig. 26. Testing to locate the spark plug which is missing, after determining that the missing must be attributable to the spark plug. (Be sure to use a wooden handle screwdriver, and do not stand on damp ground, thus avoiding a shock.)

If there is now no noticeable difference in the running of the engine when the spark plug is cut out in this manner, it is evident that this plug has not been firing even before it was killed or shorted by the screwdriver. Thus the missing plug is located.

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[1] Carburetion troubles are dealt with elsewhere. Missing is quite common when first starting the engine with cold, unvaporized gasoline. Therefore be sure that the trouble is not due to carburetion.

It is possible that a **sticking valve** or other engine trouble may cause missing. Remove the spark plug from a cylinder which you know is not missing and exchange it with the plug in a cylinder which is missing. If the missing continues, then you know it is not in the plug.

On eight-cylinder and twelve-cylinder engines it is difficult to locate missing. A good plan is to detach all the spark-plug wires from one side, or block, and lay the wires on the engine (in order not to overload the coil). Also open the relief valves, so that one side only will run on power. Thus it is easier for the test as outlined above.

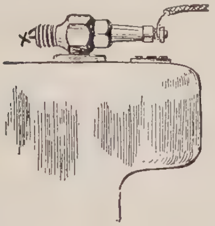

Fig. 27

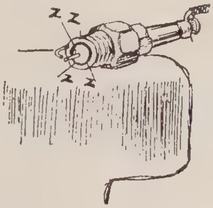

Fig. 28

To test a spark plug to see if it is carbonized: Place the spark plug on the cylinder with wire connected and switch on (Fig. 27). Crank the engine slowly. If the spark occurs at the gap (**X**) the plug is in order. If it sparks up inside of the shell, between the porcelain and shell at (**Z**) (Fig. 28), it is fouled and misses. It must then be taken apart and the carbon must be removed.

Remember the plugs may spark in the open air, but when under compression will fail to spark, because the resistance is greater. Therefore be sure the spark-plug gap is correct.

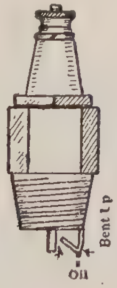

Fig. 29

Too much oil in the combustion chamber may have a tendency to cause missing due to the current passing through the oil. A good plan, if the plug points are of the type shown in Fig. 29, is to bend the outside point, as shown, which may cause the oil to collect at the bend instead of the gap

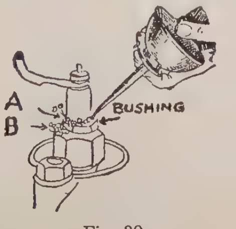

Fig. 30

To test for a spark-plug leak around the porcelain at the top (**A**) of bushing or below (**B**) where the bushing is screwed into the shell of plug (Fig. 30): squirt gasoline at these points, while the engine is running and note if bubbles appear. If so, there is a leak, and if tightening of the bushing does not remedy the trouble, then put in a new gasket.

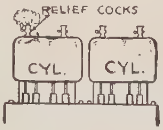

Fig. 31

A method often used to see if a **cylinder is firing** is to open the relief cocks, one at a time (Fig. 31). Watch for the flame shooting out of each opening and listen for the sharp reports of the explosions. The cylinder without flame, out of which issues only hiss, but no sharp report, is the one at fault.

This test, however, is not reliable, because, when the relief cock is open, air is drawn into the cylinder which mixes with the carburetion mixture and thus changes the proportions of the mixture.

The Airco Ignition Tester[1]

The tester consists of an insulating hard rubber shell into which is packed a sensitized glass tube of Neon. When the metal cap, which permanently seals one end of the tester, is brought into contact with a high-tension electric current, the Neon becomes luminous and emits flashes of orange-red light, visible through the indicator opening in the side of the case.

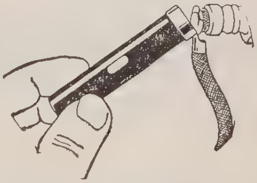

Fig. 32. The Airco tester as applied to the end of a spark plug. Flashes occur in the white gap if there is current. If placed on an insulated wire conducting a high tension, current flashes will occur.

The active element in the Airco ignition tester is a gas which the Air Reduction Company extracts from the air through a process of mechanical and chemical operation. This particular gas which is known as "Neon" has the peculiar property of becoming luminous when brought into contact with electricity. (See Index under "Neon gas.")

Neon, as applied to the Airco ignition tester, is contained in a small glass tube, the ends of which have been plated similar to the manner in which a mirror is silvered. The entire tube is then packed inside of a hard-rubber shell, and a quantity of steel wool is used to make the contact between the metal cap of the hard-rubber tube and the silvered end of the glass tube containing the Neon. By placing this device to the end of the spark-plug terminals, or even on the insulated wire itself, if there is a high-tension current passing in the wire, the gauge becomes luminous or emits flashes.

The following indications point to trouble:

No flashes: Spark plug completely fouled or shorted, or no current to the plug.

Flashes continuing for an unusual distance as the gauge is withdrawn from the plug: Broken plug—probably broken porcelain.

Very intense flashes: Spark gap too wide.

Overlapping flashes (not clean-cut with each piston stroke)**:** Leaks between feed wires or fouled distributor.

Dim or irregular flashes: Plug partly fouled, or feed wire leaking excessively. Examine plug.

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[1] Manufactured by Edw. A. Cassidy Co., New York, N.Y. Can be obtained of A. L. Dyke, Electric Department, Granite Bldg., St. Louis, Mo. Price $1.00.

INSTRUCTION No. 24

WIRE FOR IGNITION SYSTEMS

There are three kinds of ignition wire for general use with the ignition system of a car, as follows:

Primary wire or cable, made of several strands of fine wire in order to make it flexible and insulated, oil and moisture proof. This wire is usually used between the battery, coil, and timer for all low-tension work, and must be of sufficient size to carry the current. Usually No. 14 or No. 16 size is used.

Secondary cable is also made flexible and the insulation on the wire is much heavier. This is used to conduct the high-tension current from the coil or magneto to the spark plugs. It should be kept free from all metals, as much as possible. Size is usually No. 16 or No. 14.

Duplex cable is also flexible, but generally two to four wires are run in one insulation, being separated, of course, from each other by insulations. This wire is generally used for lighting and low-tension work.

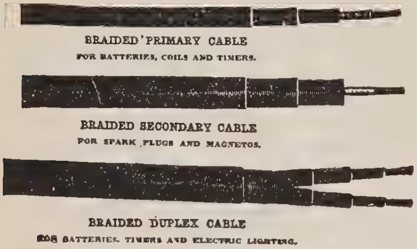
BRAIDED PRIMARY CABLE
FOR BATTERIES, COILS AND TIMERS.
BRAIDED SECONDARY CABLE
FOR SPARK PLUGS AND MAGNETOS.
BRAIDED DUPLEX CABLE
FOR BATTERIES, TIMERS AND ELECTRIC LIGHTING.

Fig. 1. Ignition wires.

Metal conduit: A good plan in wiring a car, where several wires are run together, is to enclose the wires in a metal conduit. See Index under "Wire for wiring a car."

The wires running from coil, or magneto distributor to the spark plug, carry the high-tension current and are called "secondary cables." This current escapes more readily than from the wires running from the battery to the timer or coil. The wires running to the plugs are called "high tension" wires because the tension or voltage is high and current will often jump through the insulation and short-circuit (cutting out spark plug) to any metal part it happens to be in contact with. For this reason these wires must be carefully protected and very heavily insulated.

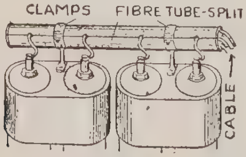

Fig. 2

Fig. 2 shows one method of distributing the secondary or high-tension cables on multi-cylinder engines. A divided fiber tube supported on brackets encloses the cables and permits of easy inspection or renewal if required. Any number of leads or cables can be distributed. The eight plug leads required for dual ignition on a four-cylinder engine can be accommodated in a two-inch fiber tube.

The primary wires running from the battery to the timer or to the interrupter on the magneto are "low tension." They do not need to have as heavy insulation, but the connections should be well made and clean because the pressure is so low that the current will not pass over dirty or loose connections, and a loss of current will result. All connections ought to be soldered and taped.

Do not use lamp-cord wire under any circumstances as it will give unsatisfactory results and cause missing if damp. Wire for the electric horn is usually No. 18.

Size of Wire Used for Winding a Coil and Magneto

Primary winding is No. 19 to 24 B. & S. gauge copper insulated wire. **Secondary winding** is No. 34 to 38 B. & S. gauge silk-covered insulation.

There is usually a ratio of about 60 to 1. For instance, if the primary consisted of 200 turns, the secondary would have 12,000 turns.

The winding of a Bosch DU4 magneto armature usually consists of three layers of No. 20 or No. 22 wire, to form the primary winding, and of 70 to 72 layers of No. 36 silk-covered wire to form the secondary winding. The reader, however, never has occasion to bother with wire on a coil or magneto armature as this is the work of a specialist.

Making Connections and Ignition Wiring Troubles

A grounded connection should be filed or scraped bright before attaching the wire, and the connection when made should be covered with vaseline or paraffine. A copper washer should be placed under the head of the screw, to hold the wire firmly in position, and tightly drawn up.

All connections must be bright and clean, for a dirty connection will add resistance. Binding posts, screws, and the ends of the wire must be scraped clean before the wire is attached. This is very important on low-voltage wiring.

When joining two wires or attaching terminals (Figs. 3, 4 and 5), solder and then tape.

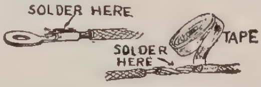

Fig. 3 Fig. 4

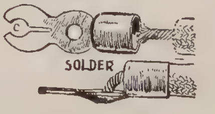

Fig. 5

Figs. 3, 4, and 5 show how to make a connection with wire and terminal; solder and tape all connections.

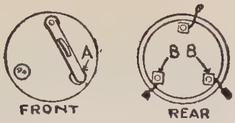

Fig. 6

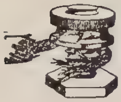

Fig. 7

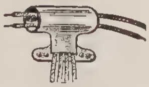

Fig. 8

Fig. 6. Loose switch terminals will cause missing as will also loose binding posts (Fig. 7).

Fig. 8. A good method of protecting primary (battery) wires when they run along the frame.

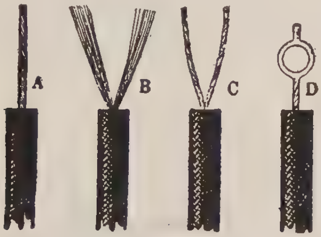

Fig. 9. Four steps in making loop end: (A) insulation removed; (B) separating the strands; (C) twisting wires into two leads; and, (D) the looped end dipped in solder. (*Motor Age.*)

No possible cause for leakage of the current should exist; a single strand of fine wire projecting from a flexible cable will be enough to cause a short circuit if it should touch metal.

Missing of ignition where dry cells are used (Fig. 10) may be due to weak batteries. To test, use an amperemeter. Test each cell separately by placing the terminal of the meter on the terminal of the battery. Each battery ought to show 15 to 25 amperes. If less than 8 amperes are shown, replace. If one should test, say, 10 amperes, and another 20, then the good battery will be brought to the level of the poor battery. Remove it and put in a fresh one. See Index for "Testing a storage battery."

An emergency dry-cell connection is shown in Fig. 11. Usually two sets of dry cells are provided when ignition is on dry cells alone. Only one set at a time is used, however. If both sets should run down, a multiple connection of the two sets can be made, as shown, which will suffice to enable the car to reach home. Dry cells are now seldom used.

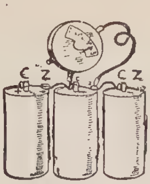

Fig. 10

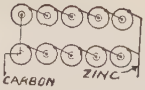

Fig. 11

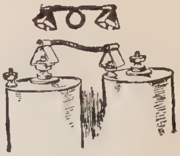

Fig. 12

Quite often missing will occur from loose connections at the battery terminals (Fig. 3). See that they are always tight. On some connections, the wire may be broken or not soldered well to the terminal. A good connector for dry cells, called the "Bull Dog," is shown in Fig. 12. For storage batteries, see Index.

On many cars one wire is grounded (Fig. 13). It is therefore essential that the grounded connection be well cleaned and then tightened. A copper terminal should be soldered to the wire, the surface cleaned, and drawn tight with a bolt.

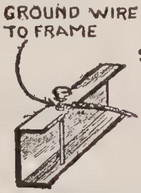

Fig. 13

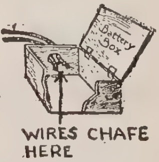

Fig. 14

When metal battery boxes are used (Fig. 14), and dry cells are placed in them, dampness will short-circuit the batteries through the paper insulation around them. Therefore keep the box dry inside, and watch the wire where it passes through the metal box.

Fig. 15

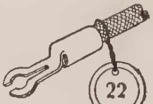

Fig. 16

When removing the wires (Figs. 15, 16), mark them by painting the ends with cheap water colors, or tag them, thus saving a lot of time when replacing.

INSTRUCTION No. 25

LOW-TENSION MAGNETO: Principle of Magneto Ignition

In the preceding instructions, we dealt with the low-tension coil, using only a primary winding, and the high-tension ignition coil using a primary and secondary winding.

In this instruction we shall deal with the low-tension magneto, a mechanical generator of a low-tension alternating current.

The difference between a low-tension magneto and a high-tension magneto is that, on the low-tension magneto armature core there is but **one winding,** called a primary winding, whereas on the high-tension magneto armature there are **two windings,** a primary winding and a secondary winding.

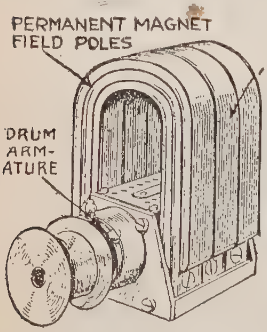

Fig. 1. Magneto.

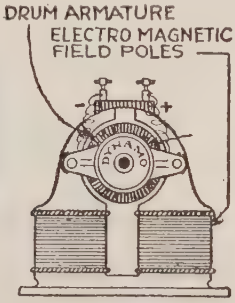

Fig. 2. Dynamo.

Mechanical devices, such as **a magneto** and **a dynamo** (Figs. 1 and 2), are termed **mechanical generators of electricity.** The armature, which revolves between the pole pieces, is driven by the engine, and alternating current is generated.

Alternating current is suitable only for ignition, and all magnetos generate alternating current.

Where a generator (dynamo) **is required** to charge a storage battery, it is necessary that **the current should be "direct,"** that is, flowing in one direction continuously, from positive (+), to negative (−).

Therefore, while, as stated above, all generators or dynamos or magnetos generate alternating current, on a generator used for charging a storage battery, the **alternating current is transformed,** or commutated, into a "direct" current by means of a commutator and brushes. Thus while alternating current is generated inside, direct current is delivered outside, or from the brushes. Generators of direct current supply current for coil ignition and lights, and also charge a storage battery. This subject is explained under "Generator principle," farther on.

The magneto generates alternating current inside and delivers alternating current outside, and, as previously stated, is suitable only for ignition. It will not charge a storage battery because the electric current it generates flows first in one direction and then in another direction, and thus "alternates" its flow.

Construction

The principle of a low-tension magneto is similar in many respects to that of a low-tension coil. In a magneto, the armature on which the primary wire is wound is called upon to produce its own electric supply, whereas in a primary or low-tension coil, the electric supply is from another source.

Field magnets: Permanent magnets (1a), called the "field magnets," are provided as shown in Fig. **1A.** The **pole pieces** (11a) provide a magnetic field for the shuttle-type armature (Fig. **4A**) to revolve in. End plates with ball bearings are attached to screw holes in pole pieces (**11a, Fig. 1A**). There is very little clearance between the armature and the poles, and therefore accurate fitting is necessary.

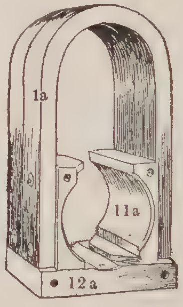

Fig. **1A.** Permanent magnets (**1a**); pole pieces (**11a**); base of brass or aluminum (**12a**).

There are usually two, four, or six magnets placed over the pole pieces; all north poles on one side and all south poles on the other side. The base (12a) is usually made of brass or aluminum, as neither will become magnetized.

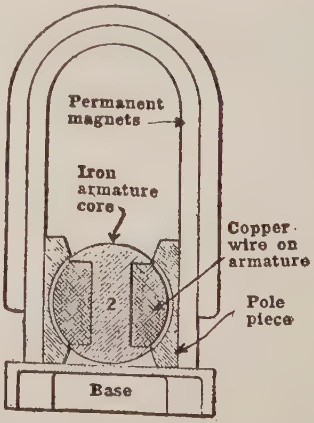

Fig. **1B.** View of a low-tension magneto with the end-plate off and the armature shown in section. (1) permanent magnets (magnetized at all times); (2) the armature, revolved by a gear connected with the engine shaft. Note that a single winding of insulated copper wire is wound on the armature.

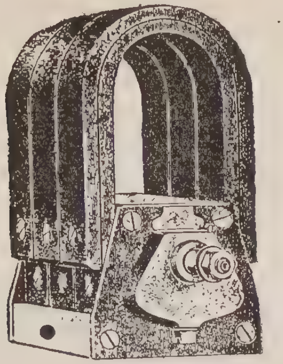

Fig. 1C. The low-tension magneto complete. View shows the drive end of the armature, which is driven at a fixed speed from the crank shaft of the engine, by gear or chains. The direction of rotation of all generators is considered at the drive end.

The armature of a direct-current generator (Fig. 3) is called a "drum-wound armature." It differs from a magneto armature in that the coils wound over the armature core are connected in such a manner with the commutator segments that the current delivered from brushes resting on the commutator segments is direct.

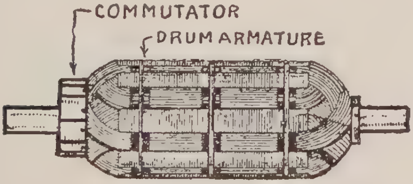

Fig. 3. Armature of a direct-current generator.

This drum-type armature could be made to revolve between permanent magnets, and current would be generated, but it is not practical, because the voltage must be a steady voltage. And since the voltage increases with speed, the armature of a direct-current generator is made to revolve between poles which are wound with wire, called "electro-magnets." This subject is dealt with under "Direct current generators," farther on.

Permanent magnets are of the horseshoe type and are permanently magnetized. They are called the "field" magnets.

Electro-field-magnets are wound with copper wire and are electrically magnetized. They remain magnetized only when the armature revolves between the field-magnet poles. This type of dynamo or generator generates a steady "direct" current, usually of 6 or 8 volts, and will light electric lamps and recharge a storage battery and supply current for ignition. It is usually run in connection with a starting and lighting system, and, in smaller models, is used for ignition on stationary and marine engines to a considerable extent.

The armature of a magneto, which delivers alternating current, is called a "shuttle-type armature." It revolves between the poles of "permanent field magnets."

The parts of an armature are as follows: Bronze heads (**B, B1**) are screwed to the armature core (**C, C1**) (Fig. 4). Shafts (**A, A1**) are driven and riveted to the bronze heads. Wire is wrapped around space (**C, C1**), called the core.

It will be seen that the core is not a solid casting; rather it is a pair of castings between which is clamped a group of soft iron stampings (**D**), having the form shown in the detail sketch. The object of thus "laminating the core," as it is called, is to retard the circulation of "eddy currents" in the core due to induction. The same forces of induction which are at play in the windings operate also in the iron core itself, and if unchecked, would both consume power and heat the armature unduly. As the voltage of these currents is very low, even the slight obstruction of the laminations is sufficient to retard them.

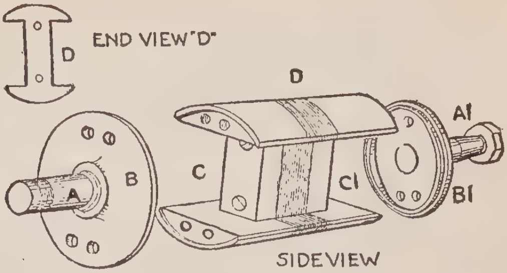

Fig. 4. Magneto armature core and end plates. The winding is placed on the core C and C1.

The laminated section of the armature is shown at (**D**). "Laminated" means that instead of the castings (**C**) being solid, there are several layers of flat sheet iron placed together, between the cores (**C**), as shown at (**D**).

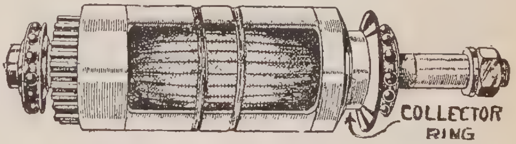

Fig. 4A. Shuttle type of armature with one winding (low-tension).

The completed magneto shuttle-type armature is shown in Fig. 4A. Note the "collector ring," from which the current is taken by a brush resting on the flat surface of this ring.

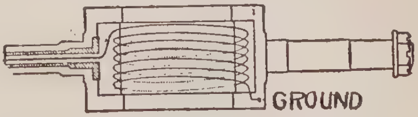

Fig. 4B. Primary winding on armature core. Note that one end is grounded to the core and the other end is insulated.

The single primary winding is shown in Figs. 4B and 4C. One end (**A**) conducts the current from the armature to the collector ring and the other end is grounded (**G**).

A sectional view (Fig. 4C) shows one method of conducting the low-tension current from the armature, where a collector ring is not used. The principle, however, is similar.

One end of the primary winding, which is heavy, coarse wire, is grounded to the armature core at (**G**). The other end (**A**), is insulated and passes through the hollow end of the armature shaft and makes contact with a point (**D**).

As the armature revolves, the spring (**S**), which is mounted on an insulated block (**IB**), conducts the current through a wire connected with it, to the terminal. "Collector rings," are more often used.

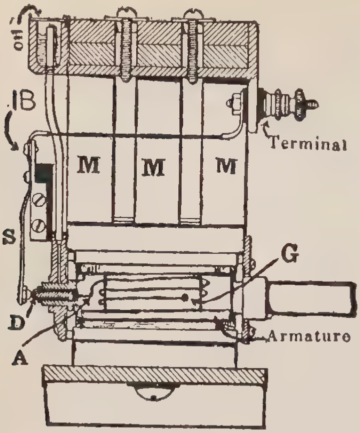

Fig. 4C

From the terminal the current is carried to the "igniter," as in Fig. 5. This is a "make-and-break" low-tension ignition system similar to the system described on page 185.

It will be noted, however, that a separate low-tension coil is not necessary in this instance, as the winding on the armature takes its place.

If the low-tension magneto is used in connection with a separate high-tension coil, then this wire (A) (Fig. 4C) from the armature would go to the primary winding of the coil.

Two methods of utilizing the low-tension magneto are therefore used, as follows:

1. In connection with a low-tension "make-and-break" ignition system.
2. In connection with a high-tension coil.

Low-Tension Magneto Supplying Current for a "Make-and-Break Ignition System

On page 185, this system is explained. The magneto, however, was not explained.

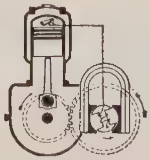

Fig. 5. Low-tension magneto supplying current for a low-tension "make-and-break" ignition system.

It is well to bear in mind that a low-tension magneto used in connection with the low-tension "make-and-break" system, shown in Fig. 12, page 185, **does not require a low-tension coil,** because the action of intensifying the current, is obtained by the snapping of the "igniter" points, by action of a cam, and the winding on the armature of the low-tension magneto takes the place of the low-tension coil. See also explanation, page 186.

Low-Tension Magneto and High-Tension Coil

The low-tension magneto can be used in connection with a high-tension coil and produce a "jump-spark" or high-tension spark at points of a spark plug in the cylinder, by using the low-tension magneto to produce the current, and a separate high-tension coil (without vibrator) to intensify the low-tension current to a high pressure, so that it will jump the gap of the spark plug.

We should need for this system **a high-tension coil, a distributor** on the magneto to distribute the high-tension current to the spark plugs (if a multiple-cylinder engine, which, in this instance, we will say, is a four-cycle, four-cylinder), and **an interrupter** to break the low-tension current at the proper time.

The coil: The double-wound high-tension coil, but without a vibrator, can be used. The interrupter will take the place of the vibrator. Therefore we should have a single spark instead of a succession of sparks. When the contact points separate, as explained under "Interrupter," the low-tension magneto current is intensified, and "induced" current is set up in the secondary winding. This coil can be placed separate from the magneto.

The distributor: This "induced" or high-tension current is then distributed to the spark plugs in correct firing order by the distributor rotor and brush, as shown in Figs. 6 and 6A. The distributor is driven at one-half the speed of the armature.

The interrupter[1] (see Fig. 6A) is mounted on the front end of the magneto armature shaft. The housing on which the interrupter parts are mounted can be shifted, by means of a rod (**SL**) (Fig. 6**A**). This rod connects with the spark lever on the steering wheel.

Therefore the time for the spark to occur can be made early ("advanced"), or late ("retarded"). The usual range of advance on a magneto is from 22° to 35°.

Attached to the housing, and moving with it, is the interrupter arm (**A**) and the terminal (**B**).

On the end of the interrupter arm (**A**) is a platinum point (**P**). There is also another platinum point (**P**) on terminal (**B**).

Platinum is used because there is more or less sparking occurring at the points and, platinum being hard, it stands the spark with less pitting than other metals.

The condenser is in the coil and takes up excess sparking to a great extent. This condenser can be placed in the coil box or on the magneto.

The cam (**C**) is attached to the front end of the armature and revolves with it.

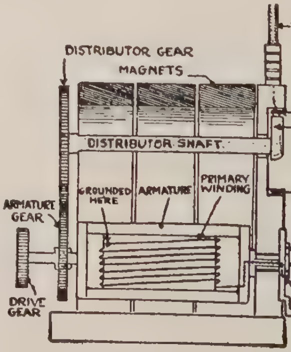

Fig. 6

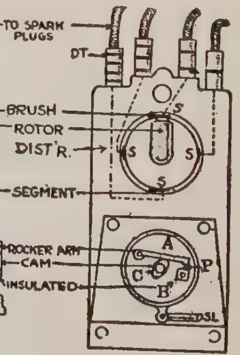

Fig. 6A

Fig. 6. Note how the distributor shaft is driven by the gear on the armature.

Fig. 6A. Front view of distributor and interrupter.

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[1] There are many different constructions of the interrupter. This one is shown in order to simplify the explanation.

When the nose of the cam raises the interrupter arm (A), the current is interrupted in the primary winding, causing the high-tension current to be set up in the secondary winding of the coil.

The cam has two lobes. It will therefore raise the interrupter arm twice during one revolution, or four times during two revolutions of the armature. The armature would then run at the same speed as the engine crank shaft. As the cam (C) is attached to the armature, it must revolve with it.

The cam is set on the armature, so that the nose will raise the interrupter just as the armature is in a vertical position.

If the cam raises the interrupter arm (A) when the armature is in a vertical position and the interrupter housing is at full retard position, this will then allow for advancing of the spark full 35° or less, according to the range of the magneto.

The primary circuit on the armature of the low-tension magneto consists of a winding of coarse wire. One end is grounded to the armature core (see Fig. 6), and the other end is carried to the insulated terminal (B, Fig. 6A).

The armature revolves, therefore the end of the armature primary winding, from which the low-tension current is taken, is carried through the end of the armature shaft (insulated).

The current is then carried through the primary winding of the coil, to the insulated terminal (B), through the interrupter points (P) (which open when the armature is in maximum position), to arm (A) which is grounded, thence to the other end of the magneto primary winding, which is grounded to the armature core (Fig. 6). This completes the primary circuit of the magneto and high-tension coil. See Figs. 38 and 39 for two different methods of connecting a low-tension magneto with a high-tension coil.

The secondary circuit is clearly shown in Figs. 38 and 39, page 252.

The magneto armature must be driven at a fixed speed because the interrupter and the position of the armature govern the time of the spark. Therefore the magneto is either driven by a chain or by a gear from the cam shaft, but not by a belt. This subject is treated farther on.

Also bear in mind that **the magneto is a closed-circuit system,** and interruption of the closed circuit by the interrupter points being separated by the cam occurs when the spark takes place.

Note the arrangement of the interrupter on page 258. It is a different construction from that shown in Fig. 6A. The interrupter on page 258 is more modern. The one in Fig. 6A is simplified.

Remarks Relative to Distributor on a Low-Tension Magneto Operating a High-Tension Coil

The purpose of the "high-tension" distributor is to distribute the high-tension current to the spark plugs. The distributor brush in the end of the rotor should make contact with one of the spark-plug leads just as the interrupter points (P) are breaking. See the discussion farther on, explaining connections to the distributor.

The distributor is usually attached to the magneto—when operated with a magneto, either of the low or high-tension type.

The distributor is usually made of hard rubber insulation material with metal segments (S). The rotor with a brush revolves by means of a gear wheel twice the size of the gear wheel on the armature (Fig. 6).

The armature for a four-cylinder magneto would revolve at engine crank-shaft speed and make four sparks during the two revolutions of the crank shaft.

The distributor, however, would revolve once and the rotor brush would make four contacts during two revolutions of the crank shaft, or one revolution of the distributor rotor. Hence the reason for the larger gear on the distributor.

On a six-cylinder engine the armature revolves 1½ times to one revolution of the crank shaft, but the distributor is geared to turn at half the speed of the crank shaft, or one complete revolution to two revolutions of the engine crank shaft.

There are two kinds of contact arrangements on a distributor: the "gap-type," and the "brush-type." The gap type does not make a wiping contact, but a slight gap clearance is allowed between the distributor rotor and segment (S). The brush type makes a wiping contact.

It must be remembered that while we are referring to the magneto distributor of the true "high-tension type magneto"—to show the parts of a "high-tension distributor"—the distributor used with the low-tension magneto and separate coil differs only in that on a true high-tension magneto there are two windings on the armature which take the place of the separate coil.

Dual System; Low-Tension Magneto, Coil, and Battery

A dual system of ignition is where a set of batteries are provided to start on. After starting the engine, the magneto is used as a source of electric supply instead of the batteries.

Types of Magneto Armatures

Magneto armatures may be classified as of two types. Although this instruction deals with low-tension magnetos, it will be necessary to allude to the armature of the high-tension magneto in order to make the explanation clear.

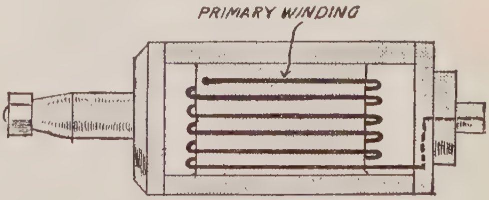


Fig. 7. Primary armature.

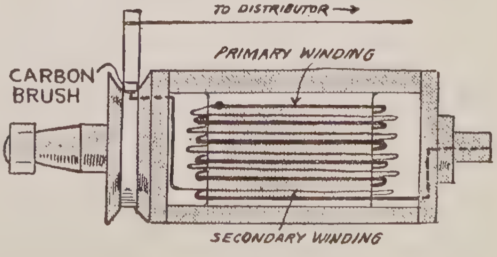


Fig. 8. Compound armature.

Magneto armatures are known as of the "shuttle" type because they are shaped like a shuttle. They are further classified as the "armature" type and the "inductor" type.

The "armature" type is where wire is wrapped around the armature core and the armature and wire revolve between the permanent magnet field poles. The armature type can be a single primary-wound armature used on a low-tension magneto, as in Fig. 7, termed a "primary-armature type." If there are two windings on the armature, a primary and secondary, as in Fig. 8, which is used on a high-tension magneto, then it is termed a "compound-armature type."

The "inductor" type of armature differs from the "armature type," principally in that the wire does not revolve. The inductor type of armature can be a low-tension magneto or a high-tension magneto, and differs from the armature type magneto only as mentioned above.

K. W. Inductor-Type Magneto

The K. W. Ignition Co. makes a low-tension and a high-tension inductor-type magneto. The Remy Electric Co. formerly made a low-tension inductor type of magneto used with a high-tension coil, as explained on page 247.

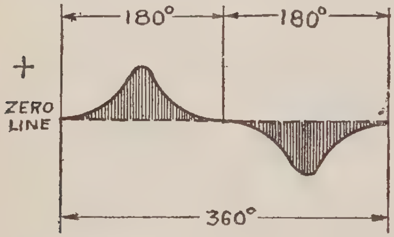


Fig. 9. Note that the shuttle type of armature produces two impulses or waves, of maximum strength per revolution (360°).

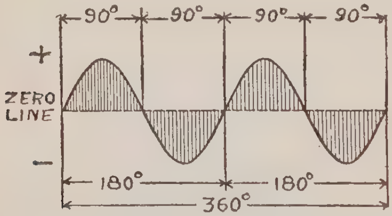


Fig. 10. Note that the K.W. "inductor" type of armature produces four impulses or waves, of maximum strength per revolution. (The line is zero, or no current.) Also note that the direction of the flow of current is changed twice in Fig. 9, and four times in Fig. 10, during a revolution.

The K. W. inductor type magneto is a leading magneto of the inductor type. Construction: magnets, permanent type; pole-pieces placed above armature 90° apart; rotors set 90° apart. There are two rotors with four ends as shown in Fig. 11, which illustrates the arrangement of the rotors on the armature shaft. This gives the same effect as if two shuttle armatures were placed cross wise—which would be four impulses per revolution (Fig. 10) instead of two in the shuttle type (Fig. 9). If we continued adding rotors we should soon have the alternations so close together that we could light an electric lamp—in fact, the K. W. low-tension magneto at high speeds will accomplish this.

The coil winding between the rotors of the K.W. magneto (Fig. 11) is stationary and the rotors revolve. With a single primary winding on this coil core it is a low-tension magneto. With two windings, it would be a high-tension magneto.

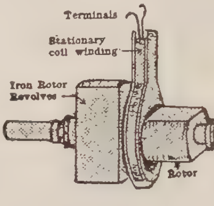


Fig. 11

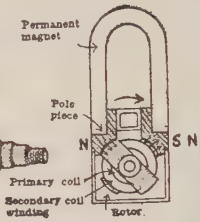


Fig. 11A

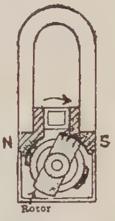


Fig. 11B

Fig. 11 shows the "inductor-type armature." Note that the winding is stationary.

Fig. 11A, shows the lines-of-force passing down through the rotor wing from N pole, then centrally through the core over which the coil is placed, up the rotor to S pole.

Fig. 11B shows rotors moved in position where the lines-of-force are now passing in the reverse direction, which causes a complete reversal of polarity through the coil winding. This is maximum position, where contact points (P) should separate.

Interrupter points are used on the K. W. inductor-type magneto when of a high-tension double-wound type.

The K. W. Low-Tension Inductor Type Magneto and Master-Vibrator

The K. W. inductor type of low-tension magneto, used with a master-vibrator, is shown in Fig. 12. Dry cells are used as a source of supply for starting when the switch lever is on the left, or (B) side. The magneto is used when the switch is on the (M) side. Note that the vibrators on the dash coil are short-circuited, as seen in the top left illustration, and are not used on the multiple dash coil to the right, as the one vibrator on the master-vibrator coil does the vibrating for the four coils.

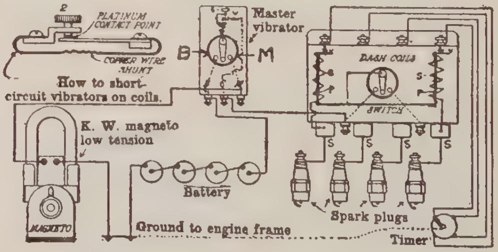


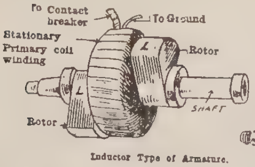
Fig. 12. K. W. low-tension inductor-type magneto connected with a high-tension coil-ignition system using a K.W. master vibrator coil.

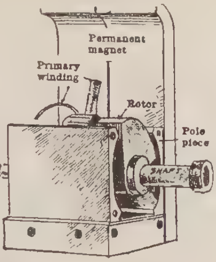
With this low-tension inductor-type magneto an interrupter is not used, because the vibrators on the coil take the place of an interrupter on the magneto. This type is not timed. Note that the commutator or timer is timed instead, as on a vibrator-coil system.

The Remy Low-Tension Inductor Type Magneto (Model R D)

The principle is similar to the K. W. (Fig. 11) except that the Remy rotor is a half-rotor, whereas on the K. W., both ends of the rotor are utilized.

The Remy produces two impulses per revolution and the K. W. four impulses per revolution.





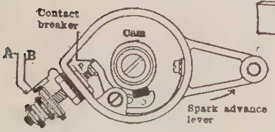


Fig. 13 (upper)
Fig. 15 (lower)

Fig. 14

Fig. 13. Remy rotors (L) which revolve and the stationary single primary winding.

Fig. 14. Remy inductor or rotor in maximum position.

Fig. 15. Remy contact-breaker or interrupter. The points (P) should have a clean surface. Dirt and grease should not be allowed to accumulate.

A distributor is mounted on the low-tension magneto which distributes the high-tension current from the high-tension ignition coil to the spark plugs.

If the engine misses with spark retarded at slow speed, adjust the contact screw (B) (Fig. 15) out a few notches.

If the engine misses with spark advanced at high speed, adjust the contact screw in a few notches.

On this magneto ignition system adjust the spark-plug points .025″.

The contact-breaker is used on this magneto just the same as on a shuttle-type magneto armature, to interrupt the flow of current in the primary winding.

To set the rotors: The rotors are placed in just the same position as on the shuttle-type armature when they are originally set, at which time the interrupter points open.

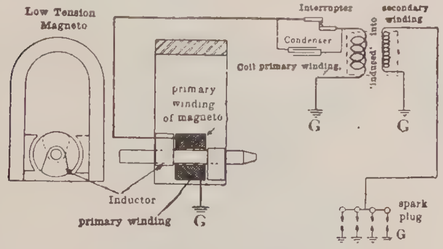


Fig. 16. Illustration showing how a high-tension coil is used in connection with Remy low-tension magneto. (G, ground.)

Note that the condenser is in the coil.

Examples of Remy Low-Tension Inductor-Type Magneto Systems

A dual system (Fig. 17) consists of a Remy model R.D. low-tension "inductor"-type magneto used in connection with a high-tension coil. Note that the condenser is placed in the coil, but is shunted across the interrupter points.

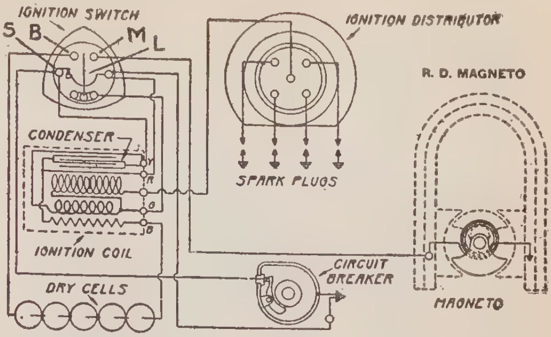


Fig. 17. Dual ignition system using a low-tension magneto of the "inductor" type in connection with a high-tension coil, with condenser in the coil. Note that the dry cells supply current for coil when on (B) side of switch, as when starting.

Dry cells are used to supply current to start with, by pressing a switch button (S) with switch lever (L) on battery side (B) of the switch, which closes the circuit between dry cells, primary winding of coil, and interrupter points. Thus when the engine is being cranked, the dry cells supply the current instead of the magneto.

The distributor and interrupter are mounted on the inductor-type low-tension magneto. The high-tension ignition coil is separate, as is also the switch.

After the engine is started, the switch lever (L) is placed on the magneto (M) side of the switch, the dry cells are cut out, and the magneto supplies current. The magneto interrupter is timed, so that the interruption of sparks occurs at the right time.

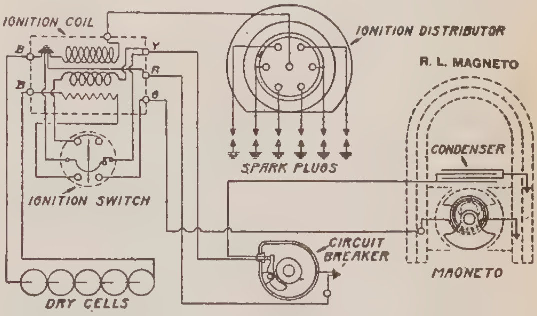


Fig. 18. Similar to Fig. 17 except that the condenser is on the magneto.

Fig. 18 is similar to Fig. 17, except that the condenser is mounted on the magneto, being across the interrupter points as usual. The magneto model is R.L., and is an inductor type similar to the model R.D. in Fig. 17.

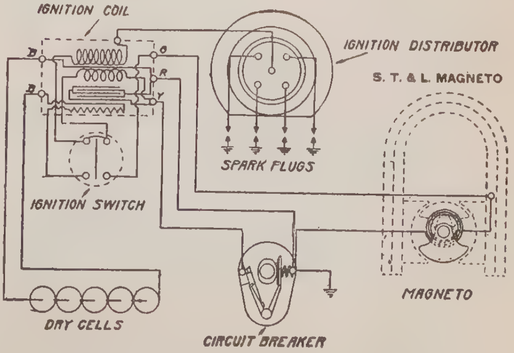


Fig. 19. See text on next page for explanation.

The system shown in Fig. 19 in many respects is similar to model R.D., except that the push button is not used and the interrupter is arranged differently. This type of low-tension inductor magneto is the S.T. & L. Dry cells are used for starting.

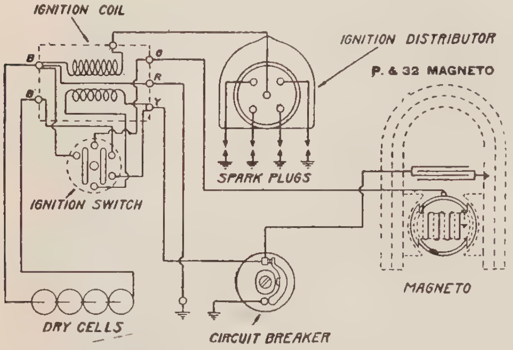


Fig. 20. Dual ignition system using a low-tension magneto of the "primary armature type."

In Fig. 20, this system (Remy P and 32 magneto) differs from that just described, in that the magneto armature is a "primary-armature type" low-tension magneto, instead of an "inductor" type. The push button is not used, and the switch is arranged differently.

All of the foregoing are examples of dual high-tension ignition systems, using a low-tension magneto of the inductor type (except Fig. 20) as a source of electric supply.

Note. The letters **Y, R, B, G,** refer to the color of wire on these systems. To time the Remy RD and RL low-tension magnetos: Place No. 1 piston on top of compression stroke. Press in on timing button (Fig. 17) which is at the top of the distributor and turn the shaft of the magneto (with coupling loose) until the plunger back of the timing button drops into the recess on the distributor gear. Then couple the magneto to its drive member. It is not necessary to set the interrupter in this instance, as the interrupter is in correct position with this operation, and No. 1 distributor segment is in contact with No. 1 distributor terminal, which is marked.

Ford Inductor-Type Low-Tension Magneto

Another form of low-tension alternating-current magneto of the inductor type is the Ford magneto.

This magneto might be termed a high-frequency magneto, meaning that there are 16 impulses per revolution. For instance, on the "shuttle-armature type" magneto there are 2 impulses per revolution. On the K.W. inductor magneto (Fig. 11, page 246), there are 4 impulses per revolution.

The term "impulse" refers to the points where the generated current is the strongest and is where the interrupter, as on the shuttle-type armature magneto, interrupts or opens the primary circuit just as the armature is leaving the pole pieces. Thus the spark or "impulse" occurs.

The term "frequency" refers to one-half the number of times the current changes its direction of flow in the winding per revolution (see "cycle" and "frequency" explanation, Fig. 7A, page 192). For instance, on an "armature or shuttle-type" magneto the direction of current in the primary winding on the armature changes its direction twice during one revolution (see Fig. 9, page 246). On the K. W. (Figs. 11 and 10, page 246), there are 4 changes during one revolution, because there are 4 ends to the rotors.

On the Ford magneto there are 16 changes per revolution, because there are 16 stationary coils attached to a plate or support inside of the flywheel housing. These coils consist of a thin strip of copper wrapped around a small soft iron core (C). The consecutive coils are wound in opposite directions on each coil core and are connected in series.

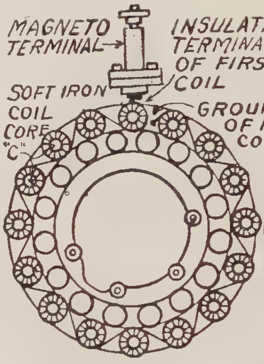


Fig. 21

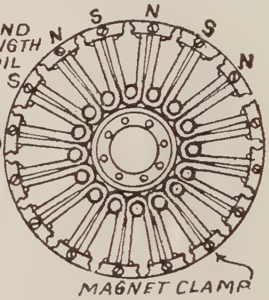


Fig. 22

Fig. 21. The sixteen stationary coils of the Ford low-tension inductor type of magneto mounted on the coil plate.

Fig. 22. The sixteen permanent magnets which are attached to the flywheel and revolve in front of the core of the coils. Like poles of the magnets are placed together.

The terminal of the first coil connects with the magneto terminal, which conducts current to the four primary windings on the four-unit vibrator-type coil. The end of the sixteenth coil is grounded.

There are 16 permanent magnets, but instead of being placed over the pole pieces and the armature being made to revolve between them, as in the "armature-type" magneto, the magnets are attached to the fly wheel by means of non-magnetic studs and are made to revolve within 1/32″ in front of the coil cores (C) (Fig. 23).

Note. Fig. 23 shows magnets separated, as if separate horseshoe magnets, as an explanation as to how they revolve in front of the coil cores. The magnets are placed close together, as shown in Fig. 22.

The N poles of the magnets are placed together; so are likewise the S poles. Thus we have N and S polarity alternately around the magnets, as shown in Fig. 22.

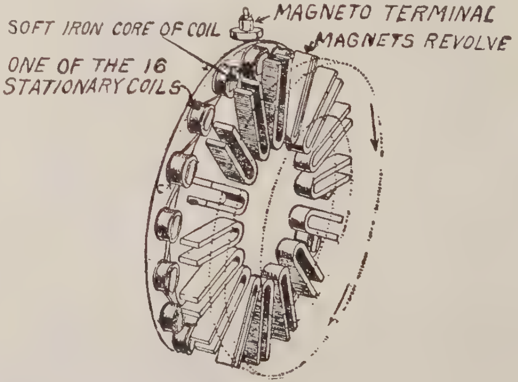


Fig. 23. Illustrating how the permanent magnets revolve in front of the coil cores. The magnets are within 1/32″ of the coil core.

When the N pole ends of the magnets are in front of one of the coil cores (C), the magnetic lines-of-force flow from N pole to the magnet, through the coil core (C), through the plate to which it is attached, through the core (C) of the coil next to it, to the pole end of the magnet, thus completing a magnetic circuit from N to S pole end of the magnet, and setting up a generated electromotive force in the coil winding, causing current to flow out of the coil windings into the magneto terminal (Fig. 21).

When the flywheel moves one-sixteenth of a revolution, the flow of current is reversed. Thus there are sixteen alternations or changes of flow of current during one revolution of the sixteen magnets, or sixteen "impulses" per revolution, because there are sixteen coils and sixteen inductors or magnets.

In other words, each revolution of the flywheel, to which the magnets are attached, means one revolution of the crank shaft. There are 16 positions of the magneto when the current output is at its maximum, and each of these positions is called **the peak** of the current wave. There are, also, 16 positions during which no current is flowing at all. Each of these is called **the neutral** position, and each is half-way between two peaks. Therefore, at every sixteenth of a revolution of the magneto a position is reached when no current is being generated. These are termed "dead points."

Each alternate peak is of an opposite polarity, that is, there are 8 positions in each revolution when the current flowing from the magneto winding to the spark coil is positive, and between these positions are 8 other positions when the current is negative. In other words, the frequency is 8 cycles per revolution.

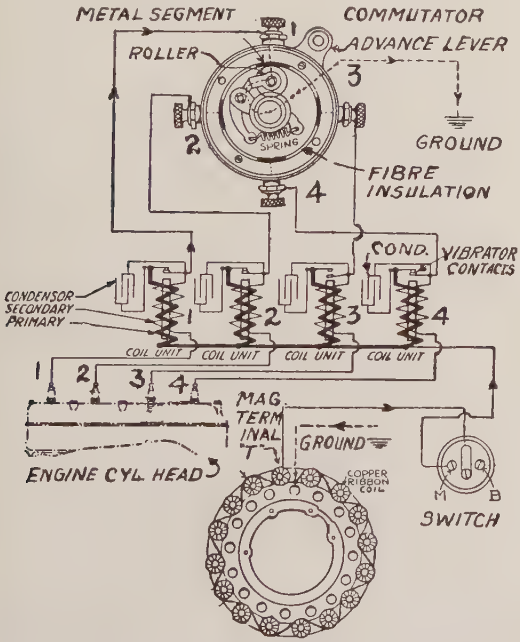


Fig. 24. Illustrating the circuit from the magneto terminal (T) to the switch, to the primary winding of one of the four high-tension coils, to segment (No. 1 in this example) of the commutator, to ground, to the grounded end of the sixteenth magneto coil. Note. There is a mistake in the drawing. The coil vibrator of No. 1 coil should be shown open instead of No. 3.

The Ford coil circuit and connections are shown in Fig. 24. See also Index for "Ford wiring diagram" and "Relation of speed of magneto to voltage generated."

The Ford inductor-type magneto, owing to its high frequency, will light lamps and supply current for a vibrator-type coil, but the voltage varies considerably. Thus the lamps will vary in brilliancy in relation to the speed of the engine. Owing to these variations of voltage, the ignition coil should be adjusted carefully, as explained on page 222, or else the spark-plug points will burn as well as the points on the vibrator blade of the coil.

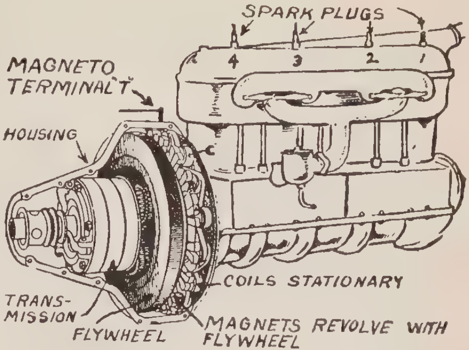


Fig. 25. Illustrating the location of the Ford magneto on the engine.

Low-Tension Magneto, "Armature Type"

The low-tension magneto like the low-tension coil, does not supply a very high voltage and would not jump a straight open gap like a spark-plug gap, but the voltage is raised sufficiently in the single coarse wire primary winding to produce a flash or spark when its circuit is very quickly opened.

The low-tension magneto can be used with a "make-and-break" igniter (Fig. 13, page 185), or with a "wipe-spark" igniter (Fig. 18, page 187).

The low-tension magneto can also be used in connection with a high-tension coil, but it would not be termed a high-tension magneto, even though the high-tension coil and the distributor were mounted on it; which is often the case. It would, however, be termed a high-tension ignition system.

The low-tension magneto is now seldom used, but is explained, because it is necessary to understand the principle of it before taking up the subject of the high-tension magneto.

The parts of an "armature type" low-tension magneto are: (1) magnets to produce the magnetic lines-of-force; (2) pole pieces of soft iron (see Fig. 1A, page 242); (3) a primary winding on a soft iron armature core which revolves, being driven at a fixed speed by the engine; (4) a contact-breaker (also called an interrupter) and a cam.

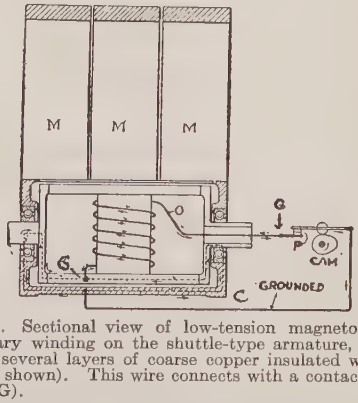


Fig. 26. Sectional view of low-tension magneto. (O) is the primary winding on the shuttle-type armature, of which there are several layers of coarse copper insulated wire (only one layer shown). This wire connects with a contact-breaker (P) and (G).

This contact-breaker would be in the form of an igniter (see page 185) and would be inside of the cylinder, if the "make-and-break" system of ignition is used.

If the system consisted of a low-tension magneto and high-tension coil, then the contact-breaker (G and P) above would be mounted on the end of the armature shaft and the circuit would be opened at the correct time, producing a spark, by a cam on the end of the armature shaft.

The circuit of a magneto system is a closed circuit; that is, the primary winding is closed and the circuit is opened by the cam only at the correct time, which is just as the armature passes the vertical position. At this time the greatest energy exists in the circuit, the position being termed the "maximum" position.

In other words, the spark is produced by the change from closed circuit to open circuit when the contact-breaker is opened by the cam. This break is made very quickly, and in order to get the hottest spark at the points of the spark plugs or igniter, the opening should occur when the armature is in "maximum" position. If the opening occurs earlier or later than maximum, then the intensity of the spark is weaker.

The primary winding on an "armature-type" magneto, consists of about 200 turns of No. 19 to 24 B. & S. gauge copper insulated wire.

HOW THE "ARMATURE-TYPE" MAGNETO GENERATES ELECTRIC CURRENT

A permanent magnet is made of hard steel and retains its magnetism. Its magnetic influence extends from one pole to the other, which is called the magnetic field, as shown in Fig. 27.[1]

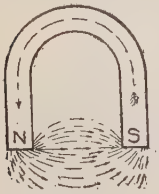


Fig. 27

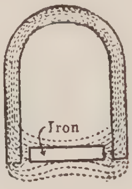


Fig. 28

The magnetic lines of force always flow N into S outside of the magnets or between the poles, and from S to N through the magnetic field poles. See Fig. 27.

If a bar of iron be placed between the poles (N and S), or in the magnetic field (Fig. 28), the magnetic lines of force will travel freely through the iron. It offers an easier path, because the air gap between poles offers 280 times the resistance that iron does. The magnetic lines will also be greatly increased, as the iron will collect a lot of stray lines of force and concentrate them.

Therefore a soft iron armature core (shuttle type) (Fig. 4A, page 243), with wire wrapped on it, is placed between pole pieces and made to revolve by being driven, usually by a gear from the cam shaft. The space between armature and pole pieces is very slight. The pole pieces (see Fig. 1A, page 242) are soft iron attached to the hard-steel permanent magnets. The armature is the "shuttle" type.

How Electromotive Force Is Induced into Wires of Armature

Whenever a loop of wire forming a closed circuit is placed in a magnetic field, an e.m.f. will be induced in the wire whenever the strength of the magnetic field changes.

Or, if a wire is moved up or down quickly in the magnetic field, so that the wire will cut across the magnetic lines-of-force or magnetic flux[1] at right angles (Fig. 29), an e.m.f. will be generated in the wire, and if the wire is in the form of a closed loop, the electromotive force thus generated will force the electricity in the wire to move. Why the electricity is in the wire we do not know, but we do know that the generated e.m.f. will cause it to move, or flow.

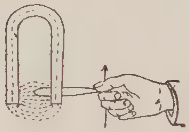


Fig. 29

The e.m.f. is induced in the wire by the lines being stretched by the movement of the wire, like rubber bands, then snapping at the weakest point—the S pole—then wrapping or whirling around the wire, thus generating e.m.f. in the wire. The intensity and number of lines-of-force around the wire will depend upon the strength of the magnetic field and the rate of speed with which the wires cut the lines-of-force. The direction in which the e.m.f. will force the electricity or current to move in the wire will depend upon the direction in which the wire itself is moved.

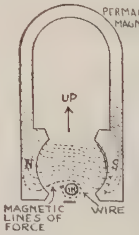


Fig. 30

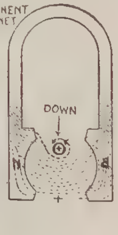


Fig. 31

If the wire is moved up (as in Fig. 30), the magnetic lines-of-force whirl around the wire in a clockwise direction and current will flow **into** the wire.

If the wire is moved down (as in Fig. 31), the lines-of-force will whirl counter-clockwise, and current will flow **out of** the wire.

If we have two wires (as in Fig. 32), revolving in the direction of the arrow point, the wire on the left would then cut the lines **up** as it revolved, and current would flow **into** the wire. The wire on the

---

[1] A "permanent magnet" will retain its magnetism a long time if a keeper is kept on the ends of the poles. The armature on a magneto, when in a horizontal position, acts as a keeper.

An "electro-magnet" is a magnet consisting of an iron core around which wire is wrapped. When direct current is passed through the wire, the iron core becomes a magnet—if current is flowing in one direction. Soft iron cores are used, as it quickly loses its magnetism when current ceases flowing.

[1] "Magnetic flux" is the total number of lines-of-force flowing through a magnetic circuit.

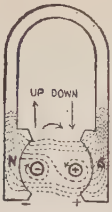


Fig. 32

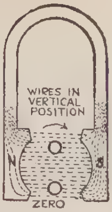


Fig. 33

right would move **down** and cut the lines down, and consequently the current would flow out. Thus we should have a complete circuit of current flowing, if the wires were in the form of a closed loop.

When the wires reached a vertical position (as in Fig. 33), there would be no e.m.f. generated in the wires and the e.m.f. would be zero value, because the wires would not be cutting **across**, or at right angles to the path of the lines-of-force.

This position of wires in Fig. 33 would be represented by the position of the armature of the magneto in Fig. 34. Note that all the lines-of-force would flow through the armature core, and the wires on the armature would not be cutting the lines-of-force at all; thus the e.m.f. is "zero" value.

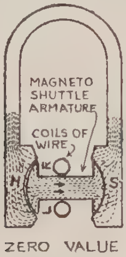


Fig. 34

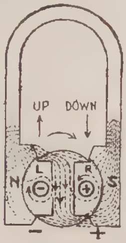


Fig. 35

Fig. 32 represents the position of the wires when the armature is in the position shown in Fig. 35. In this position the wires on the armature would be cutting the greatest number of lines-of-force, if, of course, the wires were moving rapidly with the armature. Thus the e.m.f. would be at its highest value at this position, which is called the "maximum position." It is the point at which interruption of the primary circuit should take place, if it were not for a factor called "armature reaction."

Owing to the fact, however, that the circuit is a closed circuit in which the current is flowing, there is an "armature reaction" which produces a hindering effect (explained farther on), and consequently the maximum position of the armature is reached a few degrees later, or just as the armature cheek breaks from the pole tip.

Before we proceed any farther, however, there are laws governing the generated e.m.f. which must be considered as follows:

The momentary induced e.m.f. is greatest when the wire is moved so as to cut the magnetic lines of force at right angles. Applying this principle to the coil of wire on the magneto, the coil would be cutting the greatest number of lines of force when in position shown in Fig. 35—or when it is moving at right angles so as to **cut** the lines of force.

The electric current in the wire depends upon the e.m.f. (electromotive force) causing it to flow; therefore e.m.f. is generated in wire when it is made to cut the lines-of-force, and a current flows when its circuit is complete, due to the generated e.m.f. The faster the coils cut the lines-of-force, the greater will be the e.m.f. generated.

The generated e.m.f. depends upon the speed of cutting the lines-of-force, that is, the number of lines cut per second. Therefore the greater the number of lines and the greater the number of wires there are, the greater will be the e.m.f. Therefore several layers and many turns of wire are wrapped on the armature core called the primary winding.

Referring now to Figs. 33 and 34, it will be seen that the coil is not cutting any of the lines-of-force—the lines are passing freely through the armature core from N to S; therefore e.m.f. (voltage) strength is at zero.

In the position shown in Figs. 32 and 35 the coils of the wires of the primary winding are cutting the greatest number of lines-of-force at right angles to the flow of lines-of-force. Some few lines are flowing through the ends of the armature core, but most of the lines are being cut by the wires on the armature. Therefore this position would appear to be the logical position at which the spark should occur, since it is the position where the **generated e.m.f.** in the wires is greatest.

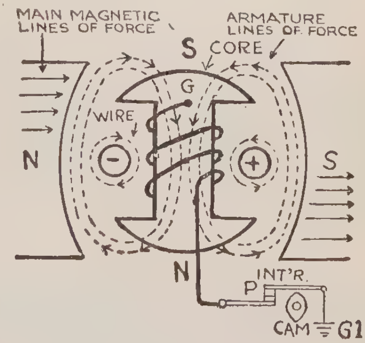


Fig. 36. Armature reaction.

There is, however, another factor which has not yet been considered, and that is, that when this generated e.m.f. is produced in the wires on the armature, by the wires cutting the main magnetic lines-of-force flowing from N to S poles of the magnets, this heavy current in the wires on a closed circuit has the effect of making an electro-magnet out of the iron core (Fig. 36). This is the same condition as was explained on page 182, where current from a battery flowing through a coil of wire around an iron core caused magnetic lines-of-force to whirl around the entire coil and thus form an electro-magnet with an N and S polarity.

Due to the generated e.m.f. in the primary wires on the armature, which is a closed circuit, the same effect is being produced, that is, independent magnetic lines-of-force are set up around the armature core which has made a S pole and N pole of the armature core (Fig. 36), with the result that these independent armature lines-of-force cause the main magnetic lines-of-force to follow their own path. This action is termed **"armature reaction."**

Note. The position of the armature in Fig. 36 is represented in Fig. 35. In the latter, the main magnetic lines-of-force are passing in at the **top** of the armature core and coming out at the **bottom.** This is due to the fact that the "main magnetic lines-of-force" are flowing "**with** the armature lines-of-force." See arrow points of both, in Fig. 36.

We have now built up a very strong magnetic field which extends all around the wire on the armature, and the principle is now similar to the coil action, explained on pages 182, 184. Now, the point is, if we could demagnetize the core of the armature, so that the lines-of-force which have been built up around the armature (Fig. 36) could collapse rapidly (as with the coil on pages 182, 184), then, as the lines-of-force collapsed, they would cut the wires at a very rapid rate of speed, if the core was fully demagnetized, or magnetized in an opposite direction. The result would be another independent induced (or self-induced) e.m.f. in the wires of a higher voltage, causing the current to flow in the wires in the same direction as it did before the circuit was opened.

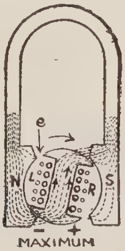


Fig. 37

The demagnetization of the core is accomplished by two different factors. If the circuit is opened at the interrupter points (**P**) (Fig. 36), just as the armature breaks from the pole piece (**e**), (Fig. 37), the magnetic lines-of-force which were flowing through the armature core in the direction shown in Figs. 35 and 36, will now flow in the opposite direction, coming in at the bottom instead of the top, as in Fig. 37, thus assisting in the demagnetization of the armature core.

These two actions combined cause the lines-of-force to collapse more rapidly on open circuit. Thus a fairly high induced voltage is built up in the wires, which, being generated on open circuit, will have no other outlet[1] except at the open points of the interrupter. Thus the voltage jumps the interrupter-point gaps in a manner similar to the action of the low-tension coil (Fig. 11, page 184). There being only a limited number of turns of rather coarse wires in the primary winding, however, the voltage will not be very great, but great enough to jump the interrupter point gap.

If the low-tension magneto is used with a "make-and-break" igniter (Fig. 12, page 185), (or a "wipe-spark" igniter), the spark is desirable at the break, because it would be in the cylinder where it is required.[2]

Low-Tension Magneto and High-Tension Coil in Series

If the low-tension magneto is used in "series" with a high-tension coil (Fig. 38), the spark is desired at the spark-plug point. It will then be necessary to have a condenser to absorb the current passing through the primary winding (**PRY**) of the coil from the magneto at the time of the break at interrupter or contact-breaker points and also to assist in demagnetizing the core of the high-tension coil, so that the lines-of-force built up around the coil core will collapse quickly and induce a high voltage in the secondary winding (**SECY**) of the high-tension coil. Thus a very high voltage will be produced at spark-plug points (Fig. 38).

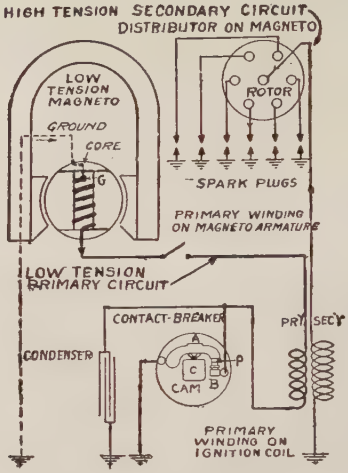

HIGH TENSION SECONDARY CIRCUIT
DISTRIBUTOR ON MAGNETO
LOW TENSION MAGNETO
GROUND
CORE
G
ROTOR
SPARK PLUGS
PRIMARY WINDING ON MAGNETO ARMATURE
LOW TENSION PRIMARY CIRCUIT
CONTACT-BREAKER
PRY
SECY
CONDENSER
A
C
CAM
B
P
PRIMARY WINDING ON IGNITION COIL

Fig. 38. Low-tension magneto connected in series with the primary winding of a high-tension coil.

Low-Tension Magneto and High-Tension Coil Shunted

If the low-tension magneto is connected with a high-tension coil, so that the interrupter or contact-breaker is "shunted" across the path from magneto to coil, instead of being in "series" with it (as in Fig. 38), the action would be slightly different as shown in Fig. 39.

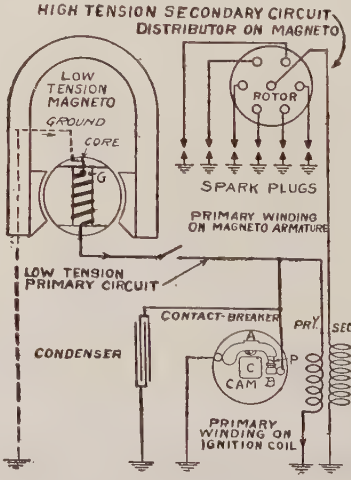

HIGH TENSION SECONDARY CIRCUIT
DISTRIBUTOR ON MAGNETO
LOW TENSION MAGNETO
GROUND
CORE
G
ROTOR
SPARK PLUGS
PRIMARY WINDING ON MAGNETO ARMATURE
LOW TENSION PRIMARY CIRCUIT
CONTACT-BREAKER
PRY
SECY
CONDENSER
A
C
CAM
B
P
PRIMARY WINDING ON IGNITION COIL

Fig. 39. Low-tension magneto connected with the primary winding of a high-tension coil, but the interrupter or contact-breaker is "shunted" across the circuit.

The primary current from the magneto would have two paths: one through the interrupter points (**P**), and the other through the primary winding (**PRY**) of the coil. The current takes the easiest path through the interrupter points, and consequently there is no current flow in the primary of the coil and its core is free from magnetism. Thus when points (**P**) are opened by the cam, this sudden break of the current flowing through the armature and interrupter points, or the shunt circuit, causes, with the assistance of the condenser, an induced current to be set up in the armature winding, as explained in connection with Figs. 35 and 36. This rush of self-induced current, having no other outlet, rushes through the coil primary winding (**PRY**). As the coil core is demagnetized, because of the fact that no current was flowing through it previously, the magnetic lines-of-force build up rapidly around the turns of wires, causing a momentary high voltage in the secondary winding, and thus causing a spark to jump the gap at the spark plug which is in the cylinder.

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[1] Even though the circuit is open at the interrupter, we term it a circuit if there is sufficient self-induced voltage in the wires to cause the electric current to jump the gap.

[2] It would appear that the "make-and-break" system would be the simplest, which it is, but the movable contact points in cylinders exposed to intensity of the heat soon get out of adjustment.

Note in Fig. 38 that **the lines-of-force in the coil core were made to collapse,** to produce the high-tension spark, whereas in Fig. 39, **the lines-of-force are built up in the coil core** to produce the high-tension spark. This was possible in this instance, because there was no current flowing in the primary winding of the coil, and its core was completely demagnetized. Thus the lines built up rapidly, generating a high induced voltage in the secondary. This system is the one in general use where a low-tension magneto is used with a high-tension coil.

It is well for the reader to grasp the difference between **generated e.m.f.** and **self-induced e.m.f.,** in order that he may clearly understand the foregoing explanations.

Generated e.m.f. refers to the e.m.f. generated in a wire when a wire is made to cut the lines-of-force, as when the armature is revolved between the pole pieces. In such a case the wires cut the main magnetic lines-of-force, and lines-of-force are built up around the turns of the wires.

Self-induced e.m.f. is where the lines-of-force have been built up around the wires, as described above, and then the circuit is suddenly opened, or the direction of the lines-of-force is changed. This causes a collapse of the lines-of-force, which cut the wires as it collapses into the core, thus causing what is termed a self-induced e.m.f. which causes current to flow.

Two Sparks or Impulses[1] per Revolution of Armature

With the shuttle type of magneto armature there are two positions of the armature during one revolution, called **"maximum position."** These are the points at which the e.m.f. is the highest and are the position in which the armature is when the contact points should open, or slightly later, owing to "armature reaction," as already explained.

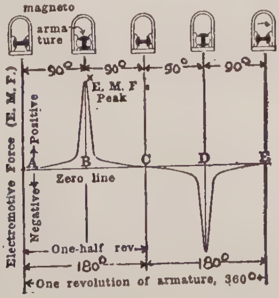

Fig. 40. Voltage wave.

In explanation of this, let us refer to Fig. 40, which shows the open-circuit voltage wave. Start with the position of the armature at (**A**) on the left. Note that the armature is in a horizontal position and the e.m.f. (electromotive force[1]) is at zero, because the lines-of-force are passing freely through the iron armature core, as is also shown in Fig. 34. Thus, at this point the wires on the armature are not cutting any lines-of-force.

When the armature travels 90°, or a quarter-revolution in the direction of rotation (clockwise, in this instance), it is in a vertical position (**B**). Technically this is the position where the highest break of e.m.f. or voltage is reached, because the wires are cutting the greatest number of lines-of-force. Practically, however, the maximum position is just a few degrees farther in the rotation, as shown in Fig. 37, for reasons already explained.

When the armature travels 90° more, or half of a revolution, it has again reached the horizontal position (**C**). The voltage is again at zero value.

When the armature travels 90° more, or three-quarters of a revolution, it has again reached another maximum voltage position (**D**).

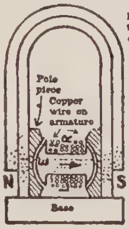

Fig. 41

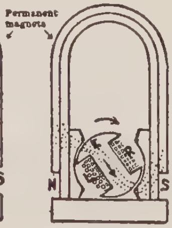

Fig. 42

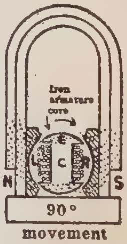

Fig. 43

Fig. 41. **Voltage is at zero.**

Fig. 42. The left (L) side of the coil is starting to cut the lines-of-force **up,** and the right side of the coil (**R**) is cutting **down. The e.m.f. is gradually increasing.**

Fig. 43. The e.m.f. is now at the highest peak because the greatest number of lines are cut in this position. The (**L**) side of the coil is still cutting lines up, and the (**R**) side down, therefore the voltage polarity is still the same.

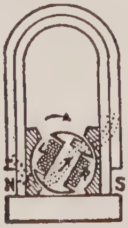

Fig. 44

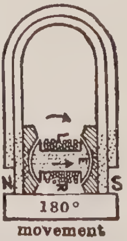

Fig. 45

Fig. 44. **The e.m.f. begins to weaken** because less lines are being cut. The voltage polarity is still in the same direction, because the (L) and (R) sides of the coil are still cutting the lines-of-force in the same direction.

Fig. 45. The armature has now turned one half-revolution. No lines are now being cut; the voltage (**e.m.f.**) strength is **at zero.** Thus we have had the positions as represented in Fig.40; (**A**) to (**C**), where the e.m.f. was in one direction. During the next half-revolution, the same action of the wires cutting the lines-of-force is repeated, except that the (**R**) side of the coil will now cut up and the (**L**) side will cut down. In this case, therefore, the e.m.f. will be in the opposite direction during the next half-revolution, as shown in Fig. 40, (**C**) to (**E**).

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[1] The word "impulse" is also used in connection with the ignition of gas in the cylinder; for instance, when the explosion takes place in the cylinder, the piston receives an "impulse."

[1] Refers to voltage.

When the armature travels 90° more, or a full revolution of 360°, it has again reached zero voltage position (E).

Thus we have during one revolution[1] of the armature two positions (B and C) when the voltage is at its highest voltage peak, and two positions (C and E) when it is at zero voltage.

The voltage wave is in one direction (A) to (C), which we will call positive, and in another direction (C) to (E), which we will call negative, or two directions during one revolution, termed "alternating" current. Thus the voltage wave changes polarity at (A) and (C), as will become clear by the following sequence:

The Current Wave

The voltage wave (Fig. 40) differs slightly from the current wave (Fig. 46). The e.m.f. or voltage generated is necessary to force the current to flow.

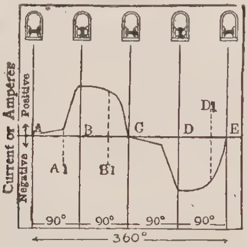

Fig. 46. Current wave diagram

The e.m.f. starts to build up at about 60° from (A) or at (A1), (Fig. 46), and consequently the current in the closed-circuit winding also starts to flow in a positive direction from (A) to (C) and reaches maximum when the contact points are opened at (B), or slightly afterwards.

Position (B) would correspond to the extreme **advance** position of the contact-breaker, and position (B1) to the extreme **retard**, or about a 35° or 40° movement.

Therefore if the contact-breaker housing was advanced so that a spark would occur before (B), or retarded after (B1), the spark would be weak.

There are two points in a revolution from (A) to (E), where a strong spark can be obtained, namely: between (B) and (B1), which represents half a revolution of the armature with the current flowing in a positive direction; and between (D) and (D1), which represents another half-revolution of the armature with the current flowing in a negative direction.

It is clear that **the contact-breaker must be opened at a certain position of the armature** and the armature and cam must be driven at a fixed speed, which is termed "setting" or "timing the ignition."

The cam: As the change takes place twice during one revolution of the armature, it is necessary that a two-point cam be used on the contact-breaker in order to break contact twice during one revolution.

To set the magneto: As stated, the point at which the armature cheek is just breaking from the pole (Fig. 37) is the correct position in which to set the magneto armature, and at the same time the interrupter points should just separate. Both operations should occur at the same instant.

Advancing and retarding: The cams are made of steel and are in a casing, and by having this casing made so that it can be moved through, say, the one-tenth part of a circle, the time of the interruption of current can be advanced or retarded with relation to the movement of the armature. This means the spark will occur early or late, relative to the movement of the pistons.

The low-tension magneto described is one which uses a shuttle-type armature, called the "armature" type of magneto. The wires revolve with the armature.

The inductor-type magneto is a magneto where the coils or wires are stationary.

Splitdorf Model "D" Low-Tension Magneto and Coil System: a "Dual Ignition System"

The illustration (Fig. 47) shows a Splitdorf dual system, using a low-tension "armature-type" magneto and high-tension coil with battery to start on and magneto to run on. The contact breaker on the magneto is utilized for either the battery or magneto system. The primary circuit through the armature, however, must be opened to prevent the battery from demagnetizing the magnets when the battery is used.

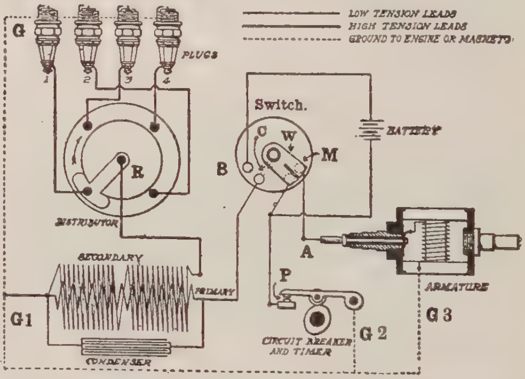

Fig. 47. Splitdorf model "D" low-tension magneto and high-tension coil—a "dual" ignition system.

Magneto circuit: from (A) to switch blade (W), through connection (C) to primary wire of coil, through ground (G1) and (G3) to armature. The breaker points (P), it will be noted, are connected or shunted across the magneto primary circuit, similar to what is shown in Fig. 39, page 252. The circuit proper is through the armature and circuit breaker, and the coil primary winding receives only the kick of the armature (extra current) when the contact points open, as explained on page 252. It will be noted that the battery circuit is open at the switch.

Battery circuit: the switch blade (W) should now be on (B) side, connecting the two terminals, and the magneto terminals on the (M) side are open. Current travels from top of battery (+) to switch point, to primary winding of coil, to ground (G1) to (G2), thence through interrupter points (P) to a lower connection of battery. Note that the armature is cut out entirely, but not the interrupter.

High-tension current is distributed from the secondary winding on the coil to brush (R) on the distributor (the distributor is on the low-tension magneto and is driven from the armature shaft), thence to the spark-plug center electrode, thence through the spark gap to plug-shell ground (G) of the engine and frame, back to the coil where the primary and secondary connect.

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[1] On some magnetos for eight and twelve-cylinder aero engines the pole pieces are arranged so that four maximum positions are reached per revolution. The K.W. magneto, page 246 produces 4 maximum positions or sparks per revolution.

Condenser: Although this is located in the coil, if the circuit is traced it will be observed that it "bridges" the points of the contact-breaker.

Splitdorf Model "T" Low-Tension Magneto and Coil System; "Dual Ignition Systems" Using a Dash Coil and a Tube Coil

The diagrams below show the Splitdorf low-tension model "T" magneto used in connection with a dash type of high-tension coil (Fig. 47A) and with a tube type of coil (Fig. 47B). The coils are also termed "transformers." Both systems are typical "dual" ignition systems of the interrupted shunt-current type.

Note that the distributor for distributing the high-tension current to the spark plugs from the coil is mounted on the low-tension magneto.

Also note the connections on the coil for the battery. By switching to one side, the magneto supplies current to the coil, and by switching to the other side, the battery supplies current to the coil.

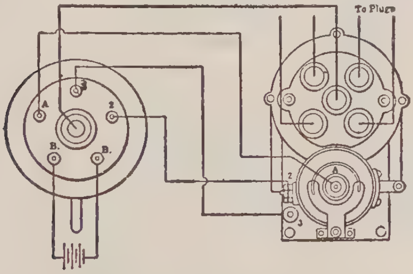


Fig. 47A. Splitdorf model "T" low-tension magneto used in connection with a "dash" or "box type" of high-tension coil.

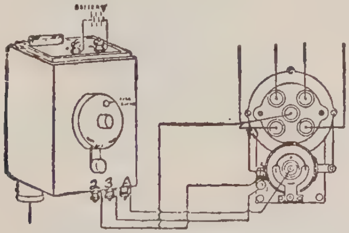


Fig. 47B. Splitdorf model "T" low-tension magneto used in connection with a "tube type" high-tension coil.

The Oscillating Low-Tension Type Magneto

This type is a regular shuttle or armature type magneto (Figs. 48 and 49), and is the original magneto principle, designed for slow-speed engines. The armature does not revolve, but oscillates back-and-forth from position Fig. 48 to Fig. 49 (30°).

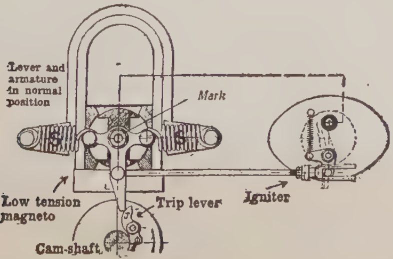
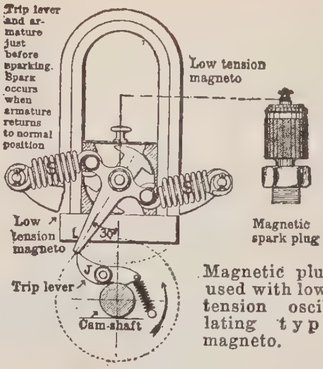


Fig. 48



Trip lever and armature just before sparking. Spark occurs when armature returns to normal position
Low tension magneto
Low tension magneto
L
30°
J
Trip lever
Cam-shaft
Magnetic spark plug

Magnetic plug used with low-tension oscillating type magneto.

Fig. 49

It can be used with an igniter arrangement (Fig. 48), which is similar to that shown in Fig. 13, page 185, except that the igniter rod is actuated by lever (L) on the magneto, which is tripped by trip (J). It can also be used with a magnetic plug, as shown in Fig. 49, which is screwed into the cylinder.

The Magnetic Plug

The principal parts of the magnetic plug (Fig. 50) are: magnetic coil (5), pole-piece (2), interrupter (20), and contact-piece on plug shell (21). The plug is screwed into the cylinder.

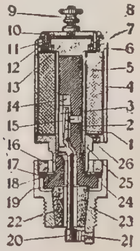


Fig. 50

Principle: owing to the sudden flow of current through coil (5), the upper portion of hammer bar (1), called the armature, is attracted to pole-pieces (2), which effects a quick separation of contacts (20) and (21), producing a spark at these points.

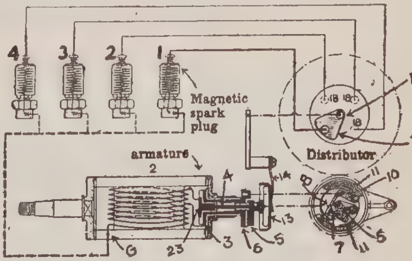


Fig. 51

The use of the magnetic plug is shown in Fig. 51, in connection with a low-tension magneto (type "K4" Bosch) with a revolving armature, with a main and auxiliary winding, one being a continuation of the other, and with a distributor for connections to the magneto plugs. This system is termed the Honold system, and is for 2, 3, 4, 6 and 8-cylinder engines.

The systems just described are not used for automobile ignition, but are designed for slow-speed heavy-duty stationary and marine engines.

INSTRUCTION No. 26

THE HIGH-TENSION MAGNETO: Principle; Construction; Types

Preliminary Explanation

The high-tension magneto is not only a mechanical generator, or a substitute for the battery, but combines all the elements of a complete ignition system, except the plugs and switch.

It performs three separate essential functions as follows: generating current; transforming the current to a high pressure; distributing the high-tension current to the individual cylinders. Besides these main functions, a number of minor functions have to be performed. The high-tension magneto differs from the low-tension magneto in only a few particulars.

The high-tension magneto can be of the "inductor" type or of the "compound-armature" type.

We shall deal here with the armature type and explain the inductor type farther on.

Armature winding: The armature (armature type) on the high-tension magneto is wound with an additional winding, called the "secondary winding," whereas the low-tension magneto has but one winding, called the primary winding.

Instead of using a "separate" high-tension coil, as with the low-tension magneto, explained in the preceding instruction, this second winding on the armature of the high-tension magneto takes its place. This secondary winding is carefully insulated from the primary winding, except at one end, where it connects at (N), (Fig. 1), with the primary winding. As the primary winding is grounded at (GP), the secondary winding is thus grounded through the primary winding. (PW) is the primary winding, and (SW) is the secondary winding.

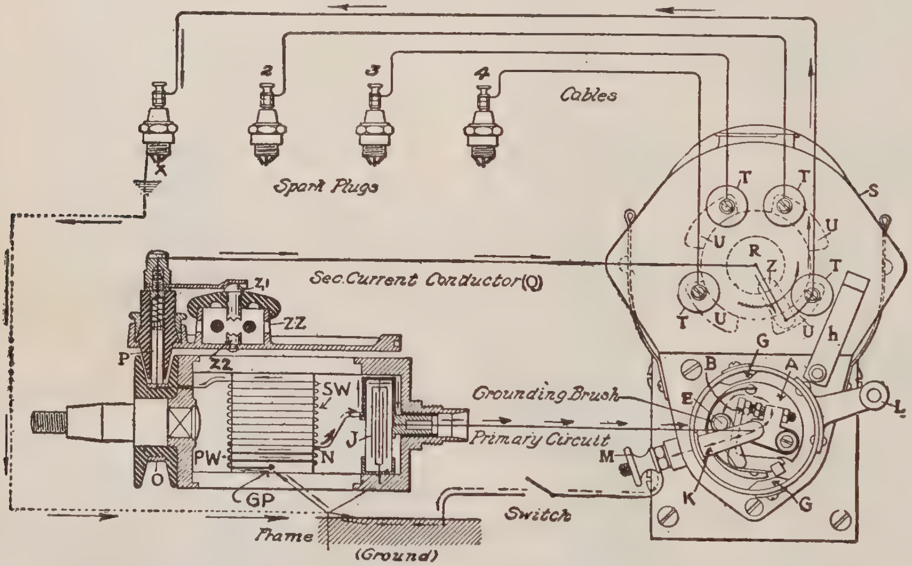


Fig. 1. Diagram of a high-tension "compound-armature-type" magneto, showing internal connections of armature The armature is double wound. It revolves between permanent magnet pole pieces with its wire winding.

One end of (SW) is led, carefully insulated, to a collector ring (O) mounted on the armature shaft, and a carbon pencil or brush (P) rubbing on this collector ring takes off the secondary current and leads it to the distributor brush (Z). The primary winding circuit is explained farther on.

The other respect in which this type differs from the low-tension magneto is that **the condenser** which is employed in connection with the interrupter is usually built into the high-tension magneto (J, Fig. 2), whereas with the low-tension magneto, the condenser is in the separate high-tension coil.

The condenser is usually, though not necessarily, located on the armature shaft in order to get it as close to the interrupter as possible, and it is there shown in Fig. 1 (J). In some magnetos, for the sake of greater accessibility and other reasons, the condenser is located outside the armature in a stationary sealed box.

Owing to the fact that the secondary coil of the high-tension magneto is located on the armature itself, it follows that it not only receives an induced current, due to the breakage of the primary current, but itself induces a current like that of the primary coil, but smaller in volume.

It has the same form of armature, field magnets, and principle of interrupter as the low-tension magneto, but of varied construction. The armature coil, however, is different, having a primary winding with a secondary winding over it, as previously explained.

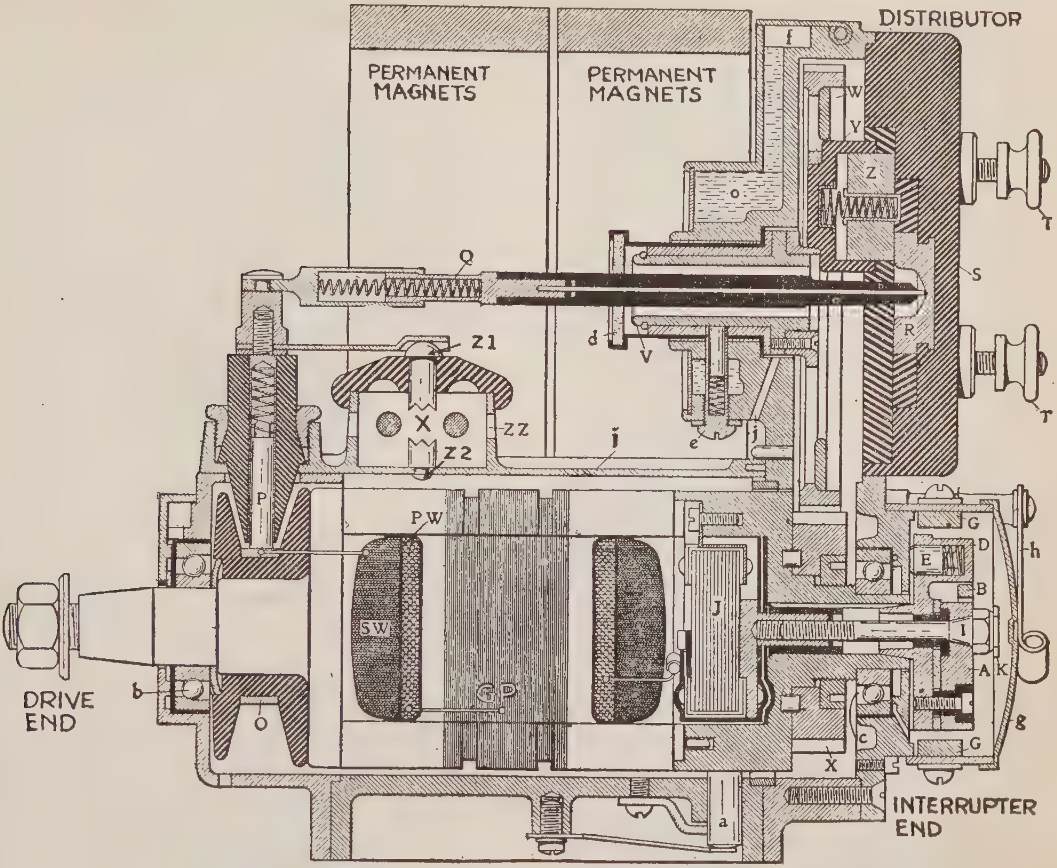


Fig. 2. Longitudinal section of Bosch type DU4 high-tension magneto. Note that distributor brush (Z) is revolved by a large gear (W) which is driven by a smaller gear (X) on the armature shaft. The armature is driven by the engine.

Principle of Operation

The primary winding usually consists of about 200 turns of No. 19 to 24 B. & S. gauge insulated copper wire.

The secondary winding usually consists of about 12,000 turns of very fine wire, No. 34 to 38 B. & S. gauge, and is of enameled silk-covered copper wire. The ratio is about 60 to 1.

We have already learned that the electromotive force induced in a winding depends upon the rate of change in the number of lines-of-force and the number of turns of wires the lines-of-force cut. Therefore with this great additional number of turns of secondary wires on the armature, the e.m.f. will be greatly increased.

The principle is very much the same as that explained on pages 251, 253. The interrupter breaks the primary circuit when the armature is in maximum position, or just when the armature cheek is leaving the pole tip. Thus the armature core is demagnetized, and the lines-of-force collapse and cut the secondary and primary wires at a very rapid rate. And, since there is such a large number of turns of wires in the secondary winding, the result is, that a very high voltage is induced in the secondary winding, which at normal speeds will cause a spark to jump across a gap of the spark plug. This spark is maintained to some extent by the voltage induced in the secondary by reason of the constant change of magnetic lines-of-force or flux in the iron core produced by the rotation of the armature during the period in which the contact points remain open. The cam then permits the contacts to close again, and the operation is repeated.

Importance of Condenser and of Quick Opening of Contact Points

The condenser is provided in order to absorb the spark at the interrupter points when the primary circuit is interrupted or separated. In other words, if the condenser were not across the points, the lines-of-force collapsing so rapidly would produce a very high voltage in the primary winding and thus cause a heavy spark at the breaker points, before they had time to separate properly, just as it does when used with a low-tension magneto and make-and-break igniter. As explained before, this results in burning the platinum points.

If the contact points could be opened quickly enough, the condenser could be dispensed with. In fact, if this were possible, the magneto would be better without it, because the condenser absorbs the initial current rush from the primary, produced by the collapsing lines-of-force, until the points are fully opened, thus preventing sparking at the points. But this is accompanied by the disadvantage of preventing the voltage from building up to a high value before the contact points have had time to separate properly. At the same time that it retards the development of the primary voltage, it retards the secondary voltage in building up also. Therefore the condenser capacity should not be greater than just enough to suppress the spark at the points. Of greater importance is the **quick opening of the contact points,** and proper adjustment.

An advertisement of a magneto manufacturer reads as follows: "The most perfect interrupter that has ever been placed on a magneto. Its quick opening is largely responsible for the efficiency of the magneto." This is mentioned so that the reader will appreciate the importance of the quick opening and the proper adjustment of the interrupter points.

In the instruction book of the K. W. Ignition Co., the following wording appears relative to the interrupter points:

> "A word of warning at this time, as to the proper distance to set the contact points to open, might be of value.
>
> "The volume of spark produced depends to a large extent on the proper break of the points. If they are opened quickly and make a clean break, the maximum spark is produced. When the points are too close, they do not break clean, as the arcing at the point causes the current to linger in the primary. When the points are too far apart, they may not close tight enough to allow current to flow, and in addition the opening of the points occurs too early and causes an unnecessary pounding on the roller. You will, therefore, note that the proper adjustment of the points will safeguard both electrical and mechanical difficulties.
>
> The points should be set to open 1/64" in order to get the best results. (This is on the K.W. high-tension magneto.) As a rule magneto manufacturers supply a gauge to which these points should be accurately set."

There are many different constructions of interrupters, some of which are shown farther on.

CONSTRUCTION OF A HIGH-TENSION MAGNETO

The following description refers to the **"compound-armature type" magneto.** As an example, the Bosch type "DU4" will be used. See Figs. 1, 2, 3, 4, and 5, and also other exaggerated illustrations in order that the purpose of the parts may be clearly understood.

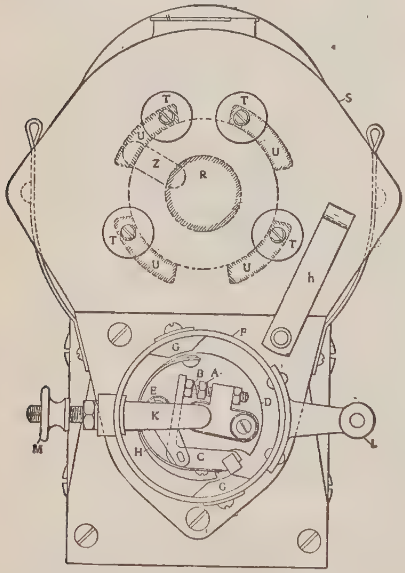


Fig. 3. Front view of Bosch 'DU4" magneto.

Interrupter Parts

A—Platinum point on insulated contact-breaker block which connects with one end of primary winding.

B—Platinum point on grounded breaker arm (C).

C—Contact-breaker arm; platinum point at one end and lug at other end, which comes in contact with cam (G) as (C) revolves.

D—Brass disk, fastened to armature shaft and rotating with it. (A), (B), and (C) are fastened to this disk and revolve with it, but (A) is insulated from (D) while (B) and (C) are grounded to it.

E—Carbon brush grounds (D) to magneto frame (see Fig. 2, page 257).

F—Cylindrical breaker-box housing which can be shifted by (L), to advance or retard.

G—Cam blocks which cause arm (C) to separate points at (A) and (B).

H—Spring keeps points (A) and (B) closed until separated by (G)

K—Connects with (A) or one end of primary, and connects with terminal (M) (insulated).

M—Connects with switch as shown in Fig. 1. Other side of switch is grounded. When switch is closed magneto is 'off".

h—Spring for holding cover in place.

Distributor Parts

T—Terminal to spark plugs.

Z—Distributor brush connecting with (R).

R—Connects with pencil brush (P) on collector ring (O), through contact conductor (Q), as in Fig. 2.

U—Segments or contact pieces connected with terminals (T) on which brush (Z) slides.

Magnets and Pole Pieces

Magnets and pole pieces: In any standard magneto made on this principle the general construction would be as follows: The permanent field magnets consist of two—or three—pairs. One magnet of each pair is superimposed above the others, as in Fig. 6; or 2 magnets are sometimes placed side by side.

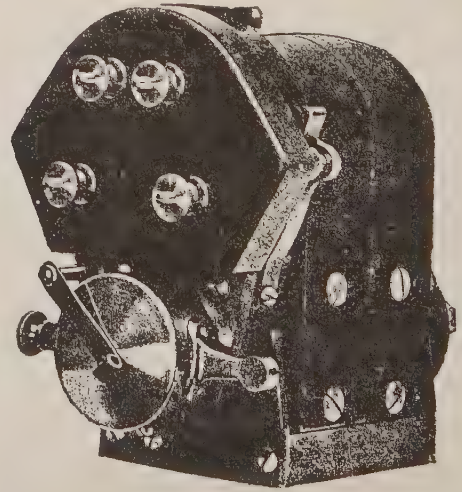


Fig. 4. Bosch "DU4" high-tension magneto for a four-cylinder engine. Note single magnets. Type "DU6" is the same, except that it is for a six-cylinder engine. Type "D4" has three-bar magnets; type "DR4," two-bar magnets.

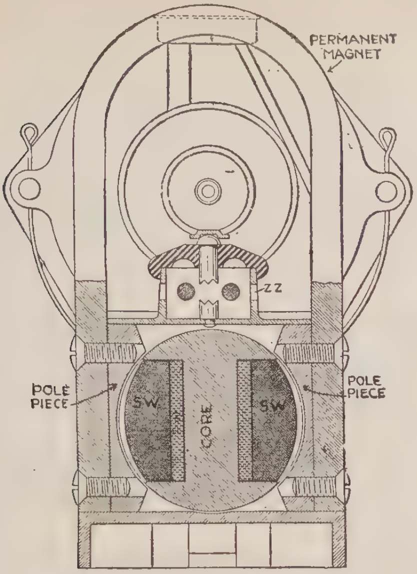


Fig. 5. Rear sectional end view. Note safety spark gap (ZZ); see also, Figs. 1 and 2. Note pole-pieces screwed to end of field magnets. The dark shaded part on the armature represents secondary winding; light shading, primary winding.

In some few cases three magnets are placed one over the other. For instance, on the Bosch "DU4," four-cylinder engine magneto, there are two magnets side by side. On the "D4" there are three magnets, and on "DR4," two magnets, as will be clear by examining Fig. 6. The magnets are set to give correct north and south polarity. All north poles on one side and all south poles on the other side.

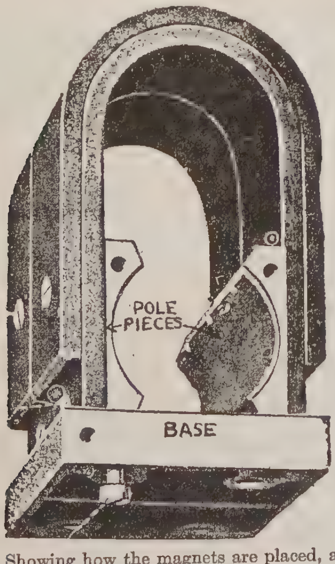


Fig. 6. Showing how the magnets are placed, and also the end pole pieces.

The ends or poles embrace "pole pieces" of soft iron bored out to allow the armature to rotate quite freely, but very closely to the pole faces; in some cases the clearance is only .002 inch. See also, Fig. 5.

Armature

The armature: This consists of a core of soft iron of H-shaped (Fig. 7) cross-section; it is also referred to as a "shuttle" armature. This core of soft iron serves to form a bridge for the magnetic flux between the pole shoes, and also to carry the winding in which the current is induced.

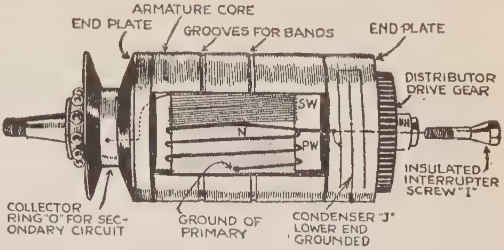

ARMATURE CORE
END PLATE
GROOVES FOR BANDS
END PLATE
DISTRIBUTOR DRIVE GEAR
SW
N
PW
INSULATED INTERRUPTER SCREW "I"
COLLECTOR RING "O" FOR SECONDARY CIRCUIT
GROUND OF PRIMARY
CONDENSER "J" LOWER END GROUNDED

Fig. 7. Armature of the revolving compound type (double wound).

The armature is found in practically every standard type of the well-known "shuttle" type. The best class machines have the armature built up of thin stampings of soft iron, each insulated from the other by a thin film of varnish. This form of construction is known as a "laminated armature core." A laminated armature core is shown in Fig. 4, page 243, and a complete armature wound with double winding is shown in Fig. 7. Laminated cores have the advantage over a solid cast-iron core in that the electrical efficiency is higher through the absence of "eddy" currents in the iron core which represent considerable waste of energy and cause heating.

By laminating or breaking up the core into thin sections, the currents are prevented from circulating through the iron (spoken of as "eddy currents"). In the case of a solid core, the iron would be annealed to render it as "soft" as possible, to obtain the best magnetic effect.

Armature winding: The armature core is first insulated with mica or similar material. Then it has several layers of heavy insulated wire wound upon it. The Bosch DU-4 magneto has approximately three layers of No. 21 insulated primary wire and seventy to seventy-two layers of No. 36 silk-covered secondary wire.

To the end of this heavy primary wire is connected the beginning of a very fine secondary wire (see **N**, Fig. 1), insulated with silk, which is wound on the core until the slot is filled almost to the height of the cylindrical portion. After this a wrapping of insulating cloth is applied, and bands are put around the circumference of the armature to prevent the wire and insulating material from flying out and coming in contact with the pole shoes when the armature is rotated at high speed. To the ends of the armature the steel shaft or spindle is fixed by brass end plates (Fig. 7).

It will thus be noted that there are really two windings on the armature, whereas the low-tension magneto has but one winding—an inner winding of relatively few turns of heavy wire, and an outer winding of a large number of turns of fine wire.

The armature shaft is mounted in annular ball bearings (Fig. 2, **b** and **c**), which are provided with oil guards so that any lubricant supplied to them will not be easily lost or reach the insulating parts. The armature tunnel is closed on top by an aluminum cover **i**, (Fig. 2), and the front of the circuit-breaker housing is provided with a brass cover (**g**), which is held in place by means of a hinged flat spring (**h**), so that it can be removed and replaced.

Primary Winding and Circuit

The winding of heavy wire, or primary winding, serves primarily for generating the current, and in connection with the fine wire or secondary winding, it also serves for multiplying the pressure or voltage to such an extent that it will produce a spark at the gap of the spark plug in the cylinder.

The primary circuit (Fig. 1) begins with the primary winding (**PW**) on the armature. It flows through the contact-breaker screw (see I, Fig. 2), to the stationary contact (**A**), thence across to the movable contact (**B**), from which it is led through the contact brush (**E**), into the metallic framework of the magneto, whence it returns to the beginning of the primary winding, which is also connected or grounded to the frame (**GP**).

Interrupter or Contact-Breaker

The interrupter, also called a "contact-breaker." To accomplish this breaking of the primary circuit at the proper moment and then to close it again, a device known as a "circuit-breaker" or "interrupter" is used. This is carried on the armature shaft opposite the driving end.

In order clearly to explain the construction of an interrupter, exaggerated illustrations will be used as, for instance, in Figs. 8 and 8**A**.

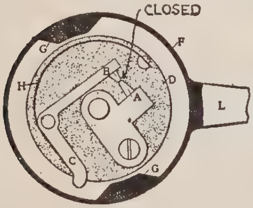


Fig. 8

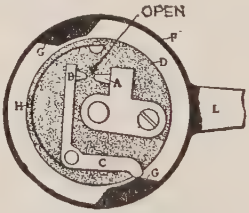


Fig. 8A

It consists essentially of a stationary insulated contact point (**A**), (Fig. 8), and a movable contact point (**B**) on one arm of the bell crank (**C**). Both of these parts are mounted on a brass disk (**D**), which is securely fastened to the armature shaft and rotates with it.

The stationary contact (**A**) is insulated from the supporting disk (**D**), while the movable contact (**B**) is in metallic connection with it, and the disk (**D**) is grounded to the frame of the magneto by a carbon brush (**E**). (See also Fig. 2.)

The circuit-breaker is surrounded by a cylindrical housing (**F**), to the interior surface of which, at diametrically opposite points, are secured steel cam blocks (**G** and **G1**).

Ordinarily the two contact-points (**A** and **B**) are kept in contact by a spring (**H**). As the disk (**D**) rotates, the outer arm of the bell crank (**C**) comes in contact with the cam blocks (**G**), whereby the contact-points (**A** and **B**) are separated momentarily, as in Fig. 8**A**.

As soon as the end of the bell crank (**C**) passes the cam block (**G**), the spring (**H**) brings the two contact-points (**A** and **B**) together again, as in Fig. 8.

The stationary contact-block (**A**) is connected with one end of the primary winding of the armature, through a screw (I, Fig. 2), which is screwed into the center of the armature shaft.

The other end of the primary winding has metallic connection with the armature core; in other words, it is grounded, as at (**GP**), (Figs. 1 and 2).

Secondary Winding and Circuit

The beginning of the secondary winding (**SW**, Figs. 1 and 2), is connected to the end of the primary winding at (**N**) (Fig. 1), and since one end of the primary winding is grounded at (**GP**), the secondary is also grounded through the primary. The end of the secondary winding leads to an insulated contact ring (**O**) (Fig. 2), at the driving end of the magneto.

From this ring the current is taken off by a carbon contact-brush (**P**). From the brush holder the current is carried through a spring contact-conductor (**Q**) to the central distributor contact (**R**).

The collector ring is made of hard rubber with a brass ferrule (**O**) surrounding it, against which ferrule a heavily insulated stationary carbon pencil (**P**) bears. The hard rubber spool has wide flanges for the purpose of preventing the high-tension current from escaping.

Secondary Distributor

The distributor consists of a disk of insulating material (**S**), in which are imbedded on the inner side one central cylindrical contact-piece (**R**) and four annular sector-shaped contact-pieces (**U**, **U**, **U**, **U**, Fig. 1).

The distributor also comprises a shaft (**V**, Fig. 2), which carries a gear wheel (**W**) meshing with a pinion (**X**) on the armature shaft. The gear wheel (**W**) has twice the number of teeth as the pinion, and the distributor shaft (**V**) therefore makes one turn while the armature makes two.

Distributor speed: The reason for driving the distributor at one-half the armature speed is as follows: The armature, as already stated, turns at the speed of the engine crank shaft. The magneto here described is for a four-cylinder, four-cycle engine. In such an engine, each cylinder requires a spark once in two revolutions of the crank shaft.

The distributor is therefore geared so that it makes one revolution to two revolutions of the crank shaft and establishes connection between the high-tension or secondary winding of the armature and the spark plug to each cylinder once in every two revolutions of the crank shaft.

Regardless of the number of cylinders an engine may have, the distributor rotor always turns at engine cam-shaft speed.

The gear wheel (**W**) carries a brush holder (**Y**) containing a carbon brush (**Z**), which is adapted to make contact simultaneously with the central distributor contact (**R**), and with one of the annular distributor contacts (**U**).

This type of distributor is the "brush" type, as it makes a wiping contact. The "gap type" is shown in the Berling, explained farther on.

The distributor sectors (**U**, Fig. 1), are surrounded at the inside and outside by annular rings of a highly insulated material, since they carry the high-tension current.

Each of the four annular contact segments (**U**) has secured to it a binding post (**T**) on the face of the distributor disk, and each of these binding posts is connected by a high-tension (highly insulated) cable to one of the spark plugs.

The connections from distributor terminals (T) to the spark plugs are connected according to the firing order of the engine.

If distributor rotor (Z, Fig. 1) revolved as shown by the arrow point and the firing order of the engine was, say, 1, 3, 4, 2, the terminals (T) would be connected with the spark plugs accordingly.

The secondary circuit to the spark plugs is from (P) (Figs. 1 and 2), to (R), to (Z), to (U), to (T), to spark-plug center electrode, through spark-plug gap (X), through engine to ground (GP) on the magnets to (N) (Fig. 1), where the secondary is connected with the primary winding.

There are numerous methods of **taking the current from the secondary winding on the armature,** but in the Bosch a carbon brush pressing on an insulated ring is adopted, thus allowing the armature to rotate freely, and also enabling the induced current to be drawn off.

The distributor is, in effect, a rotary switch, especially insulated and provided with a number of contacts equivalent to the number of cylinders on the engine.

The distributor shaft is mounted in a plain bronze bushed bearing (V, Fig. 2), which is lubricated by means of a wick oiler (e). A felt washer (d) encloses the inner end of the bearing, while at the distributor end is provided a channel (j) for the escape of any oil working out of the bearing so that it will not reach the distributor. A large-sized oil well (o) is provided for the wick oiler and is closed by a hinged cover (f) on top.

Ground Brush

Some of the mechanical details of the magneto may be seen in Figs. 1 and 2, which are views of the Bosch model "DU4." It will be observed that a spring-pressed contact brush (a, Fig. 2) is placed in the base of the magneto bearing against the circumference of one armature end-plate. The object of this contact brush is to make absolutely sure that the revolving grounded metallic parts of the magneto are at all times in good metallic connection with the stationary part and the frame of the car; in this construction, therefore, the armature bearings carry no ground current.

Magneto Condenser

Condenser principle: When the two contact points (A) and (B) of the interrupter (Figs. 1, 2, and 3) are suddenly separated, there is a tendency for the current to continue to flow across the gap, since it possesses a property similar to the inertia of matter. This would result in a hot spark being formed between the contact points, which not only would burn the points away rapidly, but also would prevent a rapid cessation of the current, which, as already explained, is necessary in order to effect a rapid change in the lines of magnetic force through the armature and a high inductive effect in the secondary winding. To obviate this effect a condenser (J, Figs. 1 and 2) is employed, which, in the Bosch magneto, is placed in a hollow of the armature end-cover at the circuit-breaker end.

Condenser construction: This condenser consists of two sets of tinfoil sheets, sheets of opposite sets alternating with one another, and being separated by sheets of insulating material. All the sheets of each set are metallically connected, and one set is connected to the conductor leading from the primary winding to the stationary contact point (A), while the other set is grounded. In other words, the condenser is shunted across the interrupter.

Such a condenser is capable of absorbing an electrical charge, and its capacity is so proportioned that it will take up the entire charge of the extra, or self-induced current produced when the contact points (A) and (B) separate; that is, the extra current, instead of appearing in the form of a spark across the gap between (A) and (B) passes into the condenser (J). In this way the objectionable arcing or burning at the contact points is avoided, and the current flow in the primary circuit is more quickly stopped. See Index under "Condenser principle."

Magneto Safety Spark Gap

Purpose: This is practically a safety valve for the high-tension current. If, for example, a wire became detached from the sparking plug or from the distributor so that the ordinary path of high-tension current was barred, there would be considerable danger of the current forcing a circuit through the insulation of the armature, and thus doing very considerable damage, were it not given some easier escape.

In order to protect the insulation of the armature and all other parts from injury due to excessive voltage, a **safety-spark gap** (Z1, Z2, Fig. 2) is provided to permit the passage of the current to ground without injury. The current will pass across the safety-spark gap (X, Fig. 2) in case a high-tension cable is disconnected, if the spark-plug gap is too great, or if for any other reason the spark-plug or distributor circuit is open.

Discharge should not be permitted to pass through the safety spark gap for any great length of time, however. This should be particularly guarded against if the engine is operated on a second or auxiliary ignition system. When the engine is operated on such a system, the magneto should be grounded (by closing the primary circuit) in order to prevent the production of high-voltage current. See also Index under "Safety spark gap."

A magneto must be so designed that it will give a sufficiently hot spark at a comparatively low engine speed, and the ability to do this implies the ability of generating very large and hot sparks and enormously high tension at high engine speed.

The actual electromotive force or tension produced in the secondary winding is, however, limited by the size of the spark gap in the spark plug, for as soon as the tension reaches a point sufficient to jump this gap the discharge occurs, and there is no further increase in the electromotive force.

Suppose, however, that the terminals of the spark plug are by chance bent unduly far apart, or that one of the high-tension connections to the spark plug accidentally comes loose, then there would be no chance for the spark to pass in the ordinary way and the electromotive force in the secondary winding might build up to such an extent as to puncture the insulation of the winding, which would ruin the armature. To avoid this the safety spark gap is provided.

Safety spark gap construction: It consists of a little chamber (Fig. 2) formed on top of the armature cover plate with a top of insulating material (ZC). Into the top and bottom of this chamber, spark terminals (Z1, Z2) are set.

The spark terminal in the bottom is, of course, grounded, and that in the insulated top is connected with a high-tension contact brush (P) by a strip connector. Or, in other words, the safety gap is shunted across the secondary circuit.

The gap (**X**) between the two terminals (**Z1, Z2**) is longer than the gap between the spark plugs, and ordinarily no spark will pass between these terminals. But if, owing to the conditions already mentioned, no spark can pass at the regular spark plug and the electromotive force in the secondary winding attains an abnormal value, a discharge will occur at the safety spark gap, thereby preventing the secondary electromotive force from rising still higher.

The width of gap should be 5/16″ to ⅜″, and, of course, is always more than the width of the spark-plug gap, otherwise the spark would occur at the safety gap.

For high-compression engines it should be set at ⅜″. Under high compression, the sparks may fire across the safety gap instead of firing in the engine. Missing under such conditions can easily be remedied by opening the safety gap so that it will offer a greater resistance to the secondary current than the spark-plug gap, under compression.

A number of other illustrations are also shown of the Bosch DU4 magneto, in Figs. 3, 4, and 5, which may aid those not familiar with mechanical drawings to grasp the arrangement of the parts.

So far as the above description of the individual parts and their functions is concerned, it applies to any true high-tension magneto, that is, a magneto having both a low-tension and a high-tension winding on the armature. .

Each of the elements here described is always present, and serves the purpose indicated, though the relative location of the parts varies somewhat.

To Cut Off the Magneto Ignition; the Switch

It is necessary to be able to stop the magneto from producing sparks when it is desired to stop the engine. (See Fig. 2.) To this end a sheet-metal strip (**K**) is provided which makes contacts with the stationary contact point (**A**) of the circuit-breaker and leads to a binding post (**M**) on the circuit-breaker housing. From this binding post a wire is carried to a switch on the dashboard. One side of this switch is grounded.

When the switch is closed (Fig. 1), the current generated in the primary winding of the armature flows to contact-point (**A**), thence through strip (**K**), binding post (**M**), and connecting wire to the switch, whence it passes through a wire into the framework of the car and returns to the grounded primary (**GP**). The effect of this is that the primary winding is "short-circuited" all the time, and the opening and closing of the contact-points (**A**) and (**B**) has no effect. In other words, the circuit-breaker is "cut out."

When the switch is open, the circuit is then from primary circuit to (**A**), through points to (**B**), through ground (**GP**) to the other end of the primary. Thus when the circuit-breaker opens, it is in series with the primary circuit, and performs its regular duty.

The flow of the primary current can easily be followed in the diagram of connections (Fig. 1), where its direction when the magneto is working regularly is indicated by full arrows, and its return path when the magneto is running but not producing sparks, is indicated by dotted arrows.

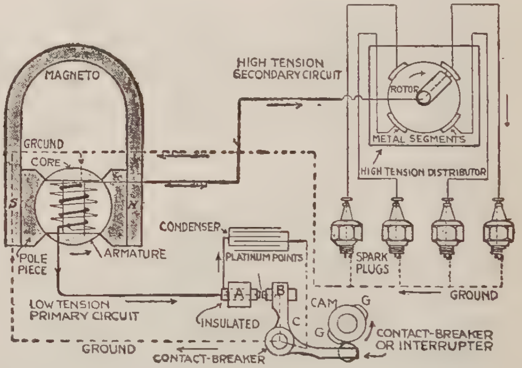


Fig. 9. Another simplified illustration of a high-tension magneto ignition system, showing circuit of primary wire winding on armature and its connection with interrupter. Note the condenser is "shunted" across the interrupter. Another view shows the distributor and spark plugs and connections. Dotted lines represent the earth or ground connection to frame.

HIGH-TENSION MAGNETO IGNITION SYSTEMS

High-Tension Magneto Alone

In Fig. 1, page 256, and in Fig. 1, below, note the high-tension magneto supplies current to the four spark splugs on a four-cylinder engine.

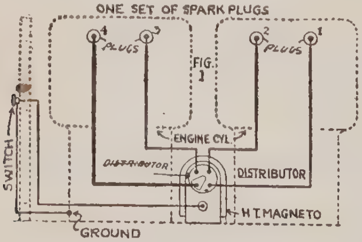


Fig. 1. A "single" high-tension magneto; engine is started direct from magneto current. Current is distributed to the one set of spark plugs. The switch connects to interrupter on magneto on one end, and to "ground" on the other. To stop magneto, the switch is closed, not opened.

The armature is double wound; therefore a separate coil is not necessary. The distributor on the magneto distributes the high-tension current to the spark plugs.

The advantage of using a high-tension magneto is that a well-designed magneto gives a very hot, fat spark and this spark exists for a definite period, thus firing all of the gas in each cylinder of the engine. The volume of the spark and the heat of the spark are important factors. Both are necessary to ignite the gas quickly, so that it will all be ignited before any part of the unburned gases can pass out of the exhaust. Thus it is clear that a heavy magneto spark has a very high degree of heat, whereas a lean spark takes longer to ignite the gas. Consequently, in the latter case, part of the gases have a chance to pass out the exhaust in an unburned state.

The disadvantage of this system is in starting. The armature on the magneto must be revolved fast enough to generate current before the spark will occur at the plugs. Therefore it is necessary to "spin" the crank. This is not very satisfactory unless an "impulse starter" or electric starter is provided to crank the engine. Hence this is one reason why "dual ignition systems" are adopted where a magneto is used. The starting of the engine is accomplished with a coil and battery system, and after the engine is started, the magneto is switched on.

The magneto, using an impulse starter (see Index) is used quite extensively on trucks and tractor engines, but is not used on passenger car automobile engines.

Dual Ignition

Dual system of ignition: Where a car has two ignition systems, for instance, a "coil and battery" and independent "magneto," but both systems using one set of spark plugs, this system is called a "dual" ignition system.

Dual ignition is quite common where magnetos are used, that is, before the advent of the "impulse starter"; the idea being to have an auxiliary battery and coil system to start on, and the magneto to run on.

There are two general principles of dual systems, which were formerly used to a great extent: the "low-tension magneto" and a separate "high-tension coil" and battery—as explained in pages 247, 254. The coil and battery were used for starting the engine; after starting, the magneto supplied the current to the coil.

The other method is the use of a "high-tension magneto" and a separate and distinct "high-tension coil" and battery ignition system. The engine is started on the battery and coil system, then switched over to the high-tension magneto which is independent of the coil and battery.

An example of a dual system using a high-tension magneto and separate high-tension coil and battery is shown in Fig. 2.

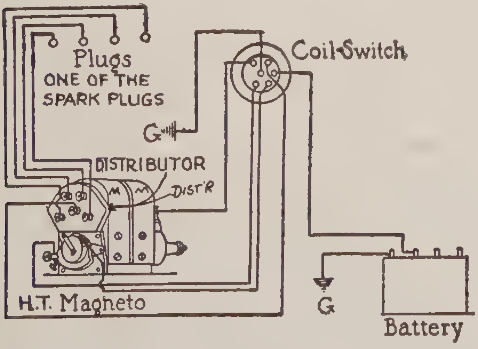


Fig. 2. A "dual" system of ignition; either the high-tension single coil with battery (using the distributor on the magneto) may be used or the high-tension magneto alone, may be used. Only one set of spark plugs.

Double Ignition

Double system of ignition: Where two sets of spark plugs are used with two independent ignition systems, this is called a "double" system. An example of a "double" ignition system using a battery, high-tension coil, timer, and distributor for one system, and a high-tension magneto for the other with two spark plugs in each cylinder, is shown in Fig. 3. Either of the two independent ignition systems can be used separately, or both can be made to operate at one time.

The positive (+) terminal of the battery is grounded and the negative (−) terminal led to terminal (5) of the stationary switch plate at the rear end of the coil. Switch terminal (1) is then connected with the binding post located on the under side of the timer-distributor. The second binding post on the timer-distributor, which is located on the under side of the timing control arm (7) is grounded. Switch terminal (2) is connected to the grounding terminal of the magneto.

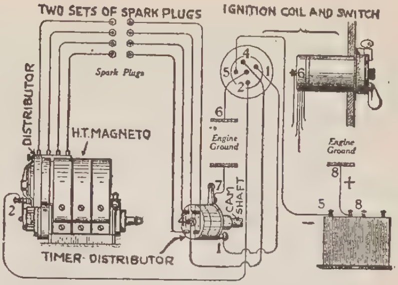


Fig. 3. Bosch "double" system of ignition—two sets of spark plugs and two independent ignition systems.

The distributor contacts on the magneto and timer-distributor are connected in accordance with the firing order of the engine.

When the switch lever is in the off position, the battery circuit is broken and the magneto is grounded, in consequence of which no sparks will be produced when the motor is cranked.

With the switch lever thrown to the battery side (B), the magneto will continue grounded, but the battery circuit will be completed, and, in consequence, the breaking of the circuit by the timer-distributor will result in the production of a spark that will be transmitted to the proper cylinder by its distributor.

The same condition will exist **with the switch lever thrown to position (MB)** (where both the magneto and the coil and battery are in operation), except that then the magneto ground circuit will be broken and magneto sparks will be produced in addition to the battery sparks.

With the switch lever thrown to position (M), or the magneto alone, the magneto will operate in the normal manner, and the battery circuit will be broken.

Two-Spark Ignition System[1]

Here we have two distributors on the one magneto, and two spark plugs are provided for each cylinder. The principle is similar to the "double" system, except that the one high-tension magneto has two distributors.

The purpose of the two-spark magneto (Figs. 4 and 5) is to produce ignition at two plug points in

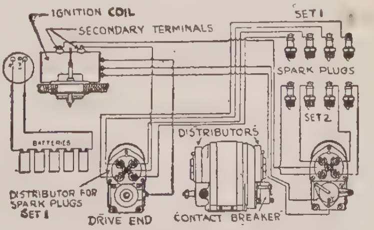


Fig. 4. Remy two-spark magneto ignition system; one magneto with two distributors connecting with two sets of spark plugs.

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[1] The "two-spark" system was formerly used on the Stutz and Mercer. It has also been used on some Fiat, Locomobile, and Marmon cars. Some of these cars are now using a two-spark coil and battery ignition system.

each cylinder, in order to reduce the time interval between ignition and complete combustion; and, where it is possible, to locate two spark plugs in each cylinder (usually in T-head engines, one set of spark plugs being placed on the inlet side of the engine and one set on the exhaust side). The result is to reduce the ignition advance necessary, and thus to secure an increase in the efficiency and output of the engine.

The advantage of having two spark plugs fire at one time in each cylinder is the resulting increase of power and speed, explained as follows: By referring to the subject of "ignition timing," we learn that there is a difference between the time when the spark occurs and the actual time of combustion. Therefore with a weak spark, the time of the spark is made to occur earlier, that is, "advanced," before the piston reaches the top of the compression stroke, in order that it may have time to ignite the gas, combust, and expand before the piston gets too far down on the power stroke. With a "double" system or "two-spark" system, or a good hot spark, this advance of ignition is less, as the combustion is almost instantaneous. Consequently, with less advancement of spark, there is less liability of firing back on the piston before it reaches the top of the compression stroke. Furthermore there is a saving of gasoline, because with a good hot spark, all of the gasoline is ignited and used for power instead of part of it passing out of the exhaust, not fully ignited. In other words, a weak spark produces slow combustion, and a hot spark quick combustion.

The Remy two-spark magneto is shown in Fig. 4 and the Bosch two-spark magneto is shown in Fig. 5.

Bosch Two-Spark Magneto

The types "ZR4" and "ZR6" Bosch magnetos are produced with the two-spark, independent or dual form. The noticeable difference in the two-spark magneto from the single-spark magneto is in the double distributor (**DD**) (Fig. 5) and arrangement of the safety spark gap under the arch of the magnets.

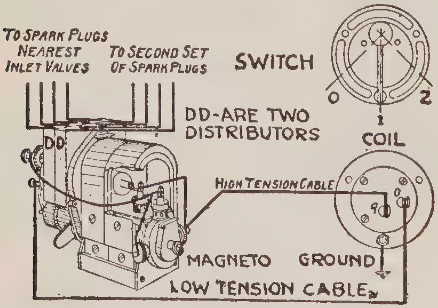

Fig. 5. Bosch two-spark magneto ignition system.

Fig. 5A (upper). Switch: 0, off; 1, one set of plugs operating; 2, both sets operating.

In the single-spark magneto, the beginning of the armature secondary circuit is grounded on the armature core through the armature primary circuit, whereas in the two-spark magneto, the two ends of the armature secondary circuit are connected to two sectional metal segments diametrically opposite on a single slipring.

Two slipring brushes are provided, which are horizontally mounted in brush holders on opposite sides of the shaft and plate. During the portions of the armature rotation when high-tension current is being delivered, each of the two slipring segments will be in contact with one of the brushes. One brush is connected to the inner distributor by means of a conducting bar similar to that used on single-spark magnetos. The second slipring brush is connected to the outer distributor by means of a short length of cable passing around the magnets. The rotating distributor piece is of double length and carries two brushes insulated from each other.

The four and six-cylinder types are fitted with eight and twelve distributor outlets respectively, each pair of outlets being connected to the spark plugs of the proper cylinder by the usual cables.

Advance and retard: The use of two-spark ignition permits the ignition lead to be cut down anywhere from 30 to 50 per cent. It will be understood that if the timing is correct for two-spark ignition, and one of the series of spark plugs is cut out of action, the remaining series will operate considerably in retard of what it would if the engine were timed for single-spark ignition. Therefore, if the two-spark ignition provides the full advance, the effect of retarding the spark is obtained by cutting out one series of plugs.

The switch (Fig. 5A) provided for the two-spark independent magnetos is so arranged that ignition may be secured, either with both sets of spark plugs, or with but one set. The purpose of this is to give the effect of retarding the spark, without altering the relation between the interrupter opening and the armature, as is done under normal conditions. The connections should be so made that the system of plugs that is operative when the switch is thrown to the single position is located near the inlet valve.

In starting, throw the switch lever to "single plug" position. This gives the effect of a retarded spark.

For ordinary running, operation should be on both series of plugs; **for slow work** through traffic, or when the engine is running idle, use the single plugs, or only one set.

Timing: "Time" in this connection refers to timing a single-spark magneto (interrupter retarded and piston on top of compression stroke). It will be found however that this timing will likely give two great a spark advance when the interrupter is fully advanced, as the two-spark magneto should have from one-third to one-half the advance of that of a single-spark magneto. Therefore retime, so that the interrupter points will open slightly later. A good method to follow is as given below.

To replace a single-spark magneto with a two-spark instrument, the maximum advance for the single-spark magneto is to be marked—preferably on the flywheel—and the two-spark magneto timed in the advanced position, so that the interrupter opens the circuit at a point midway between the mark on the flywheel indicating the single-spark advance, and that indicating top dead center retarded. A more exact timing may then be secured by experiment.

Berling Type "D" Two-Spark Magneto

This magneto is designed for four, six, and eight-cylinder engines where the charge in each cylinder is ignited simultaneously at two separate spark plugs.

The eight-cylinder type, shown in Figs. 6 and 6A, is designed to operate at twice the crank-shaft speed, and the six-cylinder magneto at one and one-half crank-shaft speed. The four-cylinder is designed to operate at crank-shaft speed. This type of magneto is designed for heavy duty, marine, and aeronautical engines.

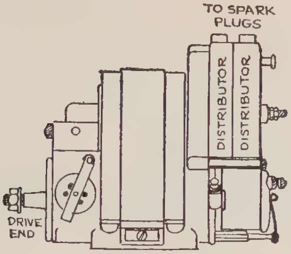

Fig. 6

In the type "D" two-spark Berling magneto, neither end of the secondary winding is grounded, but each is connected to one of the two separate segments on the collector ring.

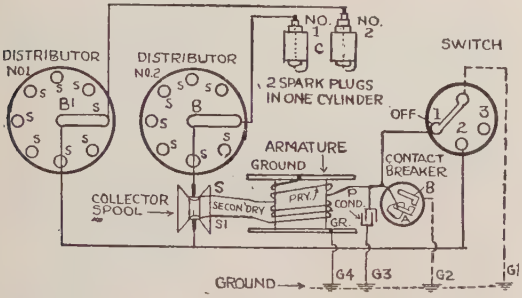

Fig. 6A

The distributing mechanism consists of two separate distributor blocks (Fig. 6) and one distributor finger carrying two separate distributor brushes (B), each brush connecting with the segments (S) of its respective distributor block. Thus, any two cable terminals directly opposite each other on the distributor blocks will practically possess an equal electrical potential relative to any part of the body of the engine.

When any two opposite cable terminals are connected each to one of two plugs in the same cylinder, the electrical circuit of the secondary or high-tension current will be closed the moment the spark gaps are bridged and that portion of the cylinder (C) between the two plugs forms part of the electrical circuit. The two sparks are the result of one break in the primary circuit by the interrupter, and are therefore absolutely simultaneous.

When the switch is in position 1 (Fig. 6A), the primary winding of the magneto is short-circuited and the magneto is "off." Note that the circuit is from (P) to (1), to ground (G1), to ground (G4), to the other end of the primary winding at "ground."

When the switch is on 2, note that the primary circuit is open at 1. Therefore the interrupter points on (A) and (B) perform their regular duty of opening the closed circuit at the proper time. The path is from (P) through (A) and (B) to (G2), to (G4), to "ground," or the other end of the primary.

The secondary circuit is then from (S) to (B), to No. 1 spark plug, through ground of engine, to ground (G1), to (2), to (S1), or to the other end of the secondary. Thus the magneto acts as a single-spark magneto and the entire voltage generated in the magneto is concentrated on the one spark plug for starting, instead of being divided in half.

When the switch is in position 3, the primary circuit is the same as when on 2 (in action), but the secondary is not grounded. Therefore, the secondary circuit would be from (S), to one of the two separate segments on the collector ring, to No. 1 spark plug, through cylinder (C) to the shell of the other spark plug (No. 2), across the spark-plug gap, to the distributor brush (B1), to the other segment on the collector ring, to (S1), thus completing the secondary circuit through both distributors with the result that the two spark plugs, which are thus in series with the secondary circuit, both fire at one time in the same cylinder.

Bosch Two-Spark Dual Ignition System

When the switch (Fig. 7A) **is thrown on the magneto side,** without the two-point switch (Fig. 7B) in the circuit, the path of the current is as follows: The low-tension current generated in the primary winding of the magneto passes through the breaker-points to ground. At the break of the points a high-tension current is set up in the secondary winding, this current leaving the magneto at 3 and passes to the point 3 on the coil, as indicated by the arrows. Then from point 3 to point 4 and thence to the distributor wire, along this wire to point 4 on the magneto. The distributor arm next receives the current which in turn is sent to the different plugs as indicated by the arrows. The current is sent to the ground after leaving the spark plugs, and the high-tension or secondary winding being grounded at one end, the secondary circuit is complete.

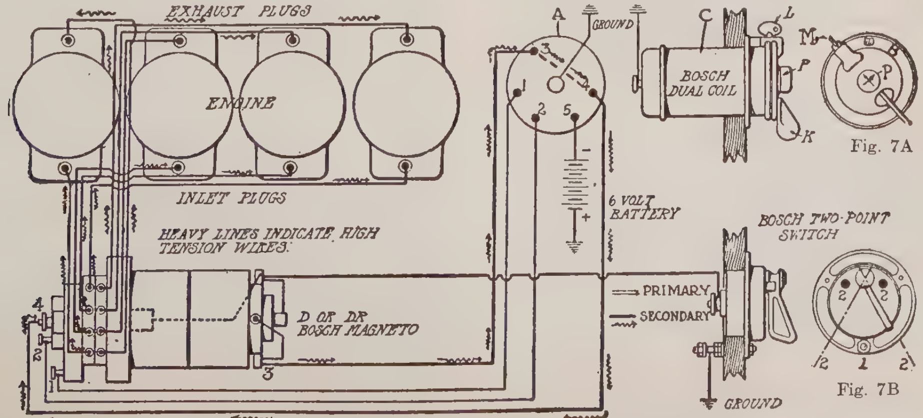

Fig. 7A

Fig. 7B

Fig. 7. Bosch two-spark dual ignition system. The coil parts (Fig. 7A) are: (L) key lock; (K) kick lever; (P) push button; (M) magneto operating both sets or one set according to position of two-point switch; (B) battery operating inlet plugs.

When the two-point switch (Fig. 7B) is thrown so that both sets of plugs are to come into play, both distributors of the magneto become operative. The path of the primary and secondary current to the magneto in this case is the same as before, but when delivered to the magneto, the current is passed to two distributors instead of one. In this way two distinct electrical currents are distributed to two different sets of spark plugs.

The coil and battery ignition is used independently of the magneto by switching to the (**B**) side of the switch (Fig. 7**A**) and one or both sets of plugs are connected with the two-point switch (Fig. 7**B**) (*Motor Age*).

Two-Point Ignition System

The "two-point" system is where two sparks occur at the same time but in different cylinders.

On a four-cylinder engine, the spark would occur at two spark plugs at once, but inasmuch as one of the pistons would be on exhaust stroke, this would make no difference.

The Bosch type "NU4" high-tension magneto is an example of a "two-point" system where two sparks occur at the same time, but in different cylinders.

Bosch Two-Point Magneto Ignition

The type "NU4" Bosch magneto differs from the usual type of magneto in that the distinct gear-driven distributor, common to other types, has been eliminated, and in its stead is a double slipring combining the functions of current collector and distributor. Otherwise it is about the same as any other form of magneto.

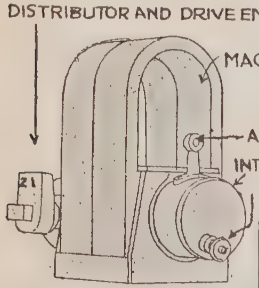

FIG 8 - INTERRUPTER END

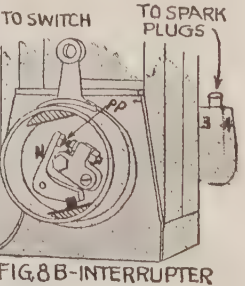

FIG 8 B - INTERRUPTER END

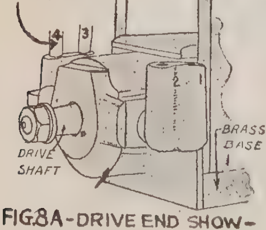

FIG 8A - DRIVE END SHOWING COLLECTOR RING ASSEMBLY

The spark occurs in two cylinders at one time with this system, but one of the cylinders in which the spark occurs has not completed its exhaust stroke; therefore the spark does no harm.

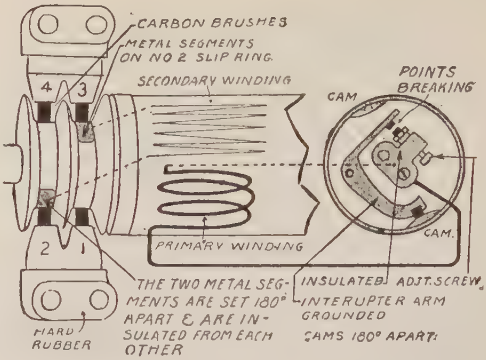

Fig. 8C

The interrupter contacts in the full retard position should open not later than top dead center of the compression stroke; therefore **the effective spark** is produced in the cylinder always toward the end of the compression stroke and **the surplus spark** will always occur near the end of the exhaust stroke and never during the inlet stroke. In any four-cylinder, four-cycle engine, regardless of firing order, when cylinder No. 1 is nearing the end of the compression stroke, cylinder No. 4 is nearing the end of the exhaust stroke, and vice versa; similar conditions apply also to cylinders Nos. 2 and 3.

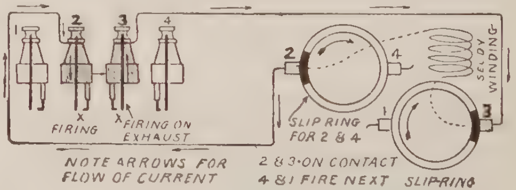

Fig. 8D

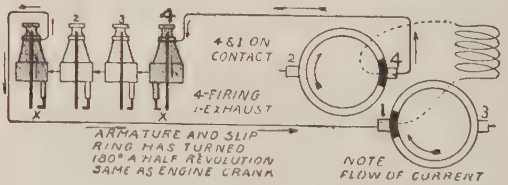
2
3
4
4 & 1 ON CONTACT
2
4
4-FIRING
1-EXHAUST
X
X
1
3
ARMATURE AND SLIP RING HAS TURNED 180° A HALF REVOLUTION SAME AS ENGINE CRANK
NOTE FLOW OF CURRENT

Fig. 8E

The brushes, when making contact with the metal strip in the collector rings, collect the high-tension current and carry it to the spark plugs. Note the connections from ring to plugs. When brushes 2 and 3 are making contact, follow the circuit in Fig. 8D, and note the arrow points. Now if the piston makes another stroke, or 180° travel, the armature will turn 180° or half a revolution also, as it runs at engine speed in the four-cylinder, four-cycle engine. Therefore the contact on the ring will turn 180° or a half-revolution and cylinders 4 and 1 will fire as in Fig. 8E. This type of magneto was used on the model 80 Overland.

Timing the "NU4" magneto: With the average engine, this result is obtained by connecting the magneto so that its interrupter housing is in full retard position, and the platinum interrupter screws just about to separate, when the piston of No. 1 cylinder is on top dead center of the compression stroke.

At the same time the metal segments of the slipring should be in contact with the brush marked "1" in each brush holder, and this can be observed by removing one of the holders.

The installation is completed by connecting the brush marked "1" with cylinder No. 1, and the other with cylinder No. 4, and the two remaining brushes, marked "2" and "3," with cylinders Nos. 2 and 3.

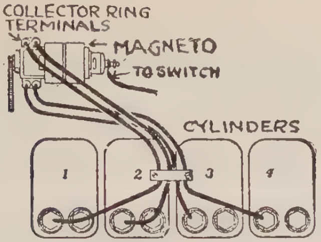

Fig. 8F. Note connections from collector ring terminals to spark plugs.

It is important to note that the type "NU4," driven, as it should be, at engine speed, produces a surplus spark in each cylinder exactly 360° behind the effective or power spark and, in coupling the magneto to the engine, it must be timed so that the surplus spark occurs during the exhaust stroke and not after the inlet valve has commenced to open.

Bosch Vibrating Duplex System

The Bosch vibrating duplex system is designed to permit easy starting on cars that are cranked by a starting motor at such a low speed that the ignition current from the ordinary magneto is insufficient to give certain ignition.

Do not confuse this system with an electric system of starting by movement of the crank shaft. The principle of this system is to supply a separate battery and vibrating coil to start the engine on, doing away with a dual system.

How it operates: The arrangement is such that, while the magneto circuit is absolutely independent and complete in itself, the battery circuit includes both the coil and the magneto.

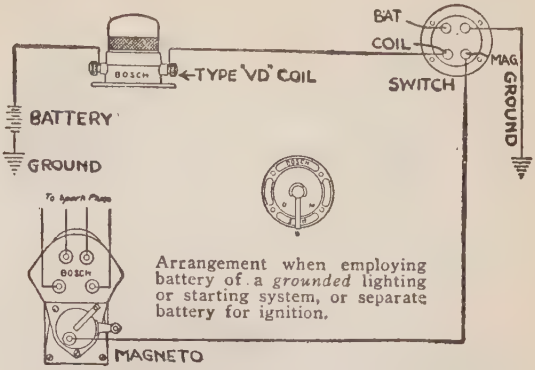
BAT
COIL
MAG
SWITCH
GROUND
TYPE "VD" COIL
BOSCH
BATTERY
GROUND
To Spark Plugs
BOSCH
MAGNETO
Arrangement when employing battery of a *grounded* lighting or starting system, or separate battery for ignition.

Fig. 9. Bosch vibrating duplex ignition system.

With the switch in the battery position, the battery and coil are in series with the primary winding of the magneto armature, and the current from the battery supplements that generated by the magneto. Thus there is induced in the secondary winding of the magneto armature a very powerful sparking current, which, on account of the vibrator action of the coil, appears not as a single spark, but as a series of intense sparks that will act with certainty on any explosive mixture. The sparking current so produced is distributed in the usual way by the magneto distributor.

After the engine is started, the switch is turned to (**M**) side, and the coil and battery are disconnected.

THE BOSCH DUAL-IGNITION SYSTEM

The parts of this system are shown in Fig. 10. This system provides a coil and battery system and a high-tension magneto system, both independent. One set of spark plugs and one distributor on the magneto is used for both systems.

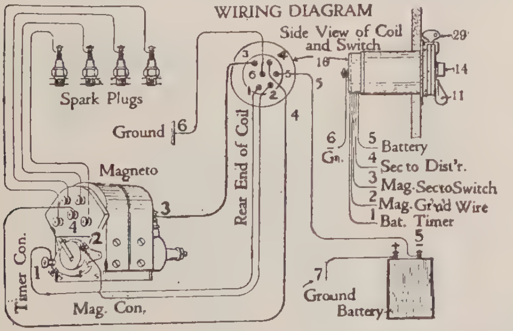

Fig. 10. Wiring diagram of the Bosch "DU4" dual-ignition system. The "DU4" type magneto is fitted with two interrupters as in Fig. 11, instead of one as generally used.[1]

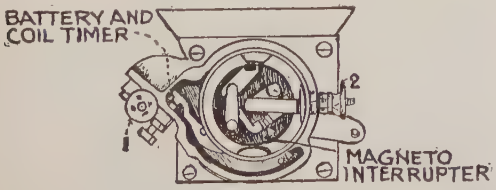

Fig. 11. The magneto is the regular "DU4" high-tension magneto fitted with an **independent timer** or interrupter for the coil and battery system. This contact-breaker has no electrical connection with the magneto. The second alteration from that of the regular single "DU4" high-tension magneto consists of the removal of the connection (see Fig. 2, page 257), which on the ordinary magneto connects the high-tension collector-ring to the distributor; when the distributor does duty for two ignition systems, the current must be carried to it through the switch, via wire 4 when the battery and coil system are switched on (see Fig. 10), or via wire 3 when the magneto is switched on.

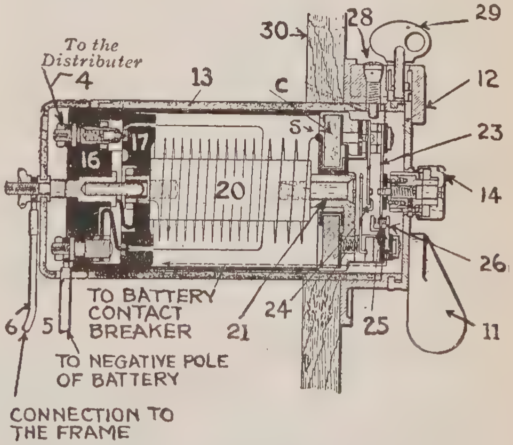

Fig. 12. The coil and switch (mounted on dash) are shown: The coil is a double-wound high-tension coil. The switch controls both ignition systems. Note that when switch (11) is turned, the coil with its core (20) and winding, and end of coil (17) turn also. Switch plate (16) is stationary.

Parts of the switch and coil are as follows: 11, switch handle (also called, kick-switch); 12, movable switch cover; 13, coil case; 14, starting press button; 16, fixed or stationary switch plate (see also, Figs. 17 and 18); 17, movable switch plate on rear end of coil (see Fig. 16); 20, iron core of coil over which primary and secondary are wound; 21, plate carrying starting arrangement and condenser; (C) condenser. Primary winding connects to it at (S); 23, contact spring; 24, trembler blade also called vibrator blade; 25, auxiliary contact-breaker; 28, screw holding switch plate to coil; 29, locking key; 30, dashboard or cowl.

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[1] In practice, connections from distributor to spark plugs are not as shown; if so, it would fire 1, 2, 4, 3, or 1, 3, 4, 2. The main purpose of diagrams is to show the switch circuits.

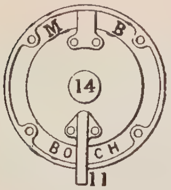


Fig. 13

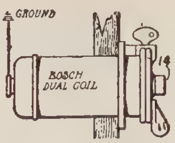


Fig. 14

Fig. 13. Front view of switch (**M**), magneto side; (**B**), battery side.

Fig. 14. Side view of switch and coil case.

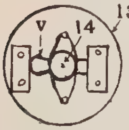


Fig. 15

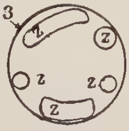


Fig. 16

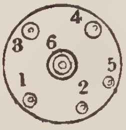


Fig. 17

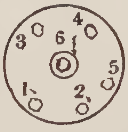


Fig. 18

Fig. 15. Front view of coil to which the switch is attached; (**V**) is the trembler or vibrator blade (26, Fig. 12); 14, the press-button contact.

Fig. 16. Rear movable switch-plate with busbars and connections (**Z**) on end of coil. (It is the part as shown at 17, Fig. 12.)

Fig. 17. Inner side of stationary switch-plate (as shown at 16, Fig. 12) showing connections 1, 2, 3, 4, 5, and 6, which make contact with connections (**Z**, Fig. 16) when switch is turned to (**B**) or (**M**) side.

Fig. 18. Rear-end view of switch-plate (16, Fig. 12) showing terminals to which wires are connected as shown in Fig. 10.

Starting Engine

The engine is usually started by the switch being placed on the (**B**) or battery side; the interrupter (1) on magneto being used for the primary winding on coil and the distributor on magneto being used to distribute the high-tension current to the spark plugs. Otherwise the magneto has no connection with the battery and coil-ignition system when the switch is on the (**B**) side.

In order to start the engine with the starting handle (or electric starter, if one is provided), the press-button (14, Figs. 10 and 12) is pressed down and then turned at right angles, a process which locks it in position for the trembler spark.

The engine can also be started on the switch or "ignition," as it is often termed. The switch is turned to (**B**) side and then the brass press-button (14) is pressed down. Often this will start the engine, if the cylinder has a charge of gas in it. If not, then it will be necessary to crank the engine after locking the press-button as explained above.

To understand this ignition starting feature, see Fig. 19. The six-volt storage battery (or 10 dry cells) is supposed to be switched on (**B**) side.

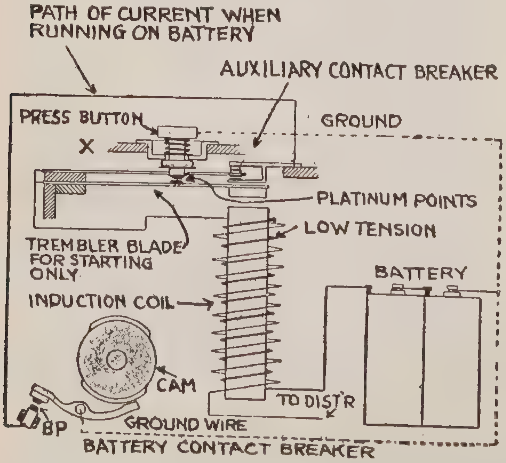


Fig. 19

Starting from the left-hand storage battery terminal (to make it easier to understand), the current passes through the primary winding and arrives at the end of the trembler blade and the blade above, called the auxiliary contact-breaker. The current cannot travel beyond the trembler blade because, as will be seen, the platinum points are separated. Neither can it complete the circuit along the auxiliary contact-breaker blade because the main contact-breaker (left-hand lower corner) also stands open, being the position in which the contact-breaker always comes to rest when the engine stops, save for the few occasions when the engine stops with the piston about dead center.

To start the engine, therefore, we have only to press the button so that the upper platinum point comes into contact with the lower one, and immediately the circuit will be completed, the trembler will start buzzing, and a shower of sparks will be sent through the plug of the cylinder which is next to fire. Now the work of the trembler blade is done, the engine has started, and the main contact-breaker is set in motion. The current troubles no longer about the trembler blade, but follows the upper path along the auxiliary contact-breaker and through the main contact-breaker, the making-and-breaking of which does the work of the trembler and creates the high-tension current. The engine may be kept running in this manner at the pleasure of the driver.

The auxiliary contact-breaker (Fig. 19): Now let us take the exceptional case of the engine stopping with the pistons about dead center and the main contact-breaker points (**BP**) closed. The current this time finds an easy circuit through the closed points, the iron core becomes magnetized, the trembler blade is held down on the core, and pressing the button as before has no effect. No spark is made because there is no break in the circuit. But if the reader will examine the diagram closely, he will observe that the act of pressing the button presses the auxiliary contact-breaker blade away from its upper platinum point and on to its lower one, the momentary break thus caused in the circuit being sufficient, under the circumstances we are supposing, to create the necessary high-tension current for the spark in the cylinder and so to start the engine.

When the engine stops in the more usual way with the storage battery contact-breaker open, the opening and closing again of the auxiliary contact blade has no effect. The diagram (Fig. 12) shows the coil as it actually exists.

Battery and Coil Position

The illustration (Fig. 20) is supposed to represent the rear of coil and switch. Points 3 and 4 are not connected, consequently the magneto secondary circuit is open. Note that the magneto primary wire is grounded at 2; therefore it is out of service.

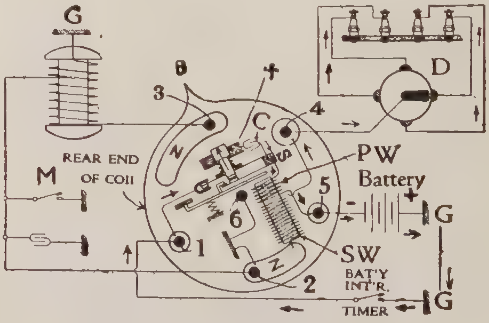


Fig. 20. Battery position.

Coil primary circuit: When the switch is on (**B**) side the current in the battery leaves it at the positive (+) side and travels through ground wire (G) to battery and coil timer or interrupter, which is operated by a cam on the magneto. The course is then to post (1) through mechanism in direction of arrows, to point (S).

It flows then through the primary winding (PW) of the coil, and as the arrows show, through point (5) back to the battery, thus completing the primary circuit.

Coil secondary circuit: In passing through the primary winding, a high-tension current is set up in the secondary winding (SW), when breaker-points separate.

This high-tension current flows to the distributor wire at (4), thence to magneto distributor (D). Here it is passed to the different spark plugs in order. It goes through the spark-plug center terminal across gap to shell of plug to cylinder, thence to ground back to other end of secondary winding (note lower end of secondary is grounded to bus-bar (Z) which is grounded with 6). The coil condenser is shown at (C).

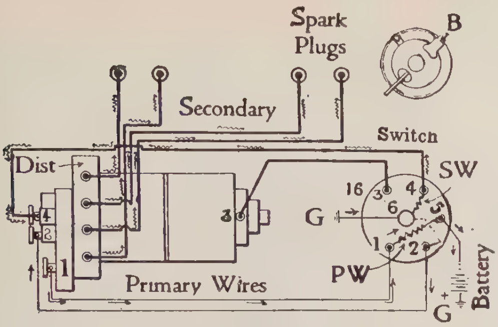


Fig. 21. Battery position.

The outside wiring of the battery and coil system is shown in Fig. 21, when the switch is on (B) side. (Note that points 3 and 4 are not connected, thus opening the magneto circuit.) The primary current leaves the battery and travels to ground (G). As (6) is grounded, current goes to (6), thence to (2) and along (2) to the magneto; then to (1) on magneto along wire as indicated by arrows to the point (1) on switch plate (16). Here it travels through primary winding (PW) of coil then to (5) and back to battery, thus completing the primary circuit. The secondary circuit is from (4) to distributor, thence to spark plugs.

Note: When the switch is turned, the rear end of coil (Fig. 16), with the bus-bars (Z) moves and connects with the inner side of switch plate (17). Therefore, when the switch is thrown on (B) side the point (1) on switch-plate (17) lines up with point (1) (one of the bus-bars Z) on rear end of coil (Fig. 16); likewise (2) and (5) line up with bus-bars on the end of coil. A study of Fig. 20 will help make this explanation clear.

Magneto Position

Note in Fig. 22 that the switch is now on (M) magneto side and there is but one closed circuit; it was made by connecting (3) and (4) on switch plate (16) with bus-bar (Z) on rear of coil. Note all other points of contact are open, including the magneto short-circuiting or grounding wire connected with (2).

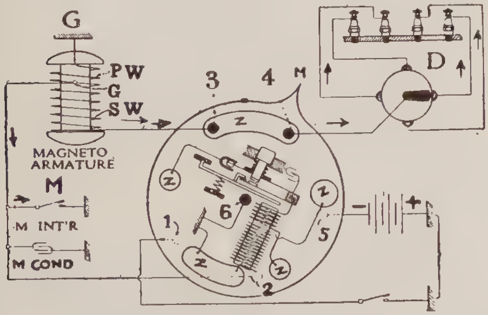


Fig. 22. Magneto position.

The magneto primary circuit is then from primary winding (PW) of magneto armature, to magneto interrupter (M), thence to ground. The other end of the primary winding (PW) is grounded, thus completing the primary circuit.

The magneto secondary circuit: One end of the secondary winding (SW) goes to (3) and (4) which are now connected with bus-bar (Z). From (4) it flows to distributor (D), thence to and through spark plugs. Here the current is grounded. The other end of the secondary winding (SW) is grounded, also by connection with primary wire, thus completing the high-tension circuit. Note the magneto condenser below the magneto interrupter.

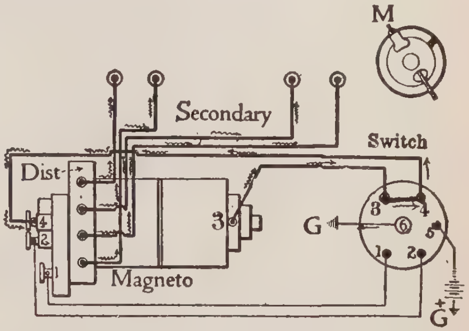


Fig. 23. Magneto position.

The outside wiring of the magneto position is shown in Fig. 23. Note points 1, 2, and 5 are not connected.

The high-tension (secondary) current generated in the magneto armature leaves the magneto at (3), travels to (3) on switch-plate (16), thence to distributor wire (4), then to the distributor, where it is then distributed to spark plugs.

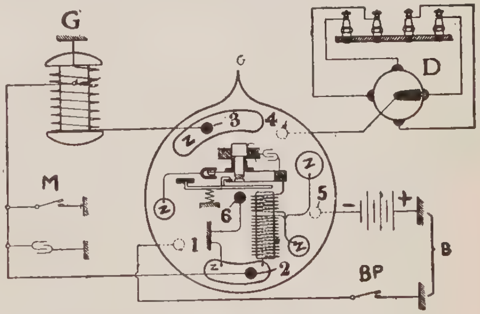
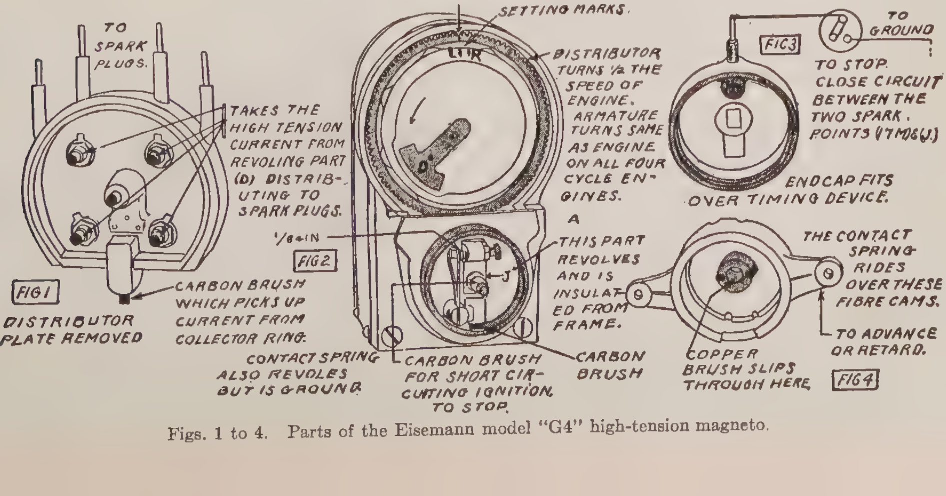


Fig. 24. Off position.

The off-position of the switch is shown in Fig. 24. Note in this position there is no complete circuit, as points 1, 5, and 4 of switch-plate do not coincide with points 1, 5, and 4 of coil switch-plate. Note, too, that the primary circuit of the magneto is short-circuited, or grounded at (2) on switch-plate; thus it is out of service. The magneto secondary circuit is open from 3 to 4.

EISEMANN "G4" HIGH-TENSION MAGNETO


TO SPARK PLUGS.
TAKES THE HIGH TENSION CURRENT FROM REVOLVING PART (D) DISTRIBUTING TO SPARK PLUGS.
FIG1
DISTRIBUTOR PLATE REMOVED
CARBON BRUSH WHICH PICKS UP CURRENT FROM COLLECTOR RING.
SETTING MARKS.
DISTRIBUTOR TURNS ½ THE SPEED OF ENGINE. ARMATURE TURNS SAME AS ENGINE ON ALL FOUR CYCLE ENGINES.
1/64 IN
FIG2
J
A
THIS PART REVOLVES AND IS INSULATED FROM FRAME.
CONTACT SPRING ALSO REVOLES BUT IS GROUND.
CARBON BRUSH FOR SHORT CIRCUITING IGNITION TO STOP.
CARBON BRUSH
FIG3
TO GROUND
TO STOP. CLOSE CIRCUIT BETWEEN THE TWO SPARK. POINTS (7M)&(J.)
ENDCAP FITS OVER TIMING DEVICE.
THE CONTACT SPRING RIDES OVER THESE FIBRE CAMS.
TO ADVANCE OR RETARD.
COPPER BRUSH SLIPS THROUGH HERE
FIG4

Figs. 1 to 4. Parts of the Eisemann model "G4" high-tension magneto.

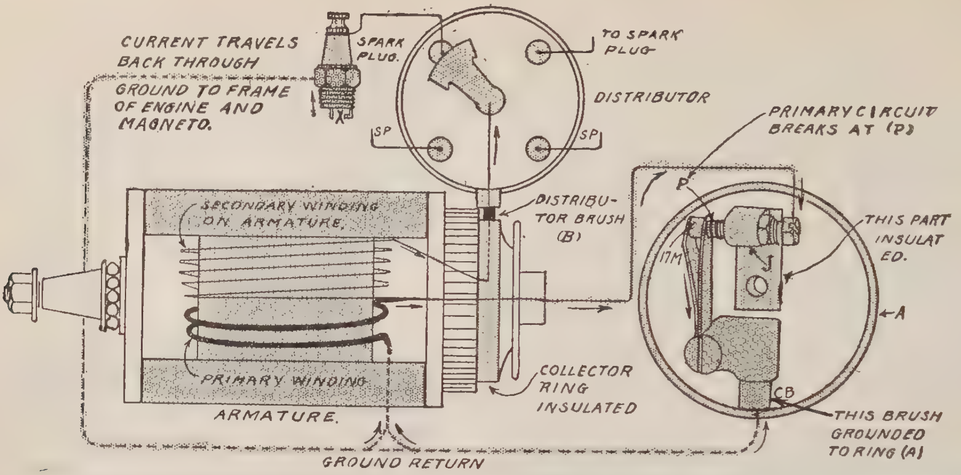

CURRENT TRAVELS BACK THROUGH GROUND TO FRAME OF ENGINE AND MAGNETO.
SPARK PLUG.
TO SPARK PLUG
DISTRIBUTOR
SP
SP
PRIMARY CIRCUIT BREAKS AT (P)
P
SECONDARY WINDING ON ARMATURE.
DISTRIBUTOR BRUSH (B)
THIS PART INSULATED.
17M
J
A
PRIMARY WINDING
COLLECTOR RING INSULATED
CB
ARMATURE.
THIS BRUSH GROUNDED TO RING (A)
GROUND RETURN

Fig. 5. Winding of armature and connections. **The primary winding** leads from the upper part of the primary winding to (J), to points (**P**), to (17**M**), to (**CB**), to ground, to the lower end of the grounded primary winding.

The secondary winding leads from the upper part of the secondary winding, to the distributor brush, to the spark plug, to ground, through the grounded primary winding, to the lower part of the secondary winding, where it is connected with the primary winding.

The Eisemann "G4" type of high-tension armature-type magneto differs from other Eisemann types in that the make-and-break or interrupter mechanism is constructed on different lines. The platinum contact springs (17**M**) (Fig. 5) connect with a carbon brush (**CB**), which revolves in a brass ring (**A**). Ring (**A**) is stationary, whereas the spring (17**M**) revolves with the other contact plate (**J**). Contact plate (**J**) is insulated from (17**M**). One end connects with primary winding on armature, and when contact is interrupted by (17**M**) and the point on the screw in plate (**J**), the spark is given as usual. Rings (**A**) and (17**M**) are grounded.

The points of (17**M**) and the screw on plate (**J**) are separated by the timing device (Fig. 4) which goes over the ring (**A**). The contact spring rides over the fiber cams.

The novel features of this system, besides the breaker, are: its accessible and efficient grouping of the working elements all at one end, and its waterproof qualities.

To set the time of spark: Place piston of No. 1 cylinder on top of compression stroke. Set interrupter points to break in full retarded position.

With these systems it is merely necessary to bring No. 1 piston to top dead center, rotate the magneto until the setting mark on the distributor is opposite the pointed screw at the top and couple up the drive. Use marks (**R**) or (**L**) (Fig. 2) for right or left-hand rotation, respectively, as needed—rotation being judged from the driving end.

Adjustments: The breaker gaps should be set .012″ and spark-plug gaps 1/64″ to 1/32″.

To stop or cut off ignition: On all magnetos the magneto is stopped generating by closing or short-circuiting the primary circuit—not by opening the circuit, as in a coil system.

EISEMANN AUTOMATIC SPARK-CONTROL MAGNETO

Construction of the Eisemann high-tension armature-type automatic spark-control magneto is the same as that of the standard high-tension magneto with the addition of the automatic mechanism.

As for the details of the method by which the **automatic timing is obtained,** a cage is mounted on an extension of the armature shaft, and a rectangular block slides in this cage. This block is drilled and threaded for the reception of a helically-cut shaft (**T**). This shaft is the driving shaft which is attached to the gearing. It has a thick, double thread which is square cut and the block slides back and forth on this threaded shaft.

Centrifugal governor weights are attached to the blocks by means of links. The weights fly outward when the shaft is revolved, and the action of the links causes the block to slide in the cage. In so sliding it travels along the threaded shaft, and as a result the block is slightly rotated.

The drive of the magneto is applied through the shaft which therefore is unyielding, and as the block rotates it carries with it the cage in which it works and the armature shaft to which the cage is fixed. The armature is thus advanced, and the contact-breaker, attached to the other end of the armature shaft.

When the speed drops, the reverse motion takes place, assisted by action of a spring against which the governor works at all times. With this device automatic advance may be obtained from 18° to 57°.

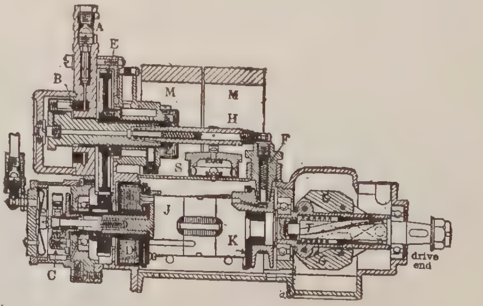
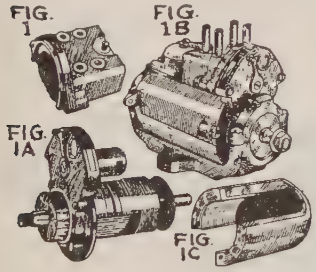


Fig. 6. Sectional view of Eisemann automatic spark-control magneto.

A—terminal to spark plug from distributor; **B**—distributor brush; **C**—contact-breaker; **D**—condenser; **E**—distributor gear on distributor to lower gear on armature; **F**—collector brush; **G**—governor weights; **H**—high-tension current conductor; **J**—armature; **K**—collector spool at end of armature; **M**—magnets; **S**—safety spark gap; **T**—spiral thread for spark advancing by centrifugal force action.

MEA MAGNETO

In the "Mea" high-tension armature-type magneto the design is such that the **magneto field can be moved round simultaneously with the contact-breaker,** so that the armature is always in the same position relative to the field when the break occurs. This is effected by having a bell-shaped magnet mounted horizontally, the axis of the armature and the magnet coinciding. As the contact-breaker is moved, so also is the magnet to a similar distance, and the result is that the spark is of ample strength at the retarded position, even allowing for the slow speed of rotation. This bell-shaped magnet (Fig. 1C), it is claimed, has some other advantages over the ordinary U-shaped magnet, inasmuch as it can hold a greater amount of magnetism and retain it at full strength for a longer period. The range of advance and retardation on this magneto is 40°. The armature and distributor are made practically on the lines of the standard magneto with fixed magnets.



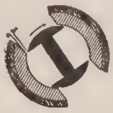


Fig. 1D. Advanced.

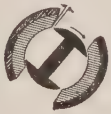


Fig. 1E. Retarded.

Fig. 1. Parts of Mea magneto: Cover: **1A**, armature and distributor units; **1B**, complete machine; **1C**, movable bell-shaped field magnets. The relative positions of the pole pieces and armature are shown in Figs. 1D and 1E. Note that 1D shows the armature advanced, and 1E in retarded position, showing that the "maximum position" where the armature breaks from the pole piece is not altered.

Timing the "Mea" magneto: Unless the timing of the magneto can easily be changed by advancing or retarding the gear driving the magneto, the coupling should not be keyed to the tapered shaft before the magneto is first placed on the engine, but it should be clamped on so that the timing may still be somewhat modified if found desirable.

Place the magneto in the position of its maximum retard (Fig. **1E**), by turning the magneto housing or timing lever in the direction of the armature rotation. Remove the cover from the breaker box and turn the armature shaft in direction of rotation until No. 1 appears on the indicator (Fig. **1B**) in the front plate of the magneto, and until the contact-breaker begins to open.

With the dual-type magneto, remove the cover over the battery breaker (driven end of magneto), and the number of the cylinder firing can be seen opposite the red line on the magneto housing. Turn the armature of the magneto until No. 1 on the distributor gear is opposite the red line on the housing and until the magneto-breaker (not battery-breaker) just begins to open. Then turn the engine to dead center of cylinder No. 1, and if of the four-cylinder type, about 1½" beyond, measuring on the circumference of the fly wheel, or from 1/16" to 3/32" downward on the explosion stroke. With six-cylinder engines, it is preferable to time full retard only slightly beyond dead center.

After the magneto and engine have thus been set, effect a positive connection between the two. Of course contact hole No. 1 of the distributor is connected with cylinder No. 1 by means of cables, and so on until all the cylinders are properly connected.

With the "Mea," the engine should be started with the spark fully retarded, and by increasing the speed gradually it can readily be determined if the engine will stand all the advance which the magneto can furnish with the original setting, or whether the whole timing can be further advanced. After it has become assured that the best timing is obtained, the coupling should be keyed to the magneto shaft.

DIXIE MAGNETO[1]

The large number of magnetos commercially in use prior to the advent of the "Dixie" were of the "armature type." It is therefore necessary to make a comparison in order thoroughly to explain the "Dixie."

Armature-Type Magneto

An "armature"-type magneto is shown in Figs. 1, 2, and 3. Referring to Fig. 1, note that the magnetic lines-of-force, hereinafter referred to as "flux lines," flow from the N to the S pole of the U-shaped magnet through the revolving armature in the direction indicated by the arrow. The shaded end (E) of the armature is shown in the figure as being under the influence of the N pole of the magnet.

In Fig. 2, the armature has revolved to the right sufficiently for the end (E) to come under the influence of the S pole of the magnet. Immediately the direction of the flux lines is reversed through the armature as shown by the arrow, and at the instant that current is generated in the winding about the armature, the spark occurs. In practice, more than one winding is employed, also an interrupter and a condenser are used. But the function of these parts need not be referred to here, it being the purpose now to show only the differences in the operation of the **magnetic circuit** of the two types.

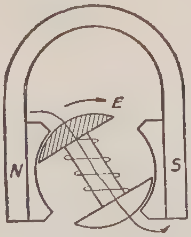


Fig. 1

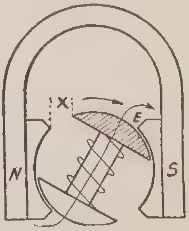


Fig. 2

Now it is obvious that the mass of iron in the armature must reverse its magnetic polarity. In Fig. 1, it is saturated with magnetism flowing in one direction. In Fig. 2, the direction is reversed. This reversal must take place in each rotation, so at high speeds the quicker the iron reverses the better the spark. As a laminated armature, or one built up of a number of pieces of iron, reverses quicker than a solid one, all good armatures are laminated. But it is also evident that to secure the desired amount of current the armature must be of a certain size to contain the necessary wire, and therefore contains a certain amount of iron in some form. Now, the more iron beyond a certain limit, the slower the reversal; also the reversal is not as abrupt.

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[1] Most of the text has been taken from the printed circular of the Dixie magneto.

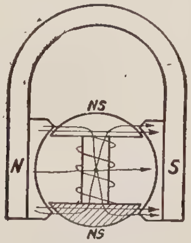


Fig. 3

Fig. 3 shows the "neutral" position of the armature wherein it is subject to flux-flowing across through its ends as shown. This position does not permit of an abrupt change of flux-flow as hereafter described, and such as occurs in the Dixie. The armature is never completely out of the flux, but simply turns around in the flux-stream, twisting the lines about, but not actually abruptly breaking them.

Dixie Principle

The "Mason" principle, on which the Dixie operates is shown in Fig. 4. The magnet has two rotating polar extremities (N) (S), which are always of the same polarity, never reversing. These poles are in practical contact with the inner cheeks of the permanent magnet (**M**), all air gaps being eliminated. Together with the U-shaped magnet, they form a magnet with rotating ends.

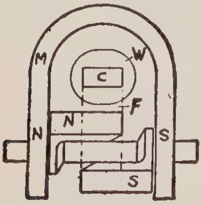


Fig. 4

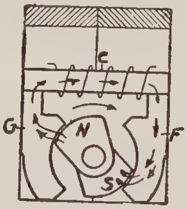


Fig. 5

The magnet is positioned at right angles to the rotating poles or ends of a field structure consisting of laminated pole-pieces (**F**) and (**G**) (Fig. 5), carrying across their top the laminated core (**C**) carrying the windings (**W**). When (N) is opposite (G) the flux flows from one pole (N) of the magnet to (G) and through the core (C) to (F), this action corresponding to what happens in the armature type with the armature in the position shown in Fig. 1.

In Fig. 6, the pole (N) has moved over to (**F**) and the direction of the flow of flux is reversed, it now flowing from (F) through (C) to (G).

Fig. 7 represents the rotating poles occupying a position midway between that shown in Figs. 5 and 6. Here the field pieces (F) and (G) are magnetically short-circuited, as it were, thereby completely scavenging stray lines of flux out of the core (C). Compare this with the uncertain corresponding action that takes place in the armature type, when the armature is in the same position (Fig. 3).

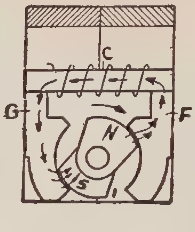


Fig. 6

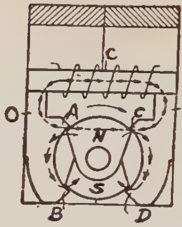


Fig. 7

Now the first great difference between the Dixie and the "armature" type is in the fact that the rotating poles in the Dixie do not reverse their polarity at any time, consequently the lag due to the magnetic reluctance in this part is eliminated. This partly accounts for the high efficiency of the Dixie at low speeds, for motorcycles and for high-speed engines. In the Dixie, the windings are never actually in the field. The flux is shot through them, as described, producing a hot, "snappy" spark of peculiar and highly efficient igniting power, owing to the quick break and absolute reversal of the flux at each revolution.

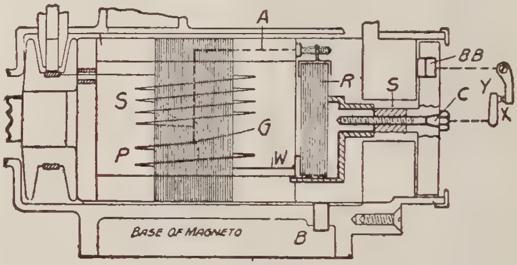


Fig. 8. Armature-type magneto armature.

With the armature-type machine, it is the central core or part actually enclosed by the winding that is laminated, as the ends adjacent the windings must be solid. In the Dixie type, not only the core (C), around which the wire is wound, is laminated, but also the pole shoes (G) and (F), consequently all parts of the magneto subject to reversal of flux are "laminated."

The armature-type magneto (Fig. 8) has a rotating element carrying windings, a laminated core, a condenser, a collector ring, etc.

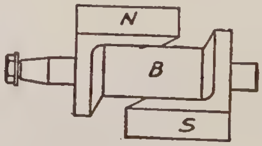


Fig. 9. Rotating element in Dixie.

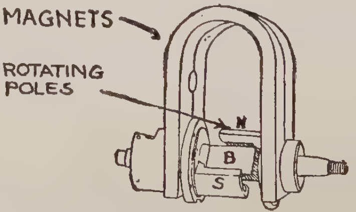


Fig. 10. Showing how the rotating poles (Fig. 9) are placed between magnets of Dixie magneto.

The Dixie rotating element, or armature construction, consists of two pieces of cast iron (N and S) (Fig. 9), and a brass block (B) placed between them. There are no rotating wires. Figs. 10 and 4 show more clearly how they are positioned between the poles of the magnets. On the four and six-cylinder magneto, there are two N and S poles and on the eight and twelve-cylinder magneto there are four.

The generating winding (W) (Fig. 4) in the Dixie is carried on a small coil placed across the upwardly projecting ends of the two pole-pieces (C) (Fig. 4).

Comparison of Primary Circuits

Fig. 8 shows **the usual primary circuit** in the armature-type machine, and Fig. 11 the same circuit in the Dixie. (A) (Fig. 8) denotes the revolving armature on which is wound the primary winding (P) and the secondary (S). Grounding brushes (B) and (BB) are necessary to insure a good contact between the grounded end (G) of the primary and the breaker point (X), the latter being positioned in the breaker mechanism which is movable for timing purposes. It will be seen that the free end (W) of the primary connects to the condenser (R), and attention is called to the fact that this condenser is built into the armature and revolves with it, and the armature must be disassembled to get it out. The shaft (S) is made hollow, and a bolt (C) is carefully insulated where it passes through. This bolt connects the free end of the primary and the condenser to the insulated point (Y) of the breaker which revolves as a unit with the armature.

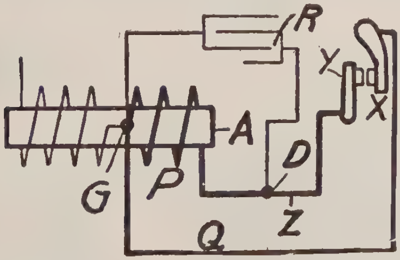


Fig. 11. Simple primary circuit of Dixie. No brushes or contacts except breaker points.

In the Dixie, the core of the coil (A) (Fig. 11) is stationary, and the inner end (G) of the primary winding (P) is grounded on the core. (Q) indicates the metal frame of the machine, which is put together with screws, so that there are no brushes or sliding contacts. Therefore brushes (B) (BB) (Fig. 8) are eliminated.

The brush (B) is necessary in the armature type to insure a good circuit from the revolving armature to the frame of the magneto and thence to the engine.

The condenser (R) in the Dixie is positioned immediately above the coil and is readily removable, it being only necessary to take out two screws. This condenser does not revolve as in the armature type. The terminal (D) is a screw on the head of the coil, and the wire (Z) connects to the contact (Y) of the breaker.

High-Tension Circuit

Fig. 12 shows **the high-tension circuit in the armature-type machine.** In the metal armature head (A) is the insulating bushing (B), through which the free end (C) of the high-tension winding passes. This connects to a metal ring (D) carried on the rubber spool (E). A brush (F) engages the ring and carries current to the terminal (G), which in turn supports one end of connector (H), which has a sliding portion (I), so that it can be removed. The outer end of (H) connects at (J) to the traveling contact of the distributor, which in turn contacts on the segment (L), to which is connected the spark-plug cable. It will be understood that the high-tension circuit is completed from the frame of the armature (N) through brush (B) to the frame of the magneto and to the engine and spark plug.

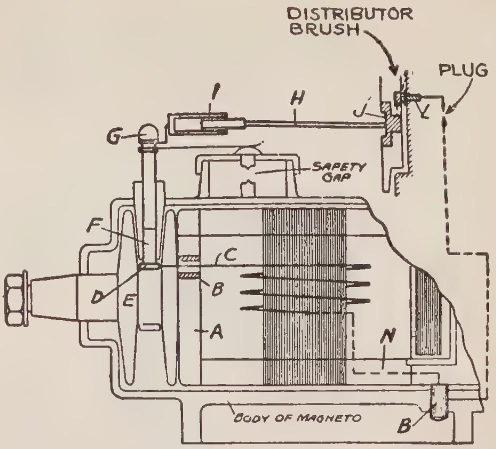


Fig. 12. High-tension circuit in an "armature-type" magneto.

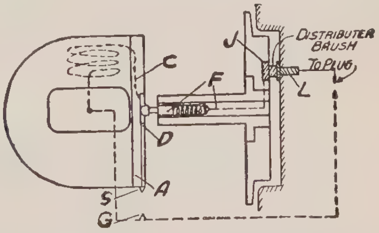


Fig. 13. High-tension circuit of Dixie magneto. Note direct path from spool to distributor; no revolving contacts except at distributor.

Fig. 13 shows the **Dixie high-tension circuit.** Here the end (C) of the high-tension winding goes to a metal plate (D) carried on the rubber side (A) of the coil. Against (D) bears a connection (F), which is practically one piece with the traveling contact (J), which connects to the spark-plug segment (L), the circuit being completed through the spark plug, engine frame, and frame of magneto in the usual manner without brush (G). The first difference to be noted in the Dixie construction is that the secondary winding being stationary, the spool (E), the revolving ring (D) and the brush (F) bearing thereon are entirely eliminated, as are also all their troubles, such as punctured insulation in the spool (E), wear of the brush (F), collection of oil on (D), etc. And the sliding connection (I) and member (H) are eliminated, their equivalent being a steel point (F) turning in contact with the plate (D).

Safety Gap

An efficient safety-gap arrangement is provided by the point (S) arranged in proximity to the framework indicated at (G), (Fig. 13). The width of gap should be 5/16″ to ⅜″. **For high-compression engines** set ⅜″. Under high compression, the sparks may fire across the safety gap instead of firing in the engine. Missing under such conditions can easily be remedied by opening the safety gap so that it will offer a greater resistance to the secondary current than the spark-plug gap, under compression. Sparks should not be permitted to discharge across the safety gap for any length of time.

Dixie Contact-Breaker or Interrupter

Contacts are stationary and do not revolve as in the "armature" type. See Fig. 14 and compare it with the armature type (Figs. 1 and 2, pages 256, 257).

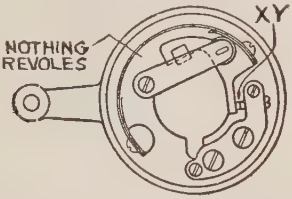


Fig. 14. Breaker (or interrupter) of Dixie magneto. A cam (Fig. 15) opens the points by raising the end of the arm. The cam is the only part of the breaker mechanism which revolves. Cam is not shown.

To adjust Dixie interrupter points (XY): This can be done while the magneto is running and the intensity of the spark can be seen while adjusting.

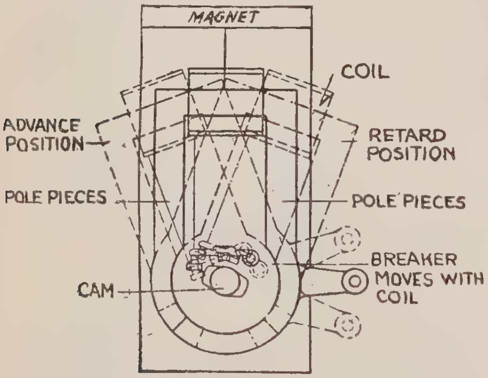


Fig. 15. Shows breaker and housing of the Dixie which, when retarded or advanced, moves the coil structure with which it is attached, giving the same intensity of spark at full advance or retard.

"Armature"-Type of Magneto Timing

The advance and retard of a magneto is necessary to make up for the "lag" in engine operation as well as variation of speed, fuel, etc.

Setting an "armature"-type magneto armature to the time of break of interrupter points is usually accomplished by measuring the distance (X) (Fig. 2, page 271) between one of the pole pieces and the adjacent edge of the armature. The breaker is then adjusted so that the points are just separating. This is taken as the advanced position of the magneto, and with this setting the maximum spark is obtained.

Timing an "armature"-type armature with engine: The usual practice is to place the piston on top dead center of compression stroke with the breaker box fully retarded and with points just opening. This of course increases the width of opening of (X) (Fig. 2) with a corresponding weakening of the spark. To advance the spark, the breaker box is moved so that the points open sooner in relation to the piston, thereby obtaining the best spark when running.

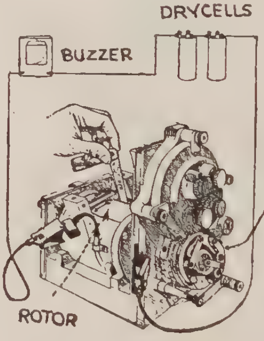
It is clear that the spark will be weak at retard position, because gap (X) is wide. Consequently the sudden surge of the flux line through the armature has already passed its maximum.

It has therefore been customary with some armature-type magneto manufacturers to use a compromise setting for the breaker in which the maximum efficiency of the machine is not utilized at full advance setting on the engine. This compromise setting permits a mechanical advance in such magnetos of approximately 30°, but it is doubtful if in many of these machines the effective range exceeds 12° or 15°, as the maximum spark of the magneto is never utilized.

Dixie Timing

The advance and retard of the Dixie magneto is obtained by shifting the breaker box. But note in Fig. 15 that it is attached to the "coil structure" (C-F-G, Figs. 4 to 7). Therefore the breaker housing and coil structure are all advanced or retarded at the same time. An absolute advance of 30° or more is obtained by simply rotating the coil-carrying structure to which the breaker box is attached, around the axis of the rotating poles N, S (Figs. 4 to 7 and 15).

Setting Dixie armature or "rotor" to breaker points: The distance (X) (Fig. 2, page 271) (armature-type illustration used to explain Dixie) is usually .020", just as points are breaking. The maximum rate of change of flux occurs in this position of rotor (X, Fig. 2), where the rotor wings have just reversed the direction of the flux through the core.



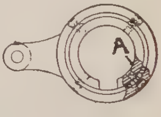


Fig. 17

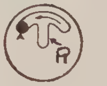


Fig. 18

Fig. 16

Fig. 16. A simple method of synchronizing the position of the rotor with the time of opening of breaker points, is explained below, and as shown in Fig. 16. Contact points should separate .020" when opened by cam.

If a buzzer is connected as shown, it will be in circuit with the contact-breaker points. While the contact points are closed, the buzzer will operate. Turn the armature slowly (direction of rotation) until the instant when the buzzer ceases. Just at this time the distance between the "rotor" and the "pole piece" should be .020". The spark-plug gap is set at .025".

Fig. 17. The breaker housing is adjustable. Being screwed to coil-carrying structure, it can be moved in the same direction as the cam operates—if rotor gap is too small. If too large, rotate in the opposite direction (to adjust for wear of fiber bumper also).

Fig. 18. Correct position of distributor brush in contact with segment (A) when breaker is fully advanced. Correct position prevents back-firing and tail-burning of distributor segment.

To facilitate this setting of the relation between the rotor and separation of contact points, a buzzer can be used, as shown in Fig. 16. The most effective distance for (X) is never varied on the Dixie.

To position breaker or interrupter box so that points open at desired point: Note that the breaker housing (Fig. 17) can be moved by means of set screws around the cam, so that the break can be made to occur without interfering with the adjustment of the points.

To time the Dixie magneto to the engine: (1) place piston on top of compression stroke; (2) uncouple magneto; (3) place breaker in retarded position; (4) rotate driving shaft of magneto in direction it is driven until platinum points are about to separate; (5) couple magneto; (6) connect distributor terminals as explained on page 294.

This timing is for the four and eight-cylinder magnetos, and also one and two twin-cylinder motorcycle type (M1 and M2); also Dixie models 11 and 21.

On the eight-cylinder, the distributor brush (A2, Fig. 20) should be in contact with No. 1 terminal of distributor block (see Figs. 22 and 23).

To time six-cylinder, model "60" magneto, place piston 1/16″ ahead of the end of the compression stroke with timing lever in full retarded position and breaker points just separating. The distributor terminal is connected with No. 1 plug terminal.

To time twelve-cylinder, model "120" magneto, place the piston 3/16″ ahead of the end of the compression stroke. With the breaker or timing lever retarded, turn the magneto drive shaft in the direction of rotation until carbon brush is in contact with the segment connected with terminal No. 1 of distributor block (Figs. 21, 24, and 25). When the points are about to separate, couple the magneto. See under Figs. 24 and 25 for distributor connections.

Cams on four and six-cylinder interrupters have 2 lobes; on eight and twelve-cylinder interrupters, 4 lobes.

Dixie Eight-Cylinder Distributor

Four sparks are produced during each revolution of the drive shaft, at the instant of the "break" from the edge of the field structure. There are four rotating poles to the eight and twelve-cylinder magneto. On the four and six-cylinder magneto there are two.

The magneto is driven at crank-shaft speed, because an eight-cylinder magneto four-cycle engine fires four cylinders per revolution. This eight-cylinder magneto generates four sparks per revolution. As the firing of the cylinders takes place at cam-shaft speed, the distributor is geared down two to one of the armature shaft.

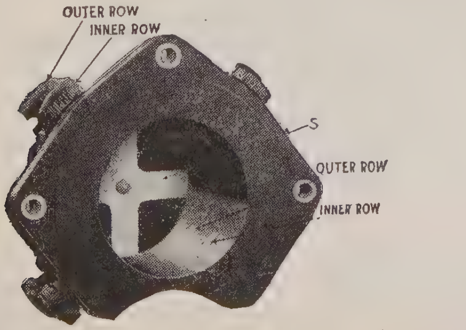


Fig. 19. 8-cylinder distributor. Note there are two rows of segments.

Distributor: On the four and six-cylinder magneto the segments are placed in one row, the proper distance apart. On the eight-cylinder magneto there are two four-cylinder distributors (Fig. 19), placed side by side, but moulded together, and having a double "finger" or rotor (Fig. 20). Contacts are so arranged that one segment in each row is alternately in contact. The rotor is hard rubber.

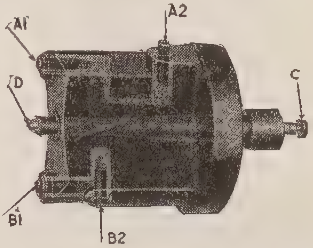


Fig. 20. The "rotor" of the 8-cylinder distributor (also for the 12-cylinder).

The high-tension current is collected by brush (**C**) (Fig. 20), which is in contact with the high-tension winding (see Fig. 13, page 273), and conducted through the center of the "finger" or rotor, to brush (**D**), thence by means of a metal sector (**S**) (Fig. 19), moulded in the hard rubber block. The current is conducted to either of two sets of brushes (**A1**, **A2**, **B1**, **B2**, Fig. 20) in the wings of the distributor rotor.

These brushes, arranged in sets, become alive alternately at the moment when they are actually in contact with a segment in either of the two rows of four segments in the block, making it impossible for the spark to jump to the wrong segment, as in this manner a spark received at any post in the inner row of the block will be followed by a spark from a post in the outer row, but 180° away.

Dixie Twelve-Cylinder Distributor

Four sparks are produced with each revolution of the drive shaft of the magneto. There are four rotating poles, the same as on the eight-cylinder.

Six cylinders must be fired with each revolution of the crank shaft. Therefore the magneto will turn 1½ revolutions to 1 of the crank shaft. The distributor is geared 3 to 1 of the armature shaft.

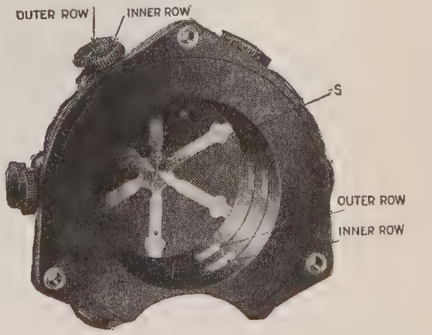


Fig. 21. 12-cylinder distributor. See also Figs. 32, 33, 34, page 278.

The distributor consists of two six-cylinder distributors moulded together as in Fig. 21. Note sector (**S**) in Fig. 21, how it differs from the eight-cylinder sector (**S**), (Fig. 19).

The "rotor" of the twelve is similar in construction, as in Fig. 20.

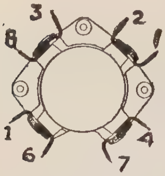


Fig. 22. Right-hand rotation.

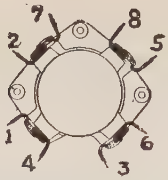


Fig. 23. Left-hand rotation.

Figs. 22 and 23 show order of sparks delivered by eight-cylinder distributor.

Figs. 24 and 25 show order of sparks of twelve-cylinder distributor.

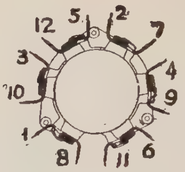


Fig. 24. Right-hand rotation.

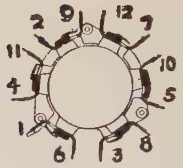


Fig. 25. Left-hand rotation.

Terminals on 24 and 25 are marked 1R–12R for right-hand rotation and 1L–12L for magnetos left-hand rotation.

Therefore, the right-hand rotation connects the cable from terminal 1R to spark plug No. 1 cylinder; cable from 2R to spark plug next in sequence of firing, and so on.

Parts of the Dixie Magneto

To replace parts on the Dixie: First remove the distributor plate carrying contacts. Then pull out the travelling contact and all its insulation. This leaves the coil and metal plate—and, if the spark does not jump the safety gap, a new coil may be put in in a few minutes.

For timing the Dixie magneto, see page 274.

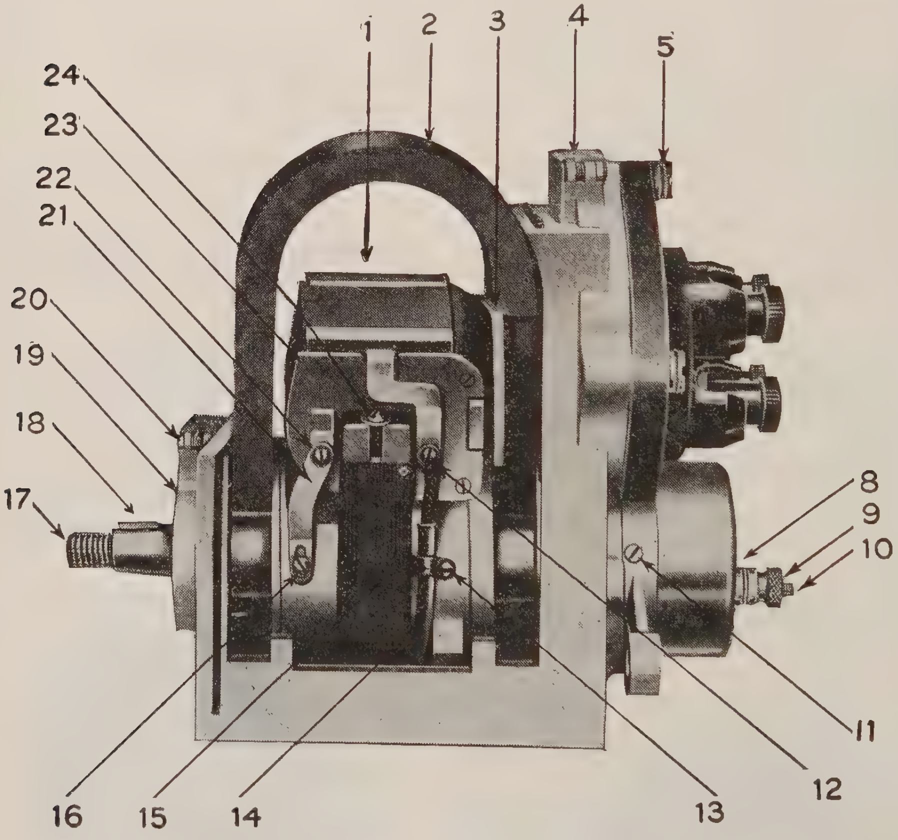


Fig. 26. Side view of parts of Dixie Magneto (4-cylinder).

1. Condenser.
2. Magnet.
3. Gap protector.
4. Oil hole cover, front.
5. Screw for distributor block.
8. Hexagonal nut for grounding stud.
9. Thumb nut for grounding stud.
10. Grounding stud.
11. Screw and washer for fastening breaker.
12. Screw and washer for fastening condenser and primary lead to winding.
13. Screw and washer for fastening primary-lead tube clamp.
14. Primary-lead tube.
15. Primary-lead tube clamp.
16. Screw and washer for fastening grounding clip to pole structure.
17. Rotor or armature shaft.
18. Woodruff key.
19. Back plate.
20. Oil-hole cover, back.
21. Grounding clip.
22. Screw and washer for fastening grounding clip to winding.
23. Winding.
24. Screw and washer for fastening winding to pole structure (Fig. 31).

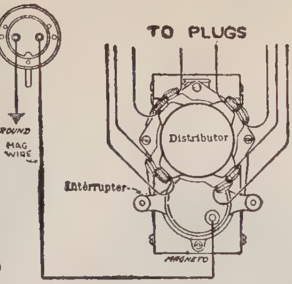


Fig. 27

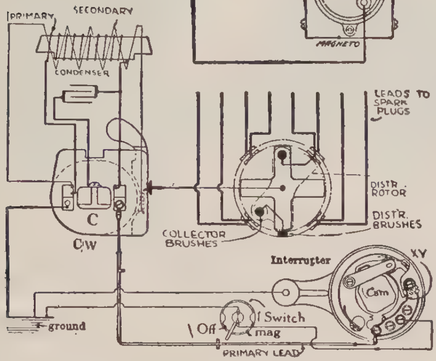


Fig. 28

Fig 27. External wiring for an eight-cylinder engine.

Fig. 28. Internal wiring for an eight-cylinder engine. See Figs. 11 and 13, which will assist in making this diagram clear. Note that (**CW**) in Fig. 28 is the coil winding and connections. Above it is the internal wiring as an explanation.

To Oil Dixie Magneto

After 200 hours of operation put oil at the point marked "OIL."

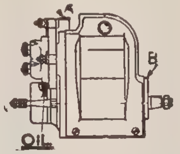


Fig. 29. Places to oil on Dixie magneto.

After every 20 hours of operation put two drops at (**A**).

After every 20 hours of operation put four drops at (**B**).

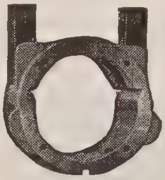


Fig. 30

Fig. 30. Pole structure in which rotating poles revolve and to which the condenser and coil winding attach to its upper part. See (24) and (16) in Fig. 26, showing how connections are made to it.

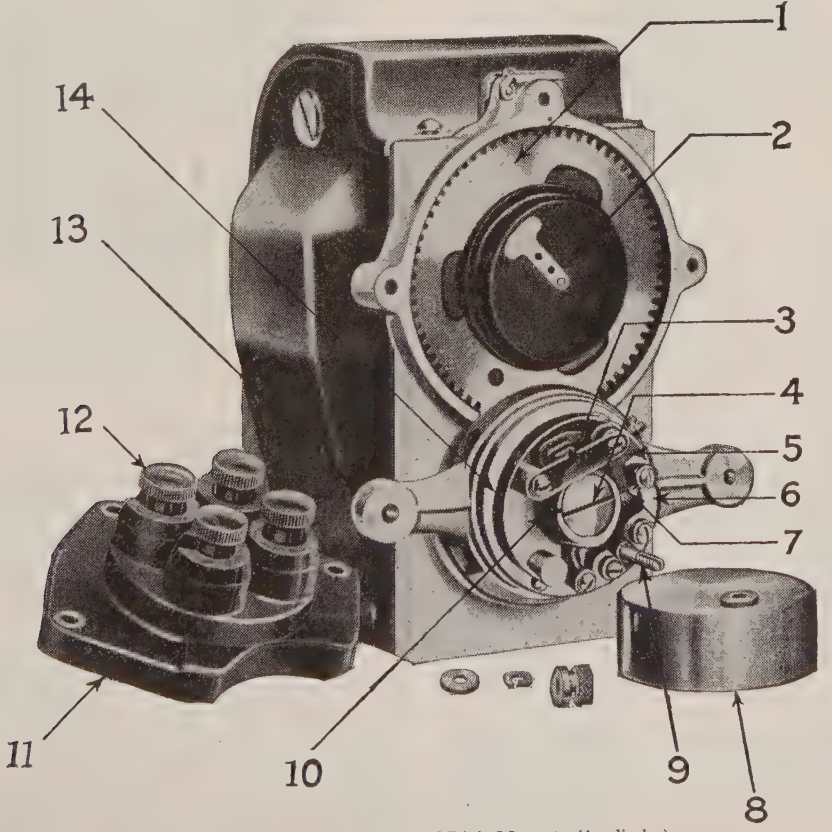


Fig. 31. Front view of parts of Dixie Magneto (4 cylinder).

1. Distributor gear.
2 Distributor disk.
3. Finger spring for breaker bar.
4. Cam screw.
5. Breaker bar with platinum point.
6. Contact screw bracket with insulation bushings.
7. Platinum contact screw.
8. Breaker-box cover.
9. Grounding stud or terminal post.
10. Cam.
11. Distributor block.
12. Thumb nut for distributor block.
13. Breaker advance and retard lever.
14. Breaker bar spring.

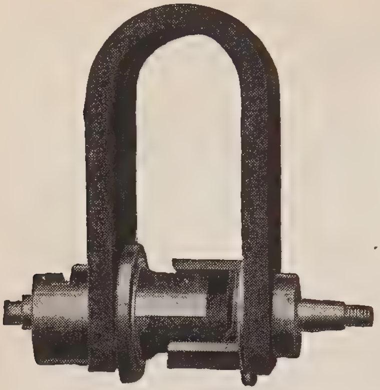


Fig. 32

Fig. 32. Rotating poles on the Dixie model "120" for 8 and 12-cylinder engines. Note that there are four rotating poles. On the 4 and 6-cylinder there are two.

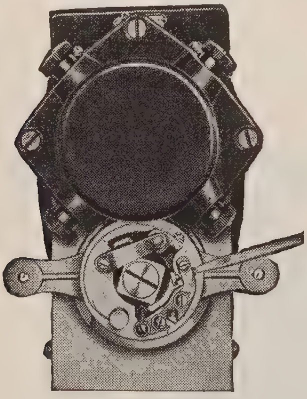


Fig. 33

Fig. 33. Showing method of raising or lowering the platinum point screw in (7) Fig. 31. The usual distance to set these points is .020″ or 1/50″. This adjustment can be made with a screwdriver. The spark-plug gap is set .025″.

Note. The contact breaker box is permanently attached to the pole structure or part (Fig. 30), which carries the coil and condenser. When moving the breaker to retard or advance, all the parts (Fig. 26) 1, 3, 24, 22, 21, 16, 15, 14, 13, 12 move with it (also shown in Fig. 15, page 274).

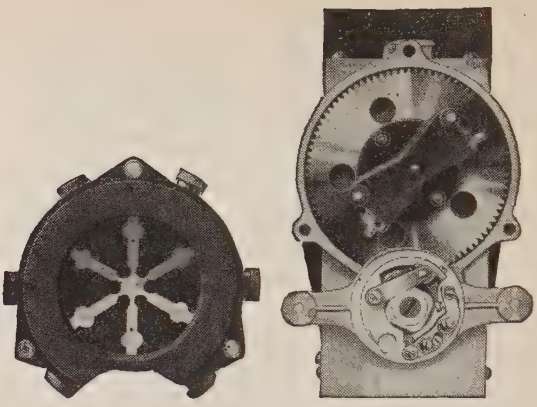


Fig. 34. Front view of Dixie model "120" 12-cylinder magneto. Note the distributor to the left and the distributor rotor and gear which is placed behind it and which drives the distributor rotor and which is driven from a gear on a rotating pole shaft. Note that the distributor rotor is arranged differently from (2) in Fig. 31, a 4-cylinder rotor.

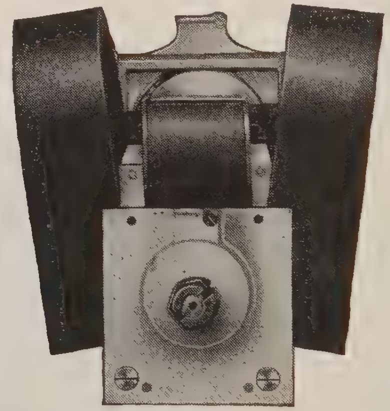


Fig. 35. Rear view of magneto. Note that by taking out four screws, the winding coil (23) and condenser (1) (Fig. 26) can be removed. The magnets (2) (Fig. 26) are exposed and removed when taking off the cover.

REMY HIGH-TENSION MAGNETO "SERIES 1500"

This magneto is a double-wound high-tension "armature-type" of magneto. The design of this magneto has been towards accessibility.

The circuit breaker, cam, and distributor rotor are mounted on a vertical shaft driven by hardened spiral gears which run in grease.

The circuit breaker and distributor parts form a complete and independent assembly which may be removed from the magneto by simply loosening one screw.

The circuit diagram(Fig. 2)shows clearly how short and direct both primary and secondary circuits are, and how accessible are all parts of these circuits.

The inner end of the primary winding is grounded to the core (**G2**) and from this point the current flows through the primary wire to a collector ring which is of copper and insulated from the armature head. Here it is picked up by a brush (**B**) carried by means of a copper pig-tail to the primary brush-holder

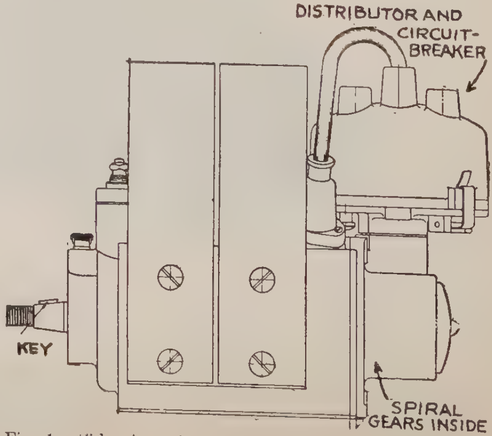


Fig. 1. Side view of the Remy "Series 1500" high-tension magneto.

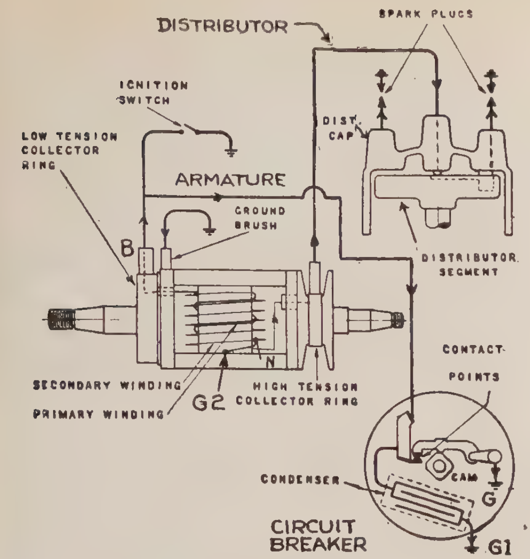


Fig. 2. Wiring diagram of the Remy "series 1500" high-tension magneto.

terminal, from which it passes through an insulated cable to the circuit breaker, condenser, and ground (G) and (G1) to ground (G2) on the magneto armature core.

Ground brush: Immediately under the primary brush holder is a brass plate grounded to the magneto frame, to which is connected a collector or "ground brush" which makes contact with the bronze head of the armature and by means of which the ground circuit is more fully completed, as, for instance, oily or gummed bearings would prevent good contact, hence the reason for using a ground brush.

The secondary or high-tension circuit is from grounded end (N), through the secondary winding, which consists of a great many turns of very fine copper wire, to the high-tension collector ring. This collector ring is bronze moulded between two flanges of hard rubber and the current is picked up from this ring by a carbon brush in the high-tension brush holder.

From the brush holder the current goes direct through a heavily insulated cable to the center terminal on the distributor cap. From here it is distributed by the rotor under the cap by means of a wipe contact to the segments. The distributor cap is of molded material with a hard-rubber track over which the distributor brush travels. From the distributor, the secondary current goes to the spark plug, to ground, to ground (G2) on the armature, to (N) where the secondary connects with the primary, thus completing the circuit.

The drive gear is fitted to a taper on the armature shaft.

Interrupter-gap clearance: Contact points on the interrupter should have a maximum opening of .020″ to .025″.

Spark-plug gap: The spark-plug gap clearance should be .030″.

Safety gap: The safety-gap clearance should be slightly more than the spark-plug gap clearance.

The safety gap on this magneto is formed between the end of the pointed screw which projects from the magneto housing and the high-tension collector ring. When this screw is in place and properly tightened, the safety gap will automatically be adjusted to the proper distance which is 7 m.m. or .275.″

THE K-W MAGNETOS

The K. W. magneto is of an "inductor" type, the principle of which is explained on page 246, and below. Unlike other magnetos, it generates four impulses per revolution instead of two, as explained on page 246. The K. W. magneto is used extensively on truck, tractor, marine, and stationary engines. The K. W. magnetos are made with two windings for high-tension work (**A**), and with a single winding for low-tension work (**J**). They both generate and deliver alternating current.

K.W. High-Tension Magneto

The K. W. magneto differs from other magnetos in many ways, and possibly the clearest information that can be given, is to assist in a careful study of the diagrams and accompanying explanation.

Diagram "A" shows a longitudinal sectional elevation of the model "HK" high-tension magneto. By referring to the numbers in the following description, a clear idea may be obtained of the function of the various parts.

Diagram "B" shows the rotor (which is the only revolving part in the K. W. magneto) and the complete assembled winding. The rotor is made up of soft Norway sheet-iron stampings, which are riveted together and very accurately machined, as these rotor blocks, which run on high-grade annular ball bearings, have only .003″ space between their face and the face of the pole-pieces. The rotor blocks are made in two halves and are held on the shaft by a taper pin, and are mounted at right angles to each other.

In mounting the winding between these rotor blocks, the pin is taken out of one half, and the rotor block is withdrawn from the shaft to allow the winding to be placed in the center.

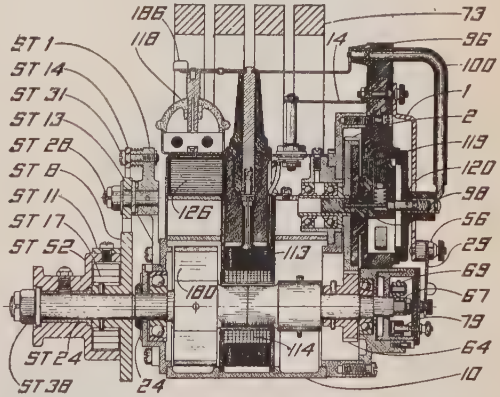


Diagram A, showing sectional view of the K. W. high-tension magneto, model "HK."

1	Bridge or spider.
2	Distributor gear.
10	Base.
14	Low-tension bus bar.
24	Dust cap or cover.
29	Retainer spring.
56	Switch binding post.
64	Driving pinion.
67	Cam.
69	Rocker-arm roller shaft.
73	Magnets.
79	Plunger for primary circuit.
96	Distributor block.
98	Distributor brush holder.
100	High-tension lead.
113	Secondary winding.
114	Primary winding.
118	Safety spark gap.
119	Secondary distributor brush.
120	Secondary contact plunger.
126	Condenser.
180	Rotor.
186	High-tension bus bar.

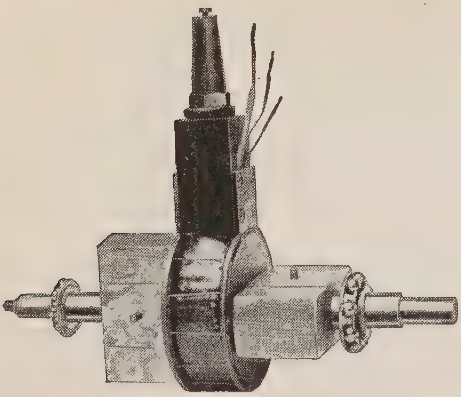


Diagram B, showing the stationary secondary and primary winding (113 and 114) (as in Diagram A) mounted between the rotors (180) which revolve.

The winding: Complete assembled winding (diagram C) consists of a primary winding of heavy copper wire and a secondary winding (see also diagram A) ,which is made up of a great number of turns of very fine wire, these coils being wound circular in shape, assuring the largest number of turns with the least length of wire, which makes the most efficient type of coil.

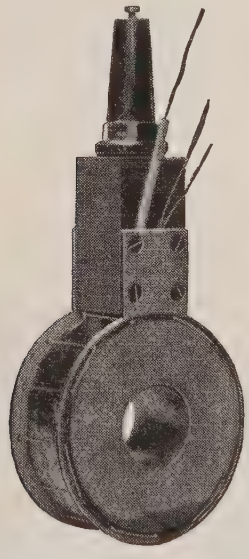


Diagram C, showing the windings (113 and 114) (as in Diagram A) and also shown in (B).

These windings are given an impregnation of high-grade insulating compound by the vacuum process, and the secondary winding is given 27 separate coats of varnish, each one being baked twenty-four hours, which thoroughly insulates it from the primary winding and also assures it being as near water and oil proof as it is possible to make any high-tension coil. These windings are assembled with the secondary outside of the primary, and then enclosed in a brass housing with a hard rubber plug, through which the high-voltage secondary is carried through parts 186 and 100 to the distributor brush of the magneto.

The condenser, No. 126, in diagram **A**, is made up of a number of alternating sheets of tinfoil and mica, every other sheet of tinfoil being connected together, which makes two series of tinfoil layers separated from each other by sheet mica. Each sheet of mica is tested separately, before being used, with 5,000 volts for breakdown and after it is assembled, it is given a test of five to six times the normal working voltage to which it is subjected, assuring reliability under adverse conditions.

The safety gap, No. 118, diagram **A**, is a necessary part of any high-tension magneto, its object being to form a path for the high-tension current to jump across in case a secondary cable, that leads to the spark plugs, should be off when the engine is running. This safety gap, as its name implies, prevents the winding from burning out, for as long as there is a path for the high-tension current to pass through, it will never puncture the insulation of the secondary winding.

The magnetic field of the magneto is composed of four horseshoe magnets, No. 73, shown in diagram **A**, which are mounted on two cast-iron pole-pieces, spaced 90° apart. The rotor, No. 180, revolves within this magnetic field, and as the rotor blocks are spaced 90° apart, they create four current waves for each revolution of the magneto shaft.

When the rotor is revolved within this magnetic field, the magnetic lines-of-force are caused to alternate through the center of the rotor, producing an electric current in the primary winding, which is carried up through part No. 14 to bridge No. 1, then through spring No. 29 to the circuit-breaker cap, and through the contact points in the circuit breaker back to the other side of the winding, completing the circuit.

When the current has reached its highest point, the circuit-breaker points are open, and the change of the magnetic flux causes a high voltage to be set up in the fine wire secondary winding. This induction is assisted by the condenser, which is connected across the circuit-breaker points, absorbing the spark which would occur if the condenser were not in circuit, and also assisting by the discharge which takes place immediately after it is loaded.

The high-tension current is carried up through the hard rubber plug to the bus bar, No. 186, then through lead No. 100 to the distributing brush, which distributes it to the different segments on the distributor block, these segments being connected by high-tension cables to the different spark plugs on the engine.

The distributor block is made of hard rubber into which are molded brass segments, one for each cylinder. The distributor brush holder which turns with the gear of the magneto is also molded of hard rubber and carries a carbon brush, which bears lightly on these segments as it passes, and the magneto is timed so that the circuit-breaker points open and the high-tension current is generated just at the instant this brush goes to the segment.

The K.W. Circuit Breaker

The entire circuit breaker is removable. Release spring No. 29 by pushing it aside. Pull out complete breaker box and remove cover nut No. 79. This allows removal of the circuit-breaker cap and gives access to the breaker parts. The same type of circuit breaker is used on all K. W. high-tension magnetos, and is shown by diagram **D**. It is arranged to have 30° of advance or retard for regular work.

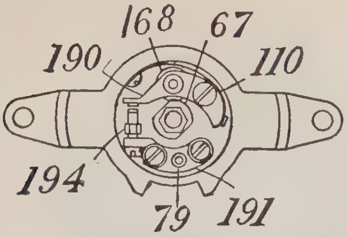


Diagram D, showing the circuit-breaker (also termed contact-breaker).

When the points fail to separate, or when the distance is too far apart, adjust part 194 with a small screwdriver inserted through the hole for that purpose in the housing. The proper distance apart is 1/64″. A gauge is sent with every magneto. Spark plug 1/64″.

The firing point of the magneto is just when the points are beginning to open or break the circuit, not when they touch.

To Open Distributor

Remove the high-tension lead No. 100, by turning it to the right, which releases it at the bottom. Unscrew nut at top of spider, and remove the bridge or spider No. 1, thus releasing the cap on the distributor block and giving a view of the distributor and brush No. 119.

Impulse Starter

Diagram **E** shows the impulse starter as applied to the model "HK" magneto, and diagram **F** shows a sectional view of the impulse starter only.

The impulse starter consists of two separate members, one of which is called the ratchet, and one the starter case. The ratchet is fastened directly to the rotor shaft of the magneto, and the case connects to the coupling, which is fastened to the shaft that drives the magneto. Interposed between these two members is a clock spring which performs the function of driving the rotor when the starting mechanism is used.

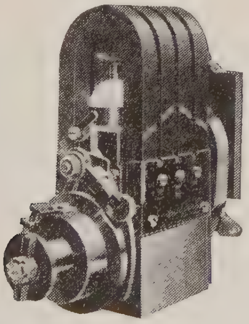


Diagram E, showing impulse starter mounted on the K. W. high-tension magneto.

When the engine is to be started, the ratchet catch lock (ST–14) is pressed down, which allows the ratchet catch (ST–13) to engage with a notch on ratchet (ST–6). Thus while the starter case (ST–2) is turned by the drive shaft, the ratchet (ST–6) remains stationary and the spring inside of the case is wound up. After the case (ST–2) has turned 80°, trip cam (ST–11) comes up into such a position as to disengage ratchet catch (ST–13).

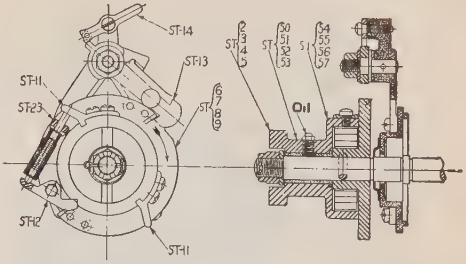


Diagram F, showing parts of the impulse starter.

As soon as the ratchet is released, it is thrown forward to its original position relative to the starter case (ST–2). In doing this, it carries the rotor of the magneto with it, and as the circuit-breaker points open during this period, an intensely hot spark is produced at the proper moment, regardless of how slowly the engine is turned over.

The starter continues to operate until a predetermined speed has been reached, when the ratchet catch is thrown up and latched, and the magneto is driven direct. The speed at which the starter throws out of engagement is determined by the tension of the cushion spring on the hook dog.

To Time Magneto to the Engine

First, Turn over crank shaft of engine, placing No. 1 cylinder from 3° to 5° past top dead center on firing stroke.

Second, Mount the magneto and turn the impulse starter case until it is just ready to disengage the ratchet catch. In this position couple it securely to the drive shaft of the engine.

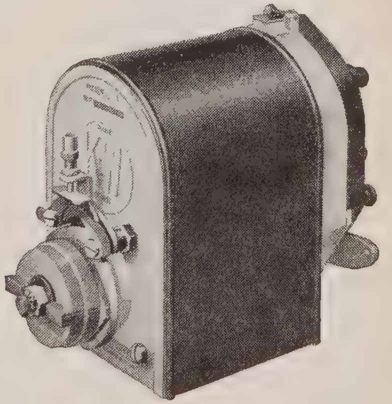


Diagram G, showing K. W. high-tension magneto, model "TK."

Diagram **G** shows K. W. high-tension magneto, known as model "TK," while diagram **H** shows a cross-sectional view of this magneto. It will be noted that the principle of the model "HK" and "TK" magnetos is exactly the same, the only difference being in the size of the magnetos and their appearance. The same principles of design and construction, are employed in both. Model "TK," however, has flat magnets.

Both magnetos are of the inductor-type construction, having a stationary winding and revolving rotor. This does away with all moving wires, collector rings, special contacts, etc., and is considered by the manufacturers the simplest form of construction.

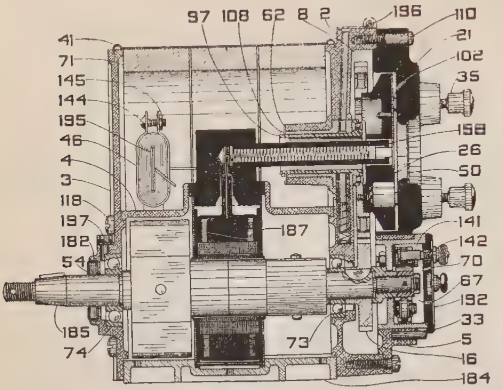


Diagram H, showing sectional view of model "TK" high-tension magneto.

K.W. Low-Tension Magneto

These generators are made for ignition, using a vibrating spark coil and low-tension timer, and are made in several models, for either friction or belt drive.

They are also made for tractor and motor-boat electric-lighting systems, feeding the current direct to the lamps. These generators will not charge a storage battery, as they produce alternating current.

Internal Construction

Diagram **I** shows the internal construction and extreme simplicity of the K.W. low-tension magneto, designed somewhat similar to the K. W. high-tension magneto, except that there is but one winding: the primary. This magneto is also termed an inductor type, designed on entirely different principles from other makes of magnetos, and patented by the makers. Instead of having wires wound longitudinally around a revolving armature, it has a stationary spiral winding of copper ribbon, as is shown in the center of diagram **J** and also in diagram **I,** which is a view of the inside of a low-tension magneto. The rotor changes the direction of magnetic flux through the winding, four times per revolution, and thus produces the electric current. This rotor revolves in two sets of high-grade ball bearings, and does not rub against or touch any other part on the entire magneto, as all other parts stand still.

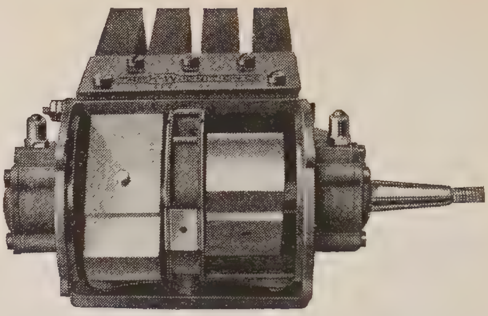


Diagram I, showing bottom view of the K. W. low-tension magneto and also showing rotor and primary winding.

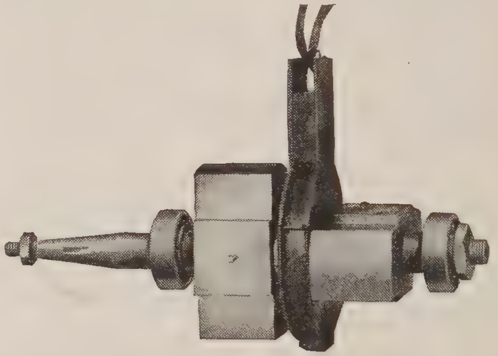


Diagram J, showing rotor and stationary winding with a single primary winding of the K. W. low-tension magneto.

The terminals of the winding extend through the top of the pole pieces in which the rotor revolves, and are securely connected to the winding posts, which are located at the end of the magneto.

The electrical part is housed in a case, making the magneto practically waterproof. It will stand any amount of spray or rain.

All models of K. W. lighting magnetos or generators, in addition to having a special winding suitable for lights, are so constructed and designed that the voltage can never exceed that actually required, regardless of speed. This takes care of various engine speeds, and entirely eliminates the use of automatic cutouts or other regulating devices.

The manufacturers of K.W. magnetos are the K. W. Ignition Co., Cleveland, Ohio.

REMARKS RELATIVE TO THE DIFFERENT MAGNETOS

If the reader will master **the purpose and principle of the following,** it will then be easy to analyze any system of ignition he may come across. For instance, learn the difference between: low-tension coils; high-tension coils; low-tension magnetos; high-tension magnetos.

Other details to classify would be: the difference between the ignition commutator, timer and interrupter, and sources of electric supply, as direct-current chemical generators (dry cells and storage batteries); direct-current, mechanical generators (dynamos); alternating-current, mechanical generators (magnetos); methods for distributing the secondary current to the spark plugs, by a distributor as used on a magneto, or by an ignition commutator in connection with a vibrator coil.

In other words, very nearly all of the systems comprise one or more of the parts of the four principles of ignition.

Difference in Makes of Magnetos

An inspection of the illustrations of **the different leading makes of magnetos** will give the reader an idea of the variance in construction. In these pages we illustrate magnetos of low-tension type and magnetos of high-tension type.

As previously explained, the low-tension type of magneto employs an armature wound with only one winding of wire, which is called the primary winding. We learned in a previous instruction that when a magneto employs a single primary wound armature, then a transformer (high-tension coil), separate and distinct from the magneto, is necessary in order to step up or transform the low-tension voltage (pressure) up to a high pressure.

By referring to pages 247,254, we find that the Remy and Splitdorf (in the models shown) have primary wound armatures and need separate coils or transformers. But going a little further into detail, we find that the Splitdorf, Eisemann, Bosch, Mea, and the pivoting magnetos all have armatures which **revolve with the winding wound on the revolving part.**

In the Remy model "RL," page 247, and K.W., as well as the Dixie and Ford inductor-type magnetos, we find that **the winding does not revolve,** but is stationary.

"Armature" and "Inductor" Type; "Primary" and "Compound" Wound Magnetos

The revolving type of armature, with the wire wound thereon, is called the "armature" type, and the type where the wire is stationary is called the "inductor" type.

If there is only one winding it is called a "primary" wound armature. **If there are two windings,** then it is called the "compound" type.

The primary wound armatures are low-tension, and require separate coils.

The compound wound armatures are high-tension, and do not require separate coils—except as a matter of convenience for easy starting or dual systems of ignition.

By referring to the K. W. magneto, in Fig. 6, page 284, we find that the winding on this type is also stationary, but instead of being a single primary winding, as on the Remy, it is a double or compound wound armature like the Bosch, Eisemann, and Mea—but differs from the last-mentioned in that the winding does not revolve.

In the Bosch, Mea, and Eisemann the armature is compound wound, and of the "armature" or revolving type. The principles of the magnetos are about the same, with some few minor differences in construction.

"Pivoting" or "Rocking" Type of Magneto

The Mea magneto (Fig. 2, this page) differs in that the magnets can be turned from side to side (called pivoting type); they are bell-shaped, and placed horizontally; therefore, unlike the customary horseshoe type, are mounted vertically. In this construction the magnets and breaker are moved simultaneously instead of the advance and retard of the contact-breaker alone.

This style of magneto, owing to the fact that it is rocked from side to side, gives an unlimited range of advance, and thus adds wonderfully to the flexibility of the car on which it is mounted. This great range of advance makes this instrument especially suitable for two-cycle engines, which require a much greater degree of advance and retard than the four-cycle type.

Magneto; Automatic Advance

The Eisemann automatic advance of spark (page 270): With all magnetos treated up to the present time, the advance and retarding of the time of spark is accomplished by hand, called "manual" advance by means of a spark lever on the steering wheel. With the Eisemann automatic advance, the same thing is accomplished by a governor arrangement automatically. This type of magneto is extensively used on commercial cars.

Illustrations of Some of the Different High and Low-Tension Magnetos

Note that while the magnetos may vary in construction, the principle is very much the same.

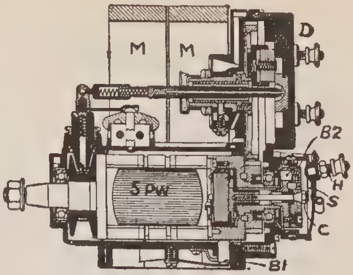


Fig. 1. The Bosch high-tension magneto. Armature revolves. The Simms, Eisemann, and other types are similar. (M), magnets; (D), distributor; (PW), primary winding; over this winding is (S) the secondary winding; (H), is the terminal which connects with the switch.

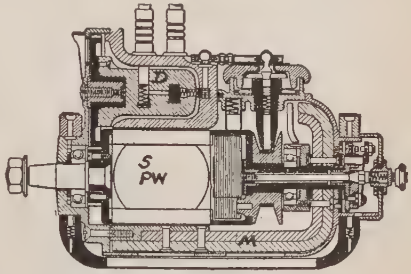


Fig. 2. The Mea high-tension magneto. Pivoting type. Revolving armature. Note that the armature is of the double-wound, shuttle-revolving type. Instead of shifting the interrupter housing, in order to advance or retard, the field magnets with the interrupter are shifted.

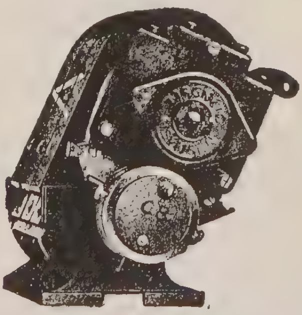


Fig. 3. The Eisemann high-tension magneto, pivoting or rocking advance magneto. The advance and retard are obtained by rocking the magneto bodily on its cradle. Otherwise the magneto is the same as other magnetos. The armature revolves.

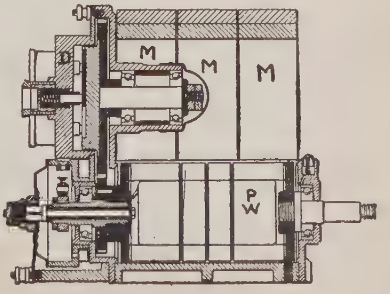


Fig. 4. The Splitdorf low-tension magneto. Armature is primary wound. Armature revolves and is of the "armature" type. A separate high-tension coil, called a transformer, must be used with this magneto. The Splitdorf Co. also manufactures a high-tension type magneto.

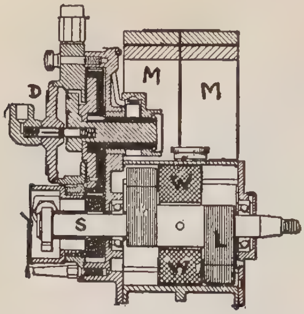


Fig. 5. The Remy low-tension magneto armature is primary wound—only one winding. The magneto is of the "inductor" type. Armature does not revolve. The winding (W) is stationary, and rotating magnets (L) revolve. Separate high-tension coil (called a transformer) must be used with this magneto. The breaker gaps are set .025″ apart.

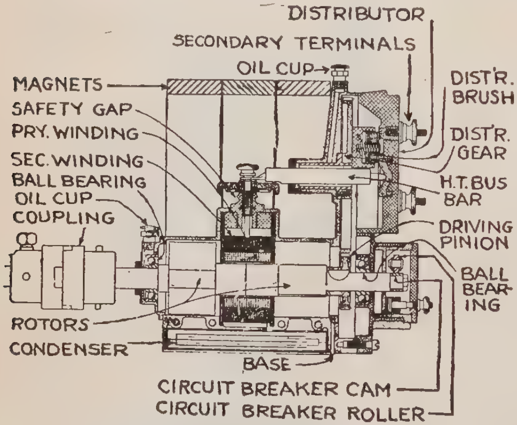


Fig. 6. The K.W. high-tension magneto with an inductor-type rotor. There are two windings on this type: a primary and a secondary. The windings are stationary, however, and the inductor rotors revolve. The principle of inductor-type magnetos was explained on page 246. The same principle applies here, with the exception that the two windings obviate the necessity of a separate high-tension coil, as it is here provided for in the secondary winding of the stationary coil winding. By referring to the Index under "Impulse and waves of current," and also on page 246, you will note that the K.W. gives four waves or impulses per revolution. However, either one, two, or four sparks per revolution can be obtained by using a single or a double cam.

On the K.W. there are four sparks per revolution, with a two-point cam, therefore the magneto would be driven at crankshaft speed for an eight-cylinder engine, and at 1½ times crankshaft speed for a twelve-cylinder.

The setting of the inductor-type armature is similar to the setting of any other type. The fact of its having two inductors, placed crosswise, is a bit confusing, but in the setting, only one is taken into consideration, and is therefore as simple to set as the ordinary type. The breaker and plug gap are set to 1/64″.

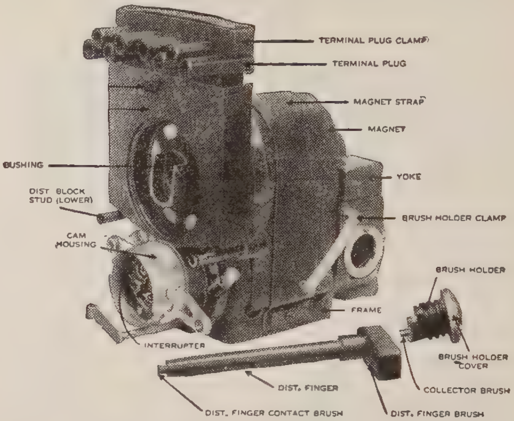


Fig. 7. Berling type D-81x-2, high-tension 8-cylinder single-spark, high-tension, revolving type of armature magneto, as used on the Curtiss training planes.

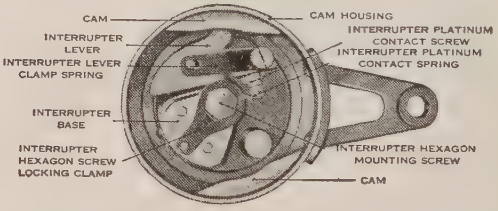

CAM
INTERRUPTER LEVER
INTERRUPTER LEVER CLAMP SPRING
INTERRUPTER BASE
INTERRUPTER HEXAGON SCREW LOCKING CLAMP
CAM HOUSING
INTERRUPTER PLATINUM CONTACT SCREW
INTERRUPTER PLATINUM CONTACT SPRING
INTERRUPTER HEXAGON MOUNTING SCREW
CAM

Fig. 7A. Interrupter or contact-breaker as used on the Berling magneto shown above.

Adjusting interrupter: With the fiber lever in the center of one of the embossed cams, the opening between the platinum contacts should be not less than .016″ and not more than .020″. The gauge riveted to the adjusting wrench should barely be able to pass between the contacts when fully open. The platinum contacts must be smooth, and if pitting of the contacts is in evidence, they should be smoothed off with a very fine file. When in closed position, the platinum contacts should make contact with each other over their entire surfaces.

Addresses of Leading Magneto Manufacturers

K. W. Ignition Co., Cleveland, Ohio.
Appollo Magneto Co., Brooklyn, N.Y.
Remy Magneto Co., Anderson, Ind.
American Bosch Magneto Corporation, Springfield, Mass., "Bosch" Magneto.
Ericsson Mfg. Co., Buffalo, N.Y., "Berling" Magneto.
The Eisemann Magneto Co., Brooklyn, N.Y., "Eisemann" Magneto.
Simms Magneto Co., East Orange, N.J., "Simms" Magnetos.
Splitdorf Electrical Co., Newark, N.J., "Aero" and "Dixie" Magnetos.

"COMBINING" THE HIGH-TENSION MAGNETO AND COIL AND BATTERY SYSTEM INTO "DUAL" AND "DOUBLE" SYSTEMS

We have now explained the different leading low and high-tension ignition systems for firing the charge of gas in the gasoline engine. In order to explain more clearly the four systems of high-tension ignition, we will now place the four ignition systems (high-tension) on one four-cylinder engine.

Some of these systems (see Fig. 8) are out of date, but are shown in order that the reader will understand the different principles. The modern battery and coil-ignition system, using a closed-circuit interrupter, as explained on page 197, is not shown.

The system of using four ignition systems on one four-cylinder engine is not in actual use, but is intended to make the combination of "dual" and "double" systems clear to the reader, by showing how they can be combined.

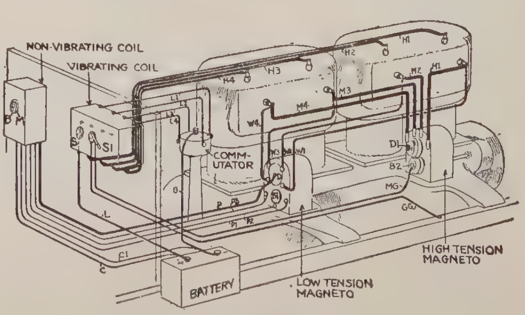


Fig. 8. Four high-tension ignition systems connected to one four-cylinder engine. Only two systems are usually placed on an engine. The idea is merely to show how the various systems can be combined into "dual" or "double" ignition systems.

The vibrating coil is seldom used. The low-tension magneto is seldom used. A modern "dual" and "double" system is shown on page 263. A modern "battery and coil" system is shown on pages 197, 211.

We shall first explain each system separately, showing how each would be connected.

First, **The "single" high-tension magneto system:** By referring to Fig. 8, we will put our pencil on the switch on the dash coil box (S1). If this lever is thrown to the left with all other switches "off," this high-tension magneto system will supply current for sparking the lower set of spark plugs (**M**1, **M**2, **M**3, **M**4). Note that these wires run from the distributor on the magneto.

Second, **The high-tension coil, battery and commutator system:** If switch (S) is thrown to the left, the four high-tension vibrating coils will spark the plugs (**H**1 to **H**4). The battery of either storage or dry cells (usually storage) will supply the electric current in this instance. The commutator, operated from one of the cam shafts through a system of bevel gears, will control the time of spark in each cylinder.

Third, **A non-vibrating single high-tension coil with battery,** using the circuit-breaker on the low-tension magneto as the timer, and the distributor on the magneto to distribute the current to the spark plugs: If the switch on the non-vibrating coil is on (**B**), the battery will supply the electric current, passing through the primary winding of the non-vibrating coil. The circuit-breaker (**B**1) on the low-tension magneto will take the place of the timer and vibrator. The secondary current from the coil will be distributed to the spark plugs (**W**1 to **W**4), through the distributor (**D**) on the low-tension magneto.

Fourth, **Low-tension magneto and separate high-tension coil:** If the switch is on (**M**) on the non-vibrating coil, the low-tension magneto will pass its current through this non-vibrating coil, increase it to high pressure, and then distribute the high-tension current through the distributor (**D**) to the spark plugs (**W**1 to **W**4), the circuit-breaker opening and closing the primary circuit of the magneto.

Combining into Dual Systems

If we were to combine the two last-mentioned systems, we should have **two systems of ignition using one set of spark plugs**—but only one system sparking the plugs at the time.

The single non-vibrating coil and battery would be used to start on, by throwing the switch to (**B**), and after the engine was started; then, by throwing the switch to (**M**), the low-tension magneto would take the place of the battery.

Another dual system: A vibrating coil with switch (S1), storage battery and commutator (timer), with secondary wires (**H**1 to **H**4), connected to the spark plugs (**M**1 to **M**4), in connection with high-tension magneto, connected to same spark plugs, would give another form of dual system.

Combining into Double Systems

The vibrating coil, timer, and battery with spark plugs (**H**1 to **H**4) would constitute one independent system. The high-tension magneto with its spark plugs (**M**1 to **M**4) would constitute the other. This would be called a double system.

Another double system could be formed by using the low-tension magneto and separate non-vibrating coil and spark plugs (**M**1 to **M**4). The vibrating coil, timer, and battery with spark plugs (**H**1 to **H**4) would constitute the other system.

There are many methods employed to combine the different ignition systems into "dual" and "double" systems.

A BRIEF REVIEW OF THE VARIOUS IGNITION SYSTEMS: ADVANTAGES AND DISADVANTAGES

We have now mastered the various methods of producing an electric spark for igniting the gas; with a "primary" or low-tension coil, and a "secondary" or high-tension coil, and a low-tension magneto; a low-tension magneto and a high-tension coil, and a high-tension magneto alone, or a high-tension magneto and a coil-and-battery ignition, as a "dual" system, also the "double" ignition system.

We shall now review the different systems as to their relative advantages and disadvantages.

Low-tension coil systems: The disadvantage of the "make-and-break" is its lack of "flexibility" and slow spark. It would be considered fairly good for a slow-running constant-speed stationary or marine engine.

Coil with vibrator: The disadvantage of a vibrator coil is its tendency to miss; if the battery is weak, the vibrator will not operate. If too strong, the points on the vibrator will weld together and stick, causing missing. The spark is not fast enough. The consumption of current is rather heavy.

Master vibrator coil: Where a system is already equipped with a multiple of vibrator coils, this would be an excellent method to improve it. Its disadvantage is a sticking vibrator, with all work on one vibrator and a succession of sparks.

Dry battery as a source of electric supply: Its disadvantage is unreliability. A battery of 5 or 6 dry cells will do fairly good work when fresh for short periods of time—provided two sets are used and the use alternates from one to the other. It gets weaker as used, however, and is unreliable. Intended for "intermittent" work—as ringing door bells, etc., where used only for a few seconds at a time.

Storage batteries are better, as they maintain their pressure until exhausted. They contain a greater quantity of current and are far more satisfactory. Their disadvantage lies in the fact that they must be recharged when exhausted, and the operator must watch it for fear of running down.

Battery, coil, and magneto: The battery and coil ignition, using dry cells or a storage battery, could be used for starting the engine and the magneto can be used for ignition after starting. The disadvantage would be that dry cells would soon get weak and the storage battery would require charging in time. If a generator or dynamo (direct current) was connected to the engine to charge the battery, this would be an improvement, but would add another piece of machinery. The magneto generates "alternating" current; therefore it is not suitable for charging a battery and can be used only independently for ignition.

High-tension magneto alone: The magneto generates a very hot and voluminous spark which is desirable as the time between ignition and actual combustion is less, with the result that more power is obtained (for the same reason that "double" and 'two-spark" ignition is an advantage). The disadvantage is that the magneto must be turned fast enough to generate current when starting, and this cannot always be relied upon when cranking by hand. Therefore some form of starter must be employed. The popular type of magneto starter is the "impulse starter," as explained on page 281. It is used extensively on truck and tractor engines. This overcomes the starting disadvantage, but is not altogether desirable for pleasure cars.

The low-tension magneto and separate high-tension coil are now seldom used, because the high-tension magneto is simpler, and thus the separate coil and wiring are dispensed with.

The high-tension magneto is a very desirable system of ignition. The spark is hotter, fatter, and exists across the spark-plug gap for a longer period of time than in other systems. Thus it fires all of the gas in each cylinder. The high-tension magneto is several times hotter than any other spark, and thus the gas is ignited more quickly. For reasons stated below, however, the magneto is not used on pleasure cars to as great an extent as formerly, and now that great improvements have been made with coil-and-battery ignition, this latter system is in general use.

The double system of ignition is an advantage. See pages 263, 264, explaining why.

The Electric System in General Use

Battery, coil, generator and electric starting motor: A very satisfactory system and one which is now generally used for pleasure cars is an ignition system using a high-tension coil without a vibrator, and a "closed circuit," "single spark" interrupter. The source of the electric supply for ignition and starting the motor is taken from the storage battery when starting the engine, and after the engine is up, speeding the "direct current" generator charges the battery and supplies current for ignition and lights. The advantages of this system would be a constant source of electric supply, a hot spark regardless of the speed of the engine, ease of starting the engine, and a constant source of electric current for lights when the car was idle or running.

The question then arises, Why use only a magneto on a truck, and this system on a pleasure car? The answer is, to avoid complication. The driver of a truck seldom runs the truck after dark, and seldom at a high rate of speed. A truck must be operated on an efficient basis, and for this reason the added complication of battery and starter is eliminated.

On the other hand, the pleasure car is driven considerably at night, and quite often at a high rate of speed. Therefore strong lights are essential. The pleasure-car driver also demands an easy method of starting. Inasmuch as a starting motor and strong lights consume a great deal of current, it is necessary that a generator be supplied that will continually charge the battery while running. Therefore, if a battery is required, and a generator to charge the battery, then by adding a timer, distributor, and non-vibrating high-tension coil, we have added an ideal ignition system, combining all the desirable features and eliminating entirely the magneto.

The disadvantage of the battery, coil, generator, and electric starting motor system would appear to be: (1) the probabilities of the dynamo at high speed burning out the ignition coil, as the voltage increases with the speed of the dynamo, or, (2) when running slow, the connection being between the storage battery and field coils, the current would flow from the battery into the generator. This, however, is all taken care of: (1) by "regulation" of the dynamo field windings, so that the output remains constant at low or high speeds; (2) by a "cut out" arrangement, which is explained farther on.

The greatest source of trouble with this system is the storage battery, as it requires careful watching. But by having the battery tested about every two weeks and seeing that the generator is charging the battery while running, which is a simple operation, battery troubles can be eliminated.

The Modern Battery and Coil Ignition System

The ignition system in general use today is the closed-circuit coil and battery system, illustrated on page 197.

The current is taken from a storage battery or the generator, then passed through the primary winding of a high-tension non-vibrating coil, using an interrupter and a distributor to make and break the primary current and distribute the secondary current to the spark plugs.

INSTRUCTION No. 27

MAGNETO INSTALLATION: Driving the Magneto; Magneto Speeds

Fitting the Magneto

One method of **fitting a magneto to the engine frame** is by means of pins, and is held down on its base by a strap of metal passing over the magneto, as in Fig. 1. The band is usually in two sections, as illustrated in Fig. 1, thus bringing the nut (A), which tightens or loosens the band at a point which is easily gotten at. In other instances, however, the magneto is bolted direct to its base, and since the nuts are below, it is almost impossible to remove the magneto after the engine has been placed in the chassis. It might also be worth mentioning, at this point, that some magnetos are strapped down on iron or steel brackets and no precaution taken to see that brass or non-magnetic fittings are used at the point where the tightening bolts join the straps. A little thought will show that, as illustrated, a portion of the lines-of-force will return by way of the bolts and base instead of through the armature. Although the effect of this may not be noticed at ordinary speeds, it will have much to do with determining the lowest speed at which a good spark is produced. Magnetos therefore must have a brass or aluminum base.

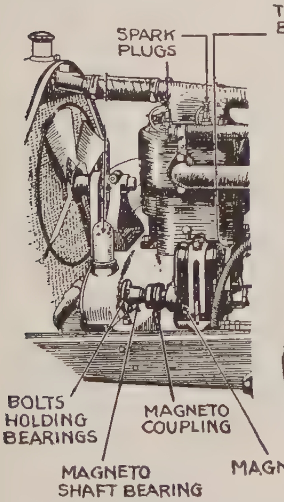


Fig. 2

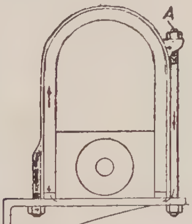


Fig. 1 (upper)
Fig. 3 (lower)

Figs. 1 to 3 apply to the types of high-tension magnetos with double-wound armatures.

Magneto Location

The magneto is usually placed alongside of the engine (see Fig. 2), mounted on a separate base provided for it. The base of the magneto is usually made of brass, as brass will not become magnetized; therefore the magnetism is confined to the magnets, otherwise they would soon lose their magnetism.

Magneto Drive

The magneto armature shaft can be driven by gears (Fig. 4), or a silent chain (Fig. 5). The usual practice is to drive with gears (see Figs. 5A and 5B).

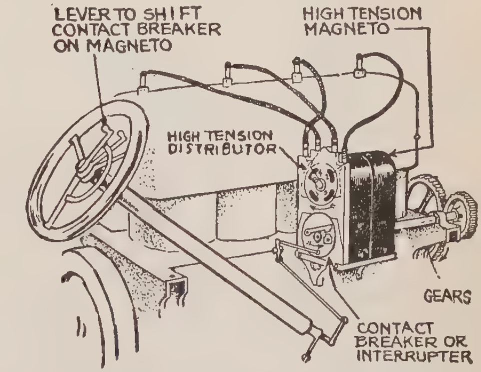

LEVER TO SHIFT CONTACT BREAKER ON MAGNETO
HIGH TENSION MAGNETO
HIGH TENSION DISTRIBUTOR
GEARS
CONTACT BREAKER OR INTERRUPTER

Fig. 4. Simplified illustration showing how the magneto is usually driven and how the interrupter, or contact-breaker, is connected with the spark lever.

The magneto which is timed to give a spark at a fixed time cannot be driven by a belt or friction, because the armature must be in a certain position in relation to the time of spark. A belt would slip.

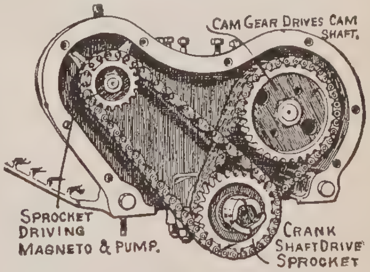

CAM GEAR DRIVES CAM SHAFT.
SPROCKET DRIVING MAGNETO & PUMP.
CRANK SHAFT DRIVE SPROCKET

Fig. 5. The silent-chain drive method on a six-cylinder engine. Note that the sprocket driving the magneto gear is slightly smaller; therefore the magneto gear will turn 1½ revolutions to the crank shaft gear's 1 revolution. (The magneto is usually driven by gears.)

A coupling is usually provided between the drive shaft and armature shaft, as shown in Fig. 2. One type of coupling is the Oldham, shown in Fig. 3; another type is a flexible leather or fiber disk bolted between two flanges. By the use of a coupling, the magneto can be uncoupled from its drive member and properly timed without removing the gear-case cover.

The coupling and shaft are usually driven by a gear. This permits undue strain on the armature, if it is not exactly in line, and also reduces vibration to the armature shaft. The chain drive is the least desirable for magneto drive, but is a popular drive method for the interrupter of a coil and battery system of ignition.

If a gear is used to drive the magneto direct to a gear on the armature shaft, sufficient clearance must be allowed between the gear on the magneto and the driving gear, in order to reduce strain on the armature shaft.

The magneto must be driven at a fixed speed, because the armature must be in approximately a vertical position and with the interrupter point just breaking when the piston is in the correct position to receive the spark. The correct position for the piston to receive the spark is just an instant before it is at the end of its compression stroke.

FIG 5A

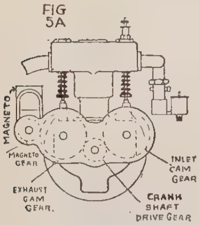


FIG. 5B

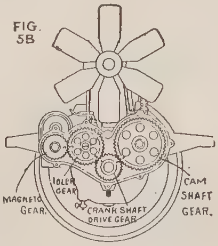


Fig. 5A. Magneto driven by gears on a "T"-head engine.

Fig. 5B. Magneto driven by gears on an "L"-head engine.

The armature is therefore set by meshing its drive gear in relation to the gear on the crank shaft, so that it will be in this position at this time.

The magneto drive shaft is usually tapered, therefore the coupling should be tapered to correspond. If driven by a gear, and teeth are meshed too tight, undue strain will result on the bearings.

Magneto Connection with Spark Lever

The method for advancing and retarding the time of spark is usually by means of a rod connected at one end with the spark lever on the steering wheel; the other end connects with the bell crank, thence by a rod to the interrupter or breaker-box housing (Fig. 4).

By shifting this housing in the opposite direction of the rotation of the cam, the cam would raise the interrupter arm and interrupt the flow of current earlier, or in "advance."

By shifting this housing with the direction of rotation of the cam, the interruption would occur later, or "retarded."

On some types of magnetos, such as the Mea, page 271, the field magnets are "advanced" and "retarded" by rocking the magnets bodily around the armature (called "pivoting advance").

The advance which can be obtained on a magneto is usually 22° to 35°.

Clockwise and Counter-Clockwise Drive

The drive-end of a magneto is the end where the drive gear or coupling connects with it. The direction of rotation of armature is always considered from the drive-end.

Clockwise rotation of the armature would therefore be as in Figs. 6A and 7A. Note that the direction of rotation of the armature is right hand, or as the hands of a clock move.

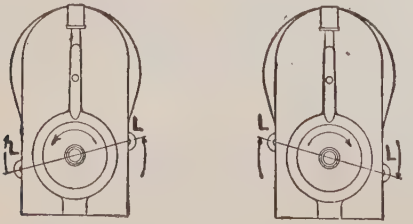
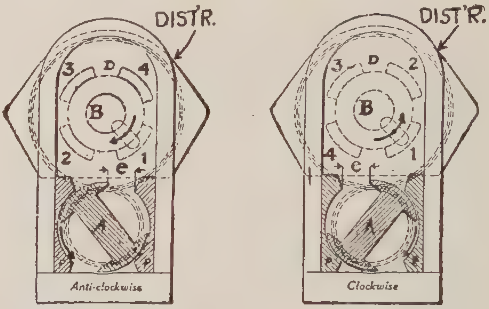


Fig. 6

Fig. 6A

Fig. 6. Positions of full retard of the cam plate when looking at the driving end of the Simplex magneto. Fig. 6 is a view of the counter-clockwise setting and Fig. 6A, the clockwise setting.

Counter-clockwise rotation would be as in Figs. 6 and 7. Note that the direction is a left-hand direction, or opposite to that of the movement of clock hands.



Figs. 7 and 7A. Drive end of magneto which is opposite to the interrupter and distributor end.

Note in Figs. 7 and 7A that the distributor would revolve in the opposite direction to the armature.

Note also in Figs. 7 and 7A the position where armature (A) should be placed when the contact-points should open, with the contact-breaker fully retarded. The illustration on the right shows a clockwise rotation, and the left-hand illustration shows it as counter-clockwise, both armature positions being retarded. By this is meant that the contact-breaker points are retarded from separating until the armature has reached a position as shown at (e).

Figs. 6 and 6A show the drive-end of a magneto with the contact-breaker lever (L) retarded when running clockwise and counter-clockwise, as in Figs. 7 and 7A.

Meaning of "Advance" and "Retard" of Spark

Since in regular operation of the engine the charge is ignited just an instant before the top of the compression stroke, the magneto armature is so set, relative to the engine crank shaft, that the maximum induction effect occurs at this moment.

It is, however, necessary to be able to vary the point in the cycle at which the ignition occurs, since, **when the engine is cranked by hand,** the spark must occur after the end of the compression stroke, or else the engine may kick back.

If started by some form of self-starter, it is then possible to start with slightly more advance than when starting by hand, because the self-starter turns the engine crank somewhat faster; however, even with a starter, if advanced too far it will cause a back-kick and may result in damage to the starter.

The meaning of "advance" of spark is to cause the spark to occur earlier, before the piston is on top of compression stroke.

The meaning of "retard" of spark is to cause the spark to occur later. On engines that are cranked by hand, the spark is usually set "retarded" after top, so that there will be no danger of a kick back.

The exact position to "advance" or "retard" is determined by running as far "advanced" as possible at all times until a knock is detected, and then "retard" until the knock disappears. The driver will then soon learn the exact position where the engine gives the greatest power. Remember also, that a retarded spark heats up the engine.

Control of Spark

Principle: As the spark occurs only when the primary circuit is broken by the opening of the platinum contacts, the timing of the spark can be controlled by having these platinum contacts open sooner or later. This latter is accomplished by the angular movement of the timing lever (**L**) (Figs. 8 and 8**A**). This movement gives a timing range of about 34°. The spark is fully retarded when the timing lever is pushed as far as possible in the direction of rotation of the armature, and is advanced when pushed in the opposite direction.

Magneto spark control: In order to make it possible to vary the time of the spark on a magneto, the circuit-breaker housing is so arranged that it can be rocked around its axis, being provided with a lever arm (**L**) (Fig. 8) for the purpose, from which connection can be made to a spark lever on the steering post, as in Fig. 4.

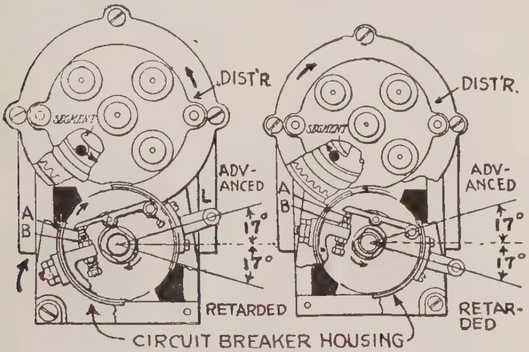


Fig. 8 Fig. 8**A**

Fig. 8. Illustration showing circuit-breaker in "advanced" position when magneto armature is running "counter-clockwise" (view from front of magneto).

Fig. 8**A**. Illustration showing circuit-breaker in "advanced position" when magneto armature is running "clockwise" (view from front of magneto).

It will readily be understood that if the armature shaft turns right-handedly (Fig. 8**A**) (view is from the distributor end, not the drive end), and if then the circuit-breaker housing is moved through a certain angle in a right-hand direction, the contact points (**A**) and (**B**) will separate later, or "retarded," with relation to the position of the engine crank shaft; while, on the other hand, if the housing is moved in a left-hand direction, the circuit-breaker point will open earlier, or "advanced," the position in which it is now in Fig. 8**A**. In this way the point at which the spark occurs can be shifted through an angle of about 34°.

Coil and battery system control: On the Delco and Atwater-Kent or similar systems, the advance and retard is obtained by shifting the housing surrounding the timer and distributor and also by governor action (see pages 202, 214).

Spark-Control Methods

There are three general principles used for control of spark: (1) by hand, to vary the spark position, which would be termed "variable spark"; (2) by a governor, which would also vary the spark according to speed; (3) by a fixed spark.

(1) **By hand** means that the spark lever on the steering post shifts the commutator or interrupter (see Fig. 4, page 287).

Where magneto ignition is used, the housing on which the interrupter arm is placed is shifted in the opposite direction of rotation to the armature to "advance," or cause the spark to occur earlier, or, in the direction of rotation to cause the spark to occur later.

When the spark is advanced or retarded by hand, it is left to the good judgment of the driver to manipulate the spark lever, except where the system is equipped with an "automatic" advance. The automatic advance is seldom used with magneto ignition.

(2) **The automatic advance** is probably the most satisfactory with a battery and coil system of ignition, because the spark occurs just at the right time automatically, and there is no guessing as to just how far to advance or retard at various speeds. See Index.

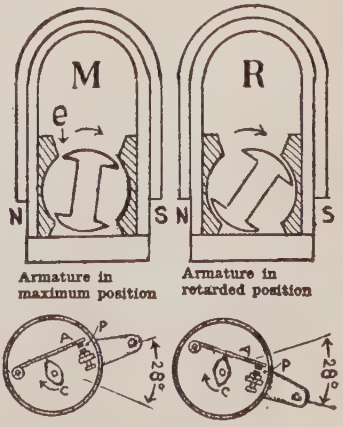
(3) **The fixed spark** is sometimes used with a high-tension magneto, which means that the time of spark is fixed at one position, usually advanced, and the contact-breaker breaks at one position, regardless of speed. This system has not proved very satisfactory on engines where speed varies, but would be satisfactory if the speed of the engine was constant and did not vary. The objection, however, would be in starting—liability of a kick—for the spark would necessarily be placed advanced for proper running.

The disadvantage in one instance: Suppose the car was running up hill, the charge of gas would be heavy and the throttle would be open, consequently there would be a high compression. If the spark was advanced, which it usually is with a fixed spark, the spark would occur at such a time that the combustion would take place before the piston reached the top, because the piston would be moving slow at, say, ten miles an hour; the result would be that the force would be exerted on the head of the piston causing the momentum of the piston to buck against the force of the combustion, which would invariably cause a knock and loss of power.

The fixed spark, however, is not at all advisable on variable speed engines.

Relation between Position of Armature to Contact-Breaker when Advanced or Retarded

Advanced position: Referring to (**M**), the armature cheek is just breaking from the pole tip (**e**), in the direction of rotation. This is the maximum position, or when current strength is strongest. At this time the contact-points (**P**) (Fig. 9) should separate.



Armature in maximum position **Armature in retarded position**

Fig. 9 Fig. 10

Fig. 9. Contact-breaker advanced.
Fig. 10. Contact-breaker retarded.

The magneto is set at the factory with armature in maximum position (**M**), and the contact-breaker housing (Fig. 9) is placed in an advanced position. That is, it is moved opposite to the direction of rotation of cam (**c**). The cam (**c**) is set so that it causes points (**P**) to separate when the contact-breaker housing is in the advanced position.

Retarded position: Suppose the contact-breaker housing is retarded, or moved with the direction of the cam rotation as far as it will go (Fig. 10) (28° is average range),[1] then points (**P**) of the contact-breaker would not separate until the armature had traveled farther[2] in the direction of rotation, approximately the position shown in (**R**). At this point the armature has passed the maximum position and is where the current strength is weaker. By referring to pages 253, 254, we learn that the current strength begins to weaken the nearer the armature travels to zero position after maximum position.

From this we learn that the spark is strongest at maximum position of the armature (**M**), with the contact-breaker in advanced position (Fig. 9), and that the spark is weaker when the contact-breaker is in retarded position (Fig. 10), because the armature has passed the maximum position.

Let us see what happens when we follow out the magneto-setting given on page 297, which says: Place piston on top of compression stroke, place contact-breaker in retarded position, then turn armature in direction of rotation until contact-points just start to separate.

This would place the armature in position (**R**), and the contact-breaker in position shown in Fig. 10; both retarded. In this position the spark would occur when the piston was on top of the stroke—but we must remember that the combustion is not instantaneous; therefore allowing for this lag, the spark would occur when the piston had moved slightly down after top—which at slow speed is desirable, but which is a weaker position of the armature for starting the engine on.

This is why spark-plug points ought to set close together, and why magnetos do not permit the engine to throttle down as slow as a constant source of electric supply, such as a battery. The contact-breaker is usually retarded when the engine is running slow and the magneto armature is turning over slowly. Therefore both actions tend to weaken the spark. Always run as far advanced on magneto ignition as possible.

As the speed of the engine increases, if the contact-breaker was retarded and combustion was not instantaneous, as explained above, then the piston, traveling fast, would move farther down after top before the spark occurred. Therefore as we have a range of 28° in which we can move the contact-breaker housing so that the spark will occur earlier, we then advance the contact-breaker more and more as the speed of the engine increases, so that the spark will occur before top of compression, thereby giving the combustion time to take place, when the piston is on top, or just starting down. The more we advance the breaker, the nearer we reach maximum or the strongest position of the armature. Therefore the current strength is greatest at high speeds.

When setting a magneto, the only point to consider is whether the breaker housing is to be retarded or advanced when interruption takes place, and the position of the piston.

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[1] The average advance range of the armature is 22° to 34°—many magnetos actually having but 22° or 28° in which the breaker moves from full advance to full retard. The Bosch Co. states that the Bosch four-cylinder standard average speed (less than 2,000 r.p.m.) has a timing range of 35° figured on the magneto axis. On a timer or commutator, it is possible to get as high as 48°; for instance on the Atwater-Kent timer, the timer shaft will advance automatically about 15° at high speed, and the housing itself can be advanced about 33°.

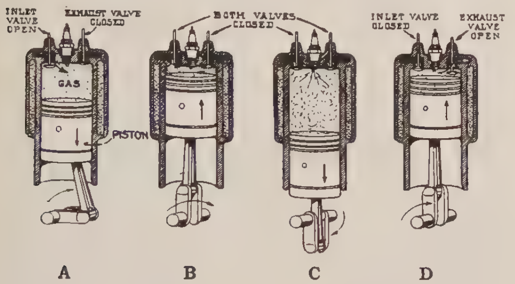
[2] About 1/16″ break from cheek of armature to pole-piece (e) when advanced, is the average break. The distance at full retard would be about 23/32″.

A four-cylinder engine, with a speed of 2,000 or less, is termed an average-speed engine, and the gap between pole-piece and armature cheek is 1/16″. An engine with speed of 2,000 to 3,500 r.p.m. would be termed a high-speed engine, and in this case the gap opening is increased to 5/32″ or 3/16″.

INSTRUCTION No. 28

IGNITION TIMING: Timing the Magneto; Timing Miscellaneous Ignition Systems

A study of Figs. **A** to **D** below will make clear the "four-cycle principle" which it is necessary to have in mind clearly in order to understand the explanations following. This explanation is also applicable to coil and battery ignition.



Suction or inlet stroke: In Fig. **A,** the piston moves downward, drawing a mixture of gas and air into the cylinder on top of the piston.

Compression stroke: In Fig. **B,** the inlet valve closes and the piston moves back in the cylinder, compressing the mixture of gas and air.

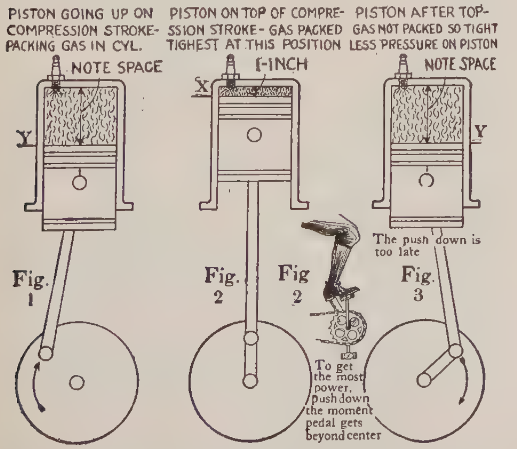
Power stroke: In Fig. **C,** the mixture of gas and air under compression is ignited by means of an electric spark; thus the expansion force of the heat pushes the piston downward. This is the power stroke. Note there is only one power stroke per cylinder for every two complete revolutions of the crank shaft.

Exhaust stroke: In Fig. **D,** the exhaust valve opens; the piston on the upward stroke forces out the burned gases, and the cylinder is again ready for a new charge, or the inlet stroke.

RELATION BETWEEN THE TIME OF SPARK AND TIME OF COMBUSTION

The combustion should take place as the piston is on top of the compression stroke, or slightly thereafter, as shown in Fig. 2 below, because at that point the gas drawn into the cylinder has been forced up into the head of the cylinder and is at the point of greatest compression. Hence more force is exerted on the head of the piston when the explosion occurs.

If it occurs after the piston has started down (as in Fig. 3 below), the compression is not as great. If it occurs before the piston reaches the top of the compression stroke (as in Fig. 1 below) it is not as great, because if the engine is running slow and the explosion occurs before the top of the stroke, the force will be exerted against the piston's upward travel, and will cause a knock and loss of power.


PISTON GOING UP ON COMPRESSION STROKE- PACKING GAS IN CYL.
PISTON ON TOP OF COMPRESSION STROKE - GAS PACKED TIGHTEST AT THIS POSITION
PISTON AFTER TOP- GAS NOT PACKED SO TIGHT LESS PRESSURE ON PISTON
NOTE SPACE
1-INCH
NOTE SPACE
Y
X
Y
The push down is too late
Fig. 1
Fig. 2
Fig 2
Fig. 3
To get the most power, push down the moment pedal gets beyond center

An example: In Fig. 1, note that the piston is going up on compression stroke, pushing or compressing the gas (which was drawn in at the previous suction stroke) into the head of cylinder. At the point where piston is now, the gas is not very tightly compressed.

In Fig. 2, the piston has now reached the top of compression stroke and the gas is packed tight into the head of the cylinder. It is clear that if the combustion took place just as the piston started down, the expansion force against the piston would be greater than if the combustion did not take place until the piston had passed over the top and was on the way down, as in Fig. 3.

Also observe that if the combustion took place, before the piston reached the top of the compression stroke, as in Fig. 1, especially if running slow, the power would be exerted on the up-coming piston's momentum and would not only cause a falling off of power, but a knock would occur, caused by the sudden reversed force of the combustion on the piston.

Remember, the momentum of the fly wheel carries the piston up and down on the other three of the four strokes.

Note. The automatic spark control takes into account variations in speed only.

Time for the Spark to Occur

There is a difference in time, between the time the "spark" is made at the spark plug, and the time at which the "combustion" of the gas actually takes place. If combustion took place immediately when the contact was made or broken, then the proper time to set the spark to occur would be on top of the compression stroke.

But, as stated, there is a slight difference in time allowed for the gas to burst into full explosion after the spark occurs; but as we desire that full explosion occur at the highest point of compression, we will figure out just how we can make the combustion take place at the highest point of compression.

First: We must figure out how far in advance of the top of the compression stroke the spark must be set to occur, in order to have combustion take place on top of the compression stroke.

There are two main points to be considered; the system of ignition being one. If a coil and vibrator system is used, then it is natural to suppose that the time consumed in making contact on the commutator and the time of action of the vibrator will result in more time than a single contact, as in a magneto or single-spark system. Therefore if a vibrator coil system is used, we would have to set the spark to occur a longer time before the top of the compression stroke, than if a quicker single spark system of ignition was used.

The second consideration is speed. If the piston was traveling slow, the spark would be set (retarded) to occur later or nearer the top of compression stroke than if the engine was running fast.

Speed Relation to Time of Spark

Suppose the engine was running 500 revolutions per minute. Taking (X) (Fig. 6) as top of compression stroke, the distance to set the spark would be, say, at (Y), in order to give the combustion time to take place when the piston was on top of compression stroke.

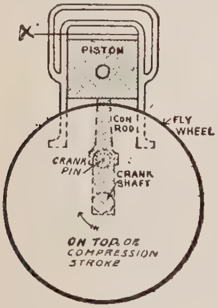


Fig. 4

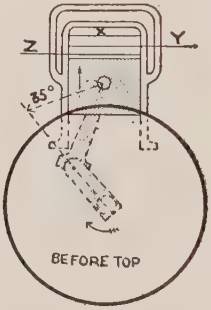


Fig. 5

Now if the spark was fixed to occur at (Y) (Fig. 6), and speed was increased to 1,000 revolutions per minute, then the piston would go to the top of compression stroke at (X), (Fig. 7), and pass over it and down to (Y), on the other side, or down in power stroke, before the process of combustion was completed. The result would be a loss of power during the piston's down travel between the points (X) and (Y) (Fig. 7), the full force of the explosion not being exerted on the piston until the latter point (Y) was reached.

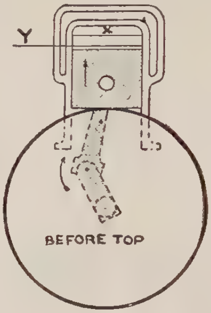


Fig. 6

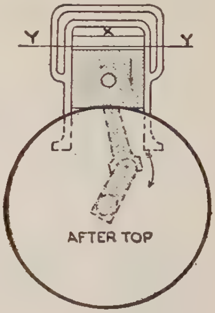


Fig. 7

To increase this, it will be necessary to recalculate the piston speed at 1,000 r.p.m. and set the spark at a point say, (Z), (Fig. 5), which will allow of complete combustion by the time the piston reaches the top of compression stroke (X).

Setting the time of spark to occur before the top of compression stroke is called advancing the spark.

In setting a magneto, the usual extreme range of advance is 22° to 35°; therefore if it was desirable to set the spark to occur at 35° at full advance position, so that the spark would occur 35° before top, when running at full speed, simply place the piston on top of compression stroke, and set the contact-breaker in "retard" position.

If only 30° advance was desired at full speed, place the piston 5° past the top of compression stroke and set the breaker-box housing at full retard.

RELATION OF MAGNETO DISTRIBUTOR AND ARMATURE SPEED AND OF THE CRANK SHAFT OF THE ENGINE AND THE CAM SHAFT

A high-tension magneto of standard construction produces a high-tension or jump-spark current, this current being generated in the windings of the magneto armature without the use of a separate induction coil.

Two ignition sparks are produced during each revolution of the armature in the "armature type" magneto, and these are transmitted to the proper cylinders by means of the high-tension distributor, which is integral with the magneto. Once during each half-revolution of the armature the primary circuit is broken, and the abrupt interruption of the primary current results in the production of the high-tension current in the secondary winding.

The variation in ignition timing is effected on the magneto itself, the arrangement permitting the interruption of the primary current to occur earlier or later in the revolution.

Armature and Distributor Speed

On a four-cylinder engine, four sparks are required during two revolutions of the crank shaft. The magneto gives two sparks or impulses to one revolution of its armature; therefore it would be geared to drive at the same speed as the crank shaft.

On a six-cylinder engine, six sparks are required during two revolutions of the crank shaft; therefore the armature would revolve one turn, and half of another turn, making three sparks, while the crank shaft made one turn. Therefore on two revolutions of the crank shaft, the armature would make three revolutions, or six sparks.

The distributor, however, on both the four and six-cylinder engine, would revolve at one-half the speed of the crank shaft, as the distributor brush would make one revolution, to two revolutions of the crank shaft.

The distributor rotor on all ignition systems revolves at one-half the speed of the engine crank shaft.

A two-lobe cam is generally used on the interrupter, with lobes or projections 180°, or one-half revolution apart. This causes an interruption of current every half-revolution of the armature.

Speed Relation between Crank Shaft of Engine and Cam Shaft

On a four-cylinder, four-cycle engine, the crank shaft turns two revolutions (or 720°) to complete its four-cycle operation. The cam shaft turns 1 revolution; the magneto armature turns 2 revolutions; the magneto distributor brush, 1 revolution.

Four sparks are necessary during the two revolutions of the crank shaft; therefore as the magneto armature turns two revolutions, the same as the crank shaft, it produces four sparks, or a spark at every one-half revolution.

The distributor brush is geared to turn one-half the speed of the magneto armature; therefore, it will turn one revolution (360°) to two revolutions of the crank shaft. As the four contact segments on the distributor are spaced 90° apart, then one revolution of the distributor brush will make four contacts, producing four sparks 90° apart during one revolution of the distributor brush, or 180° apart relative to the crank shaft, or four sparks to two revolutions of the crank shaft.

A two-point cam is used on the "armature type" magneto contact-breaker, which interrupts the primary circuit twice during each half-revolution of the armature.

Four-cylinder magneto speed: Refer to Fig. 8. Note that **when the piston makes a full stroke,** or when the crank shaft or fly wheel of the engine travels from (A) to (B), one-half revolution, or 180°, the armature also travels 180°. Both travel at the same speed.

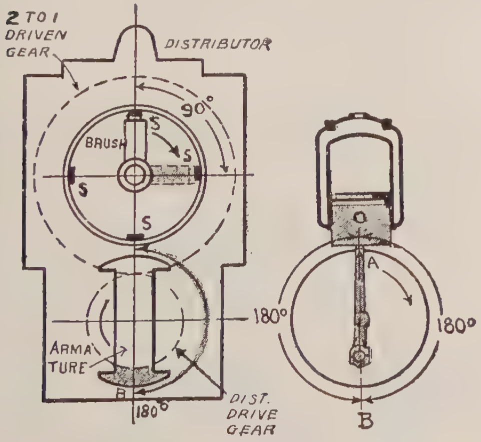


Fig. 8 Fig. 8A

Figs. 8 and 8A. A magneto for a four-cylinder engine.

The four-cylinder engine requires four sparks during two revolutions of the crank. **The armature** gives two sparks or impulses every revolution, therefore, traveling at the same speed as the engine crank, it will give four sparks during two revolutions.

The distributor would be geared for one-half the speed. Every time the crank shaft moved 180°, or one-half revolution, the distributor brush would move 90°, or one-quarter of a revolution.

The distributor always runs at one-half the speed of the crank shaft on all four-cycle engines.

On a six-cylinder, four-cycle engine, the crank shaft turns two revolutions to complete the four-cycle operation, just the same as the four-cylinder engine. The cam shaft also turns the same as the four-cylinder engine, that is, one revolution to two of the crank shaft.

But six sparks are necessary during the two revolutions of the crank shaft, because the crank shaft is divided into three pairs of throws (see page 45), each pair firing 120° apart, or one-third of a circle. It is then necessary to gear the magneto armature so that it will turn three times to the crank shaft's two, or one and one-half times to each revolution of the crank shaft. The armature produces three sparks during one and one-half revolution, or six sparks during three revolutions (see Fig. 9).

The distributor brush must turn one revolution to the crank shaft's two; therefore, if the armature turns three times when the crank shaft turns two times, the distributor is geared from the armature shaft to turn one revolution when the armature turns three revolutions, or one-half revolution when the armature turns one and one-half revolutions.

As the six contact segments on the distributor are set 60° apart, then one revolution of the distributor brush will make six contacts, producing six sparks 60° apart during one revolution of the distributor brush, or 120° apart relative to the crank shaft, or six sparks to two revolutions of the crank shaft.

Six-cylinder magneto speed: Refer to Fig. 9. Note that **when the piston makes a full stroke,** or when the crank shaft or fly wheel travels from (A) to (B), or 180° or one-half of a revolution, the armature would turn three-quarters of a revolution, or 270° (**A** to **B**).

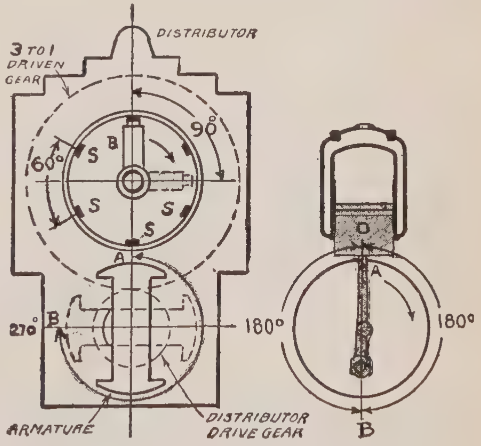


Fig. 9 Fig. 9A

Figs. 9 and 9A. A magneto for a six-cylinder engine.

Therefore if the crank pin made one complete revolution, the armature would make twice three-quarters or one and one-half revolutions. During this one and one-half revolutions it would have made three impulses.

When the engine crank makes another revolution, then the magneto armature would have made one and one-half revolutions more, or three revolutions to two of the crank; therefore, it would make six sparks during the three revolutions of the armature, or two revolutions of the crank shaft. Therefore the armature is geared to run one and one-half times as fast as the crank shaft.

The six-cylinder engine crank must make two revolutions to complete its four-cycle operation; therefore it would require six sparks during its two revolutions (720°).

The distributor, however, having the six plug connections to make during one revolution of its rotating brush (B), would have to be geared so it would make a connection every 60°, or 1/6th of a revolution. For instance: If the crank shaft traveled one-half of a revolution, or 180°, the distributor would travel 90°, or one-quarter revolution.

If the crank shaft traveled one revolution, or 360°, the distributor would travel 180°, or one-half revolution.

If the crank shaft traveled two revolutions, or 720°, the distributor would travel 360°, or one revolution.

If one of the cylinders fired every 120°, or one-third of a revolution (there being six cylinders to fire during two revolutions, or 720° travel of the crank) then we would need six sparks or impulses during 720° travel of the crank.

The distributor being geared one-half the speed of the crank shaft, the segments would be placed 60° apart; therefore, when the crank shaft traveled 120° and required a spark, distributor brush (B) would travel 60°. There being six segments 60° apart this would give six sparks or impulses during two revolutions, or 720° travel of the crank, or one revolution, or 360° travel of the distributor brush (B).

Magneto Distributor Speed

Fig. 10: Illustrates the ratio of gearing between the armature and distributor gear on the four and six-cylinder magneto (four-cycle).

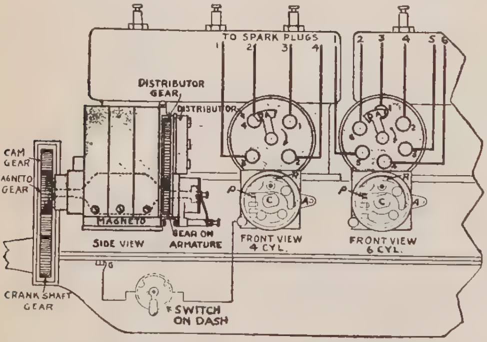


Fig. 10

On a four-cylinder engine, the armature and cam (C) turn at the same speed as the crank shaft, but the distributor rotor (DA) turns once to the crank shaft's twice.

On a six-cylinder engine, the armature and cam (C) turn one and one-half times to the crank shaft's once, or three revolutions to the crank shaft's two, but the distributor rotor (DA) turns once to the crank shaft's twice.

On the distributor of four-cylinder magneto (see illustration, Fig. 8), the contact segments (S) are 90° apart.

On the distributor of six-cylinder magneto (Fig. 9) the segments (S) are 60° apart.

Distributor Connections: Relation of Distributor Connections to Cylinders

The following discussion applies to distributors on coil and battery ignition as well as magneto ignition.

Before the magneto distributor can be connected with the spark plugs, the firing order of the engine should be determined, and in the case of four-cylinder four-cycle engines, the firing order must be either 1, 3, 4, 2, or 1, 2, 4, 3, or if a six-cylinder engine, it would probably be 1, 5, 3, 6, 2, 4, or 1, 4, 2, 6, 3, 5. The firing order may be determined by cranking the engine slowly and observing the order in which the inlet or exhaust valves operate, this order of operation being identical with the firing order.

The method of connecting the spark plugs with distributor on four-cylinder engines is shown below in Figs. 11 to 15, when the engine is firing 1, 3, 4, 2, or 1, 2, 4, 3. Note also the different method of connection when the magneto runs clockwise, and counter-clockwise. Clockwise means in the same direction as the hands of a clock move; counter-clockwise, in the reverse direction.

Note that when the armature revolves in one direction, the distributor revolves in the opposite direction. This is due to the motion of the gears. In the case of a magneto, the direction of rotation clockwise or counter-clockwise, is always stated by viewing the magneto from its shaft or driving end.

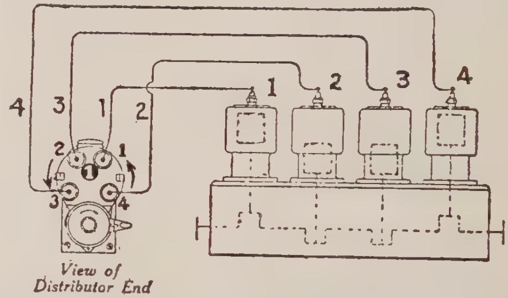


Fig. 11. Magneto armature is running counter-clockwise, if viewed from the drive end (opposite the distributor end). The distributor rotor is revolving as shown by the arrows, and is connected with the cylinders, so that the firing sequence of the cylinders is 1, 3, 4, 2.

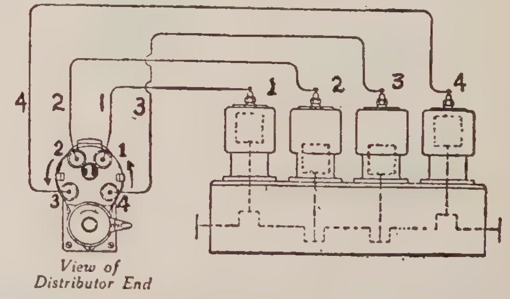


Fig. 12. Magneto armature is running counter-clockwise. The distributor rotor is revolving as shown by the arrows, and is connected with the cylinders, so that the firing sequence of the cylinders is 1, 2, 4, 3.

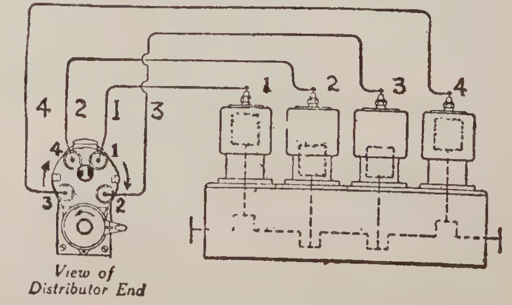


Fig. 13. Magneto armature is now running clockwise, if viewed from the drive end (opposite the distributor end). The distributor rotor is revolving as shown by the arrows, and is connected with cylinders, so that the firing sequence of the cylinders is 1, 3, 4, 2.

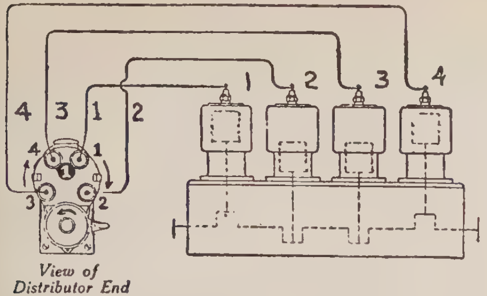


Fig. 14. Magneto armature is now running clockwise. The distributor rotor is revolving as shown by the arrows, and is connected with the cylinders, so that the firing sequence in the cylinders is 1, 2, 4, 3.

Never allow the ignition wires to lie on or near the exhaust pipe, as the insulation will burn off and lay the wire bare, causing a short circuit.

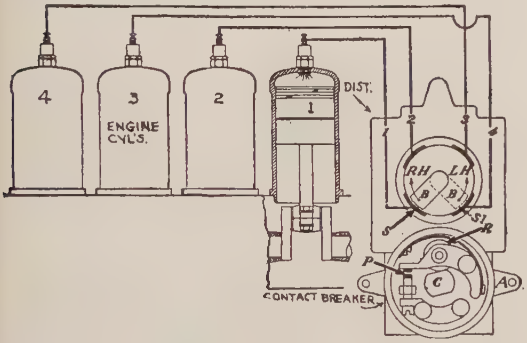


Fig. 15. K.W. high-tension magneto used as an example showing connections of spark plug wires to distributor on a four-cylinder engine, when firing 1, 2, 4, 3, or 1, 3, 4, 2, and when distributor brush rotates right-hand or left-hand. **RH** means arm **(B)** turns to the right hand, when cam (C) turns to the left; **LH** means arm **(B)** turns to the left hand, when cam (C) turns to the right; **P,** platinum contact points on interrupter; **R,** roller raised by cam (C) which causes separation of (P); **A,** interrupter or contact-breaker housing.

How to Connect Spark-Plug Cables with Distributor

It will first be necessary to determine the firing order of the cylinders of the engine.

If the firing order on a four-cylinder engine, for example, is 1, 2, 4, 3, then the direction of rotation of the rotor of the distributor is the next point to determine. See Fig. 15.

If cam (C) turns to the left when viewed from the front, set the distributor rotor (B) on segment (S) and connect cylinder No. 1 with (S). The next segment of the distributor in the direction of rotation (RH) would be connected with the second cylinder, the next with the fourth cylinder, and the next with the third cylinder.

If the cam turns to the right, when viewed from the front, place (B) on segment (S1) and connect cylinder No. 1 with (S1), then connect the segment or cable coming next in the direction of rotation with the second cylinder, the next with the fourth cylinder, the next with the third cylinder.

If the engine fires 1, 3, 4, 2, connect in the same manner so that the rotation of brush (B) will cause the engine to fire 1, 3, 4, 2, in order as they come.

If cam (C) is turned to the left, by shifting the interrupter housing down, by movement of lever (A), the spark would occur earlier, or "advanced." If (A) was shifted up, with cam (C) rotating to the left, the spark would occur later, or retarded.

Fig. 15 is that of the K. W. high-tension inductor-type magneto. It will be observed on page 246 that this magneto differs from the armature type and other magnetos, in that it gives four sparks or impulses per revolution of armature instead of two. By using a two-point lobe cam (C) and revolving armature and cam (C) at crank-shaft speed, there are but two interruptions of the primary circuit per revolution of armature and crank shaft, or four interruptions or sparks for two revolutions.

The distributor rotor, like all other ignition distributors, revolves one revolution to the crank shaft's two.

MAGNETO INTERRUPTERS[1]

The purpose of the interrupter, also termed a contact-breaker, and breaker-box, is to open the primary circuit when the magneto armature is at maximum position, as explained on pages 253, 289.

The interrupter housing can be shifted by movement of lever (L), so that the interruption will occur advanced or retarded; as shown in Fig. 1.

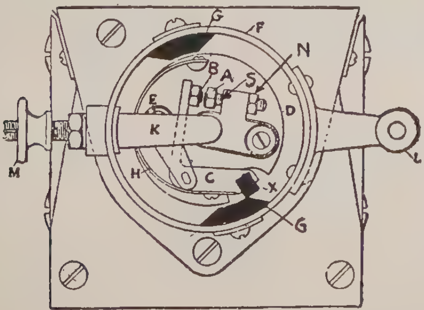


Fig. 1. Interrupter or contact-breaker as used on the Bosch "DU4" high-tension magneto.

On the "armature-type" magneto, the armature is in a maximum position twice during one revolution; therefore, if the interruption occurs twice during a revolution of the armature, two sparks will occur during one revolution. See page 253.

In order that the interrupter or contact-breaker points (A) and (B) (Fig. 1) may be separated twice during one revolution, two fiber cams (G), placed 180° apart, cause the points to separate twice during one revolution.

Note the arrangement in Fig. 1. Here we have two cam blocks (G) stationary to the inside of the interrupter housing (F) placed 180° apart. As the disk (D) revolves, the parts **C, H, E, B, A,** and **X** revolve with it.

At the extreme end of (C) is a projection (X). When this fiber projection (X) strikes cam-block (G), the platinum point contacts (B and A) are opened. (H) is a spring provided for holding the points together at other times. (K) is a flat metal spring which connects with terminal (M) and is used to carry current to grounding switch (see Fig. 1, page 256).

Interrupter Cams

The interrupter is constructed in various forms. The principle, however, is about the same.

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[1] The S.A.E. designates the interrupter as "breaker box." The term "interrupter" is used in this book, owing to the fact that this term is the one more commonly adopted. In some instances the change will be made.

The interrupter on the four-cylinder, as well as on the six-cylinder engine magneto, must interrupt the current twice during one revolution. Therefore a cam with two projections placed 180° apart, as shown in Fig. 2, would serve the same purpose as the cam blocks (G) in Fig. 1.

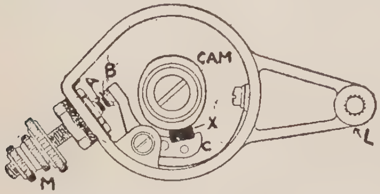

Fig. 2. Interrupter or contact-breaker used on the Remy "RL" magneto.

In Fig. 2, the cam revolves on the end of the armature shaft, thus at the same speed as the armature.

The production of the spark at a definite time is therefore controlled by the cam.

On a single-cylinder engine, requiring but one spark during two revolutions of the crank shaft, a single cam (Fig. 3) is used which is attached to the end of the armature, which revolves one-half the speed of the crank shaft.

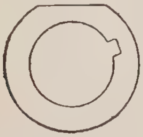

Fig. 3. Single-spark cam.

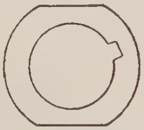

Fig. 3A. Two-spark cam.

The usual practice, therefore, is to pass over one of the two "maximum" positions of the armature, simply by omitting one of the two cams, thus leaving the primary winding short-circuited. Therefore as the magneto is driven at cam-shaft speed in this instance, a single spark is obtained.

On a four-cylinder engine, the cam would open the interrupter twice during one revolution. Therefore it would run at the same speed as the engine, causing four openings during two revolutions, and would have two high points or lobes, as in Fig. 3A.

Speed Relation of Interrupter Cam and Magneto Armature to Engine Crank-shaft Speed[1]

The following refers to a four-cycle engine where a two-lobe cam is used on an armature-type magneto.

Two and four-cylinder engines: half the speed of the crank shaft.

Three-cylinder engines: at three-quarter speed of the crank shaft.

Six-cylinder engines: at one and one-half speed of the crank shaft.

Eight-cylinder engines: twice the speed of the crank shaft.

The interrupter gap clearance mentioned above refers to the opening of the interrupter points when the cam is in such a position as to open the points to their fullest extent.

If the gap clearance of the interrupter points is not correct, the adjustment can be made by revolving the armature by hand until the arm (X) (Fig. 1, for example), is on the high point of cam (G), which causes the points (A and B) to separate fully. Then loosen lock nut (N) and adjust screw (S) until the proper clearance is obtained. Be sure and tighten the lock nut.

Widening the interrupter air-gap causes the interrupter points to open earlier, because, when lowering the screw (S, Fig. 1), the point (X) on arm (C) will begin to rise earlier, causing a spark to occur when the magneto armature is at a more favorable position—giving a more intense spark. Closing of the gap, by turning screw (S) up, is just the reverse of the foregoing. Usually, a small flat wrench is provided with the magneto for adjusting.

The proper opening as well as the quick opening of the interrupter points is a very important factor. See pages 257, 258, 252, 190, and read carefully.

If the engine misses with the spark retarded (and misses more at low than at high speed), the contact screw should be screwed out a notch at a time until the missing is overcome.

If the engine misses with the spark advanced (and more at high speed than at low), the contact screw should be screwed in a notch at a time until the missing is overcome.

As previously stated, there are many different methods adopted by the various manufacturers for opening the interrupter points.

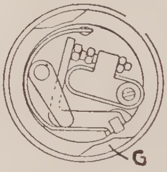

Fig. 4

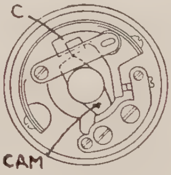

Fig. 4A

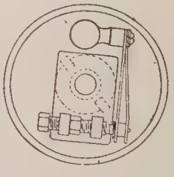

Fig. 4B

The Bosch is shown in Fig. 1 and in Fig. 4. In this the moving contact (X) is carried on a bell crank which rotates with the armature shaft, the cams (G) being inside the breaker box.

For **the Dixie**, see Fig. 4A and page 274. The cam revolves with the armature shaft operating a bell crank (C), which remains stationary so that adjustments can be made while running.

For **the Eisemann**, see Fig. 4B and page 269. This consists of two spring members separated by a fiber (S) piece; one of the springs carries the moving contact point. The cam is stationary.

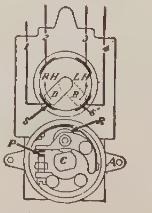

Fig. 4C

For **the K. W.**, see Fig. 4C. The cam (C) revolves against roller (R), thus opening contact points (P) when the highest point of the cam is against roller (R).

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[1] Two-cycle engines: one and two-cylinder engines, same speed as crank shaft; three-cylinder engine, one and one-half the speed of crank shaft; four-cylinder engine, twice the speed of crank shaft; six-cylinder engine, three times the speed of crank shaft.

Interrupter Gap Clearance

There is one adjustment on the magneto which needs watching: that of the platinum point breaker contact screw. The interrupter air-gap clearance adjustment should be made so that the maximum break of the platinum points is about .015″ to .020″, which varies slightly on different magnetos as follows:

Bosch, approximately .016″[1]
Berling, approximately .015″
Dixie, approximately .020″
Eisemann as shown on page 270, .012″
Other Eisemann magnetos .016″
Remy low-tension .020″
Remy high-tension .020 to .025″.
K.W. high-tension 1/64″

The interrupter adjusting screw is very delicate and needs to be adjusted carefully. If the platinum points are "pitted," then they should be filed down flat with a very fine jeweler's file. (See pages 221, 225). **Keep oil away** from the points.

Common contact-breaker troubles are: insufficient lubrication causing wear; loose breaker bar; fiber bumper worn.

Spark Plugs for Magneto Ignition

The spark plugs used should be those recommended by the manufacturer because, in some instances, the points of the plugs are of a higher resistance metal. The average gap for magneto ignition is .020″, or about 1/64″, and on battery and coil ignition, .025″ to .030″.

The spark-plug gap recommended by some of the magneto manufacturers is as follows:

Berling	.030″
Bosch	.016″ to .020″ ("NU4" is .016″)
Dixie,	.025″[1]
Eisemann,	.025″
K.W	1/64″
Remy (low t.)	.025″
Remy (high t.)	.030″ or 1/32″

SETTING TIME OF SPARK OF MAGNETO

There are three general positions of the piston for setting the time for the spark with the magneto:

1. Top of compression stroke.
2. After top of compression stroke.
3. Before top of compression stroke.

A variable spark is where the breaker can be shifted to advance or retard the time of spark.

A fixed spark is where the breaker (or interrupter) is set or fixed at one position and cannot be varied (see page 289).

In setting a magneto of the fixed-spark type, the instructions for moving the breaker housing to the extreme advance or retard position are to be disregarded. The magneto should be set so that the spark occurs at the most advantageous point in the cylinder. This should be decided upon by the engine manufacturer, but where such information is not available, the spark should occur at top-center.

In setting a magneto of the variable-spark type, one of three methods can be used:

(1) By setting the piston on top of the compression stroke and setting the magneto breaker retarded. In this instance the most advantageous position of the piston for the spark to occur, when the breaker is fully advanced, is determined by how much advance the magneto is capable of giving. A high-speed engine requires more advance than a slow-speed engine. Magnetos vary from 22° to 35° or more. However, this is the average and general setting. This is termed "setting piston on top and ignition retarded."

(2) Sometimes, on truck and tractor engines and others, the spark is made to occur when the piston is slightly down after the compression stroke, and the breaker is retarded. This would not permit advancing the spark so far ahead of the stroke—unless a magneto with a greater range was used, but this is done on slow-speed engines and where very slow running or idling is desired.

(3) Setting the piston before the top of the compression stroke and advancing the breaker would be termed "setting ignition advanced." The point to determine here, as to where to set the piston, depends entirely upon where you wish the spark to occur when the breaker is fully retarded. For instance, suppose the magneto range of advance was 35° and you wished the spark to occur on top of compression stroke: simply set piston 35° before top, with the magneto breaker full advanced. This would mean the same thing as setting the piston on top with the magneto retarded.

Setting the High-Tension Magneto "Retarded on Top"

The average plan for setting a magneto: Where the magneto has been removed from the engine and its connections were not previously marked, it can be retimed as follows:

1. Place No. 1 piston on top of compression stroke. To find compression stroke, see pages 307, 70.
2. Uncouple magneto from its drive shaft. If the magneto cannot be uncoupled, then time from magneto gear and gear driving it, by taking them out of mesh.
3. Retard the breaker box (also called interrupter) (**F**) (Fig. 5), by turning it in the direction of rotation of the armature shaft, as far as it will go.
4. Turn the armature in the direction of rotation until the distributor arm (**DA**) is on segment (**S**) of No. 1 spark-plug cable connection; then turn the armature one way or the other slightly, until the interrupter arm (**A**) is just starting to separate the platinum point connection (**P**) with (**K**), which of course is caused by cam action, as shown. In other words, just when the points start to separate is the time to set the magneto.
5. Couple the magneto shaft, or mesh the gears driving the magneto, at this point, being careful not to move either the armature or piston.
6. Now see that the wire cables from the distributor are properly connected, as explained on page 295. In this instance, by looking at the distributor connections and noting direction in which rotor (**DA**) turns, the firing order would be 1, 3, 4, 2.

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[1] See Index for "Conversion of thousandths of an inch in decimals to fractions of an inch."

[1] .025″ on four and six-cylinder engines, and .020″ on eight-cylinder engines.

The foregoing setting is for retarded position of interrupter and piston on top. This setting would allow the spark to occur considerably before the piston reached top of stroke when the interrupter was advanced, which is usually the case with high-speed engines, and the average and usual setting.

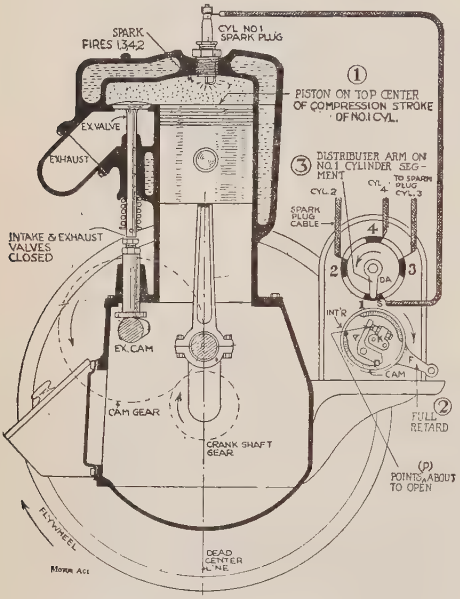

Fig. 5. Diagram showing how a high-tension magneto is usually timed; interrupter housing (F) is retarded and the piston is placed on top center of the compression stroke.

No hard-and-fast rule can be given in the absence of specific instructions of the manufacturer, as to the best piston positions corresponding to full advance and retardation; but, in general, a trial setting on the average plan (as in Fig. 5) might be tried, in which the gear wheels are meshed so that, with the contact-breaker fully retarded, the piston is on top of the compression stroke.

If it is found that the contact-breaker cannot be properly retarded at slow speeds, without the engine tending to knock, another setting must be made, and the piston moved farther on the firing stroke.

After a few trials and after carefully noting the pull of the engine, the best setting for the particular conditions will be attained.

The "breaking" distance between the platinum points should be .015″ to .020″. The amount of range provided for advancing and retarding is greater on some magnetos than on others; an average range is from 22° to 35°.

Setting Magneto "Retarded—After Top"

If a manufacturer's instruction said, "Place piston, say, ⅛″ down after center of compression stroke with breaker box retarded," then this would not permit advancing the spark so far ahead of the stroke. In some instances, this is done on slow-speed engines and where very slow running or idling is desired, as on truck and tractor engines.

Note. The armature turns in the opposite direction to the distributor. Therefore always note the direction in which the distributor turns before connecting cables to plugs. To tell how an engine fires, see pages 79, 78.

The breaker box (F) is stationary. The arms (**A**) and (**K**) revolve with the armature (Fig. 5).

Usually when viewing the magneto from the front of the engine, the magneto would be facing in the opposite direction to that shown in Fig. 5, i.e., towards the flywheel, as the rear end of a magneto is usually driven from the front of the engine.

When the breaker points are just breaking, the armature cheek, breaking from the pole, is in correct position, as it was set at the factory; this is true, likewise, of the speed of the distributor to the armature.

How the Instructions for Setting a Magneto Vary

(1) **Set by marks on flywheel.** Usually designated on the flywheel by a mark (C) or (F). This mark is placed in line with a punch mark on the cylinder which indicates that piston No. 1 is on compression stroke and the magneto is to be set advanced or retarded as instructions may be given, at this point.

(2) **Set by inches.** Should the time for the spark to occur be given in inches, for example, "time for spark to occur is full advanced position measured 3½″ on flywheel, before upper dead center," as is the case in the instructions given to set the valves on the Simplex engine, which is 4⅜″ bore, 6¼″ stroke, and 18¾″ flywheel:

To do this, set the spark lever or breaker on the magneto at "full advance" position. Then turn the flywheel until the top center of compression stroke is reached. At this point a center mark on the flywheel is in line with a center mark on the inspection hole. To have the spark occur 3½″, as measured on the flywheel, would mean to turn the flywheel back or before top of compression stroke until this center line was 3½″ away from the center line on the inspection hole. This would be the position for the spark to occur in.

The armature of the magneto would then be uncoupled, the breaker advanced, and the armature turned slightly until points were just starting to separate. The coupling would then be tightened. This setting would cause the spark to occur 21° before top of compression stroke, with breaker housing advanced. (The value of degrees relative to that of inches was found by referring to the table on page 299.)

(3) **By measurement of armature from pole piece,** as in Figs. 7 and 7A (page 288). Note (e), which is the distance the armature is to be set with piston on top and breaker points separating (see "Synchronizing distributor with armature").

(4) **By sight hole,** as in Fig. 6 (page 299).

(5) **By degrees:** Should the firing position be given in degrees, the movement of the piston, measured in inches corresponding with any given number of degrees of the crank shaft (where the relation of the crank shaft throw to the length of the connecting rod is as 1:4.5),[1] may be determined by reference to diagram, page 299.

Example: Suppose you were instructed to set the spark 34° before top of compression stroke—"advanced," on an engine with 5½″ stroke.

(a) Turn to table on page 299; find 5½″ at bottom. Next find 34° to right. Follow instructions for finding result given in chart. The distance in inches at which to place the piston would be midway between ¼″ and ⅜″ from top.

(b) With this information you would then proceed to place the piston, say, within 5/16″ of top of compression stroke.

(c) The interrupter housing would then be full advanced and the armature turned in direction of rotation until the cam just started to separate the interrupter points.

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[1] See footnote, page 299.

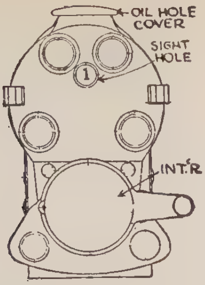

Fig. 6. Magneto setting by sight hole.

In some magnetos, "ZR" Bosch, for instance, the magneto can be set by observing the sight hole.

The piston is placed to firing position, for full advance position. This point is determined by the engine manufacturer.

The armature is then rotated until the figure 1 can be seen in the window in the face of the distributor plate, which indicates that the distributor rotor is on No. 1 segment to fire No. 1 spark plug. The cover of the oil well is then raised, and the armature turned a few degrees in one direction or the other until the red mark on one of the distributor gear teeth is brought into register with red marks on the side of the window. The magneto is then turned for full advance position, and the gear or coupling is secured to the armature shaft.

Setting Magneto by Degrees

A diagram for determining the advance in "inches," or a fraction thereof, to set the piston when the stroke is known and when the time to set the spark is expressed in "degrees," is shown in Fig. 7.

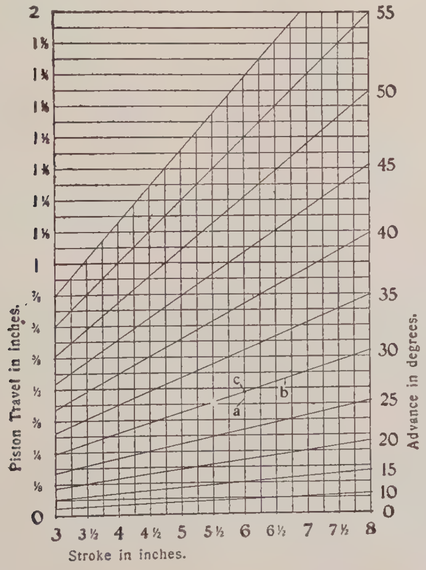

Fig. 7

The relation of the piston travel to the rotation of the crank shaft depends on the stroke and the length of the connecting rod.

The piston travel of an engine[1] is easily determined, and the determining of the rotation of the crank shaft in degrees, corresponding to any desired piston travel, may be ascertained from the accompanying diagram. In this diagram the relation between the crank and the connecting-rod length is as 1:4.5 (see footnote).

In the diagram the vertical lines numbered at the bottom give the stroke of the engine in inches, the rotation of the crank shaft in degrees being indicated by the slanting lines and the figures at the right.

The figures on the left and the horizontal lines indicate the piston travel in inches.

As an example in the use of the diagram: It may be desired to find the piston travel for an advance of 30° on a motor of 6″ stroke. The vertical line for the desired stroke may be identified by the figures at the bottom of the diagram; and this vertical line may be followed upward until it cuts the diagonal line indicating the desired number of degrees, which is 30° in the present case.

The horizontal line nearest this point should be followed to the left, until it meets the diagonal line, and this should be followed to the left-hand side. In the present instance it will be seen to indicate about ¼″. This gives the advance in inches, corresponding to 30°.

Timing the Bosch Dual Magneto

This system is explained on pages 267 to 269. Note that there is a **battery interrupter** and a **magneto interrupter** (see Fig. 11, page 267). Although both are in the same housing on the front of the magneto, but one setting—that of setting the magneto interrupter—is necessary.

The battery interrupter is so arranged that it will then interrupt or break its circuit approximately 10° later than the magneto interrupter; this feature gives the full timing range of the magneto. For instance, if the timing lever is fully retarded and the magneto interrupter is set to break when the piston is on top of compression stroke, the battery interrupter, with the switch in battery position, would break slightly after top, or 10° later. Therefore set the magneto interrupter just the same as you would set the Bosch independent type of magneto.

Timing the Bosch Independent Type

Place the piston on top of the compression stroke with the interrupter retarded as explained on page 297.

The magneto points on the dual system should be adjusted to open about 0.35 millimeters, or slightly under 1/64″, and the **interrupter points** full 1/64″. **The spark-plug points** should have a gap of about 1/64″ to .025″.

Timing the Remy Magneto, Model "RL"

Model "RL" is to be timed to the engine by the break of the contact points. When the piston is on exact dead firing center, the cam house must be in full retard position, and the platinum points must just be separating.

The high-tension cable from this cylinder, which is in exact dead firing center, should then be connected to the distributor terminal, to which the distributor segment, which is opposite, corresponds.

The remaining distributor terminals should then be connected up in the proper firing order of the engine.

The position of the "inductor" or "rotor" type of armature is just the same as on a "shuttle" type armature; the interrupter should just be breaking when the "rotor" is just leaving the vertical position.

Sectional cuts explaining the Remy magneto, with its inductor type of armature, are shown on page 247. Set the breaker points at .025″ gap.

Timing the Eisemann Magneto, Dual System

To set this type, turn the engine by hand until the piston of No. 1 cylinder is on the dead center (compression stroke). Place the timing lever of the magneto to fully retarded position, then turn the armature of the magneto until No. 1 appears at the glass dial of the distributor plate. Make sure that the platinum contacts of the magneto are just opening. Fix the driving medium in this position.

In order to insure absolute safety when cranking on the battery, the contact-breaker of the battery system is arranged so that it will open 10° later than the magneto contact-breaker.

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[1] 1:4.5 is a ratio equation and means, as 1 is to 4 5/10, or, in other words, the connecting rod is 4½ times longer than the crank throw.

Timing the Splitdorf Low-Tension Magneto

Set the piston on top of compression stroke with the interrupter retarded.

Now revolve the armature shaft in its direction of rotation until the oval breaker cam comes in contact with the breaker bar and just begins to separate the platinum contacts. Set the coupling or gear at this point.

Berling High-Tension Magneto

The model "E-41" four-cylinder engine magneto is shown in Fig. 8.

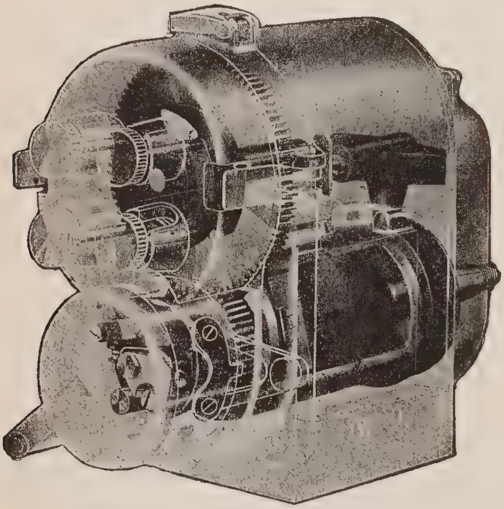

Fig. 8. A phantom view of the "E-41" Berling high-tension magneto. A "gap-distributor" is used. Usual setting; retarded, piston on top. Interrupter adjustment, .015" to .019"; plug .031". (Ericsson Mfg. Co., Buffalo, N.Y.)

Simms Magneto

A special feature of the Simms magneto is the design of the pole pieces which have extensions on the edges following the direction of rotation of the armature. These extended edges keep the edges of the armature shuttle within influence of the pole in all positions from full advance to full retard. That is to say, that at the moment of breaking the current the edge of the shuttle is never widely separated from the edge of the pole piece. Therefore the current is generated at low or high speeds without much loss of intensity.

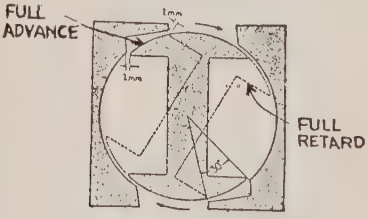

Fig. 9. Special pole piece used on Simms magneto to give equal spark intensity at all speeds.

Checking Ignition Timing of Magneto

When the gears which drive magneto or timer are disengaged, be sure they are marked as indicated in Figs. 10 and 11. When connecting high-tension wires, first learn the firing order, and then connect as explained on page 295. Remember, the distributor on a magneto revolves in a direction opposite to that of the armature. For instance, see Fig. 10: crank gear (C) revolves to the left (view supposed to be from rear of engine); idle gear to right; magneto gear to left, and distributor to right.

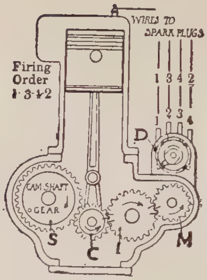

Fig. 10. Rear view of engine.

In Fig. 10 the rotor of distributor (D) turns in a clockwise (right-hand) direction, so that it next will make contact with the stationary segment No. 2. As the engine fires 1, 3, 4, 2, the cable No. 2 should lead to No. 3 cylinder, No. 3 to No. 4 cylinder and cable No. 4 to No. 2 cylinder.

Re-Meshing Timing Gears

To assemble gears if removed (Fig. 11): Turn flywheel until Nos. 1 and 4 pistons are at top-dead-center, with No. 1 ready to fire (top of compression stroke). Key the crank-shaft gear (C) and cam-shaft gear (S) to shafts so that Fig. 1 on each will mesh. Then replace idler gear (I) so that Fig. 2 on it will mesh with Fig. 2 on the crank-shaft gear. Then mesh Fig. 3 on the magneto gear (M), with Fig. 3 on the idler gear.

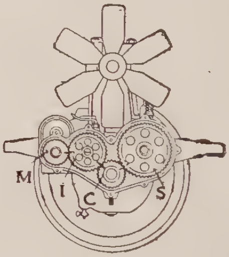

Fig. 11. Showing front view of engine.

Synchronizing Distributor with Armature

Synchronizing the interrupter points, cam, and distributor: If the magneto has been entirely disassembled, proceed as follows:

Bosch "DU4" as an example: (1) place the distributor brush on the segment—just starting; (2) place armature in direction of rotation 3/32" from pole shoe—just breaking; (3) breaker to start opening must be advanced.

Bosch "DU4," model 5: (1) place the brush in the center of the segment; (2) armature 1/16" from pole shoe; (3) breaker points will start to open at full retard.

Bosch dual system: (1) place the brush 1/16" on the segment; (2) armature breaks from pole 1/64"; (3) breaker points will separate at full advanced position.

K. W. High-Tension Magneto Circuit

This is the inductor type of magneto explained on page 246.

The rotor, with paddles (A) (B), revolves between the poles of the magnets (not shown here), and the magnetic lines-of-force pass through the rotor in the direction shown by the small arrows, then in the reverse direction, and so on.

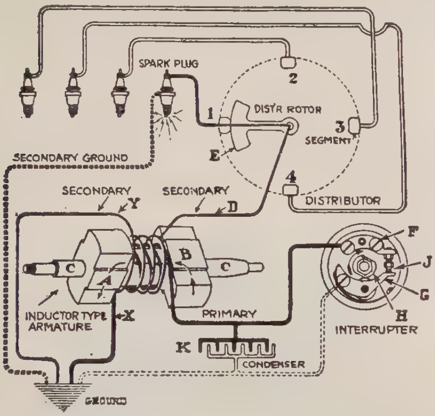

Fig. 12. Diagram of operation of the K-W magneto.

This reversing and moving of the magnetic lines causes current to be generated in the primary coil or winding (X). The current passes through the circuit-breaker arms (F) and (G) and through the metal of the engine (ground) back to the coil.

When this current in the coil (X) gets to the proper point, the cam on the end of the shaft (H) presses down the roller in the little arm (G) and pulls apart the breaker points (J), thus breaking the current in the primary circuit.

The stoppage of current in the primary coil (X) instantly causes a high-tension current to be induced in the secondary or outside coil (Y).

This high-tension current is carried up and delivered to the distributing arm (E).

This distributor arm (E) is for the purpose of distributing high tension to the different terminals 1, 2, 3, 4, which are in turn connected to the spark plugs in the cylinders in the order in which they fire. This arm (E) is so timed that it reaches one of these terminals just as the breaker points open in a primary circuit, that is, just as the high-tension current is being generated.

This distributor arm is shown delivering current through terminal No. 1 to spark plug No. 1, whence the current jumps across the gap to ground (that is through the metal of the engine), back to the end of the secondary coil.

SETTING TIME OF SPARK—MISCELLANEOUS IGNITION SYSTEMS

The timing of ignition is merely a procedure where the lever controlling the advance and retard of the spark is usually set retarded, advanced, or midway between full retard and full advance when the piston is either on top, before top, or after top of compression stroke.

In order to understand clearly the meaning of "advance and retard," see Figs. 1 and 2.

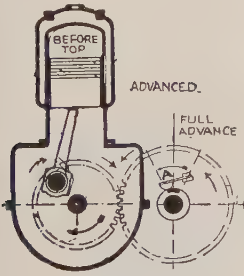

Fig. 1

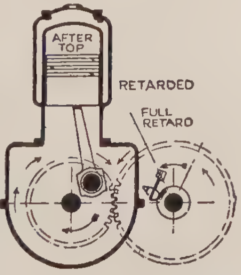

Fig. 2

The illustrations are exaggerated as to the actual distance at which the piston is placed before or after top of dead center. An **ignition commutator** is illustrated to explain the principle, but the principle applies to a magneto breaker-box, battery, and to a coil system of interrupter, or to any type of contact-breaker for an ignition system.

Note in Fig. 1 that the commutator arm (A) is at **full advanced position.** Thus the time of the spark, or when contact is made in this instance (contact would be broken if an interrupter was used instead of a commutator), would occur a considerable time before the piston was at top of its compression stroke. Thus the spark would occur at full advanced position.

Note in Fig. 2 that the commutator arm (A) is moved in the direction of rotation to a **full retarded position.** Therefore the contact would be made later than in Fig. 1, or retarded, or after the piston was over the top dead center of compression stroke and part of the way down on power stroke.

On a magneto or coil-and-battery system of ignition, the interrupter housing is advanced and retarded in the same manner, except that the points of the interrupter are made to open at a certain time instead of contact being made, as with a commutator.

Thus **the object of setting the ignition** is to set the contact-breaker so that the spark occurs either in an advanced position when (or before) the piston is on top of the compression stroke, or in a retarded position when piston is past the top of dead center of the compression stroke.

For instance, if the contact-breaker was set at full **retard position** when the piston was on top of its compression stroke, this would allow for a wide range of advance before top.

On many engines and ignition systems this practice is followed out, but on others, the contact-breaker housing is set at a **full advanced position** at a certain point before the piston is at the top of its compression stroke, as indicated by a mark on the fly wheel. For example, let us take the timing of ignition on the Studebaker "Light-six," using either a Wagner or Remy coil and battery ignition system. The instructions follow.

Timing the Spark on Studebaker "Light-Six" Coil and Battery Ignition System

This car uses an automatic and manual advance of the spark, and either the Wagner or Remy coil and battery ignition system is used.

Unless the engine has been completely overhauled, it will not ordinarily be necessary to readjust the timing of the spark. But if it has been necessary in making repairs to disturb the relation between the cam-shaft sprocket and the distributor shaft, the following instructions should be carefully followed.

Remove No. 1 spark plug and crank the engine by hand until the piston in No. 1 cylinder has begun its compression stroke. The beginning of the compression stroke may be detected by holding the thumb over the spark-plug hole until compression is felt.

The upper-dead-center position is indicated when mark "UP-D-C-1" on the fly wheel is opposite the pointed projection on the rear of the Bendix starter housing. Before this mark "UP-D-C-1" comes to the pointer you will notice a line marked "AD-SP" which indicates the manual advance spark position. When this line reaches the pointer, stop turning the engine and proceed as follows:

Place the spark lever at **full advance position.** The timer control lever should then be in its extreme forward position. Remove the distributor cover without disconnecting wires and lift off the revolving segment.

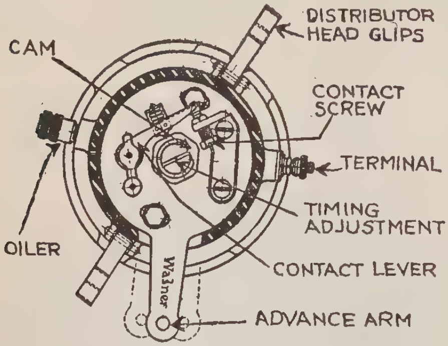

Fig. 3. Top view of the Wagner interrupter (Studebaker).

On cars with Wagner equipment, loosen the screw which holds the cam on the taper shaft. Pry the cam from its seat on the shaft, by using a screwdriver (Fig. 3). Turn the cam in a counter-clockwise direction, or to the left, until it reaches a position such that, when all parts are assembled, the edge of the revolving segment comes directly under the No. 1 distributor terminal and the breaker points are just in the act of breaking. Tighten the lock screw to hold the cam in this position and replace the revolving segment and distributor cover.

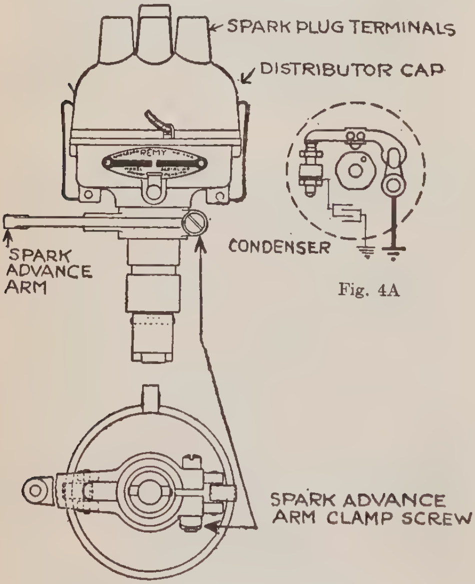

Fig. 4A

Fig. 4. Side view of the Remy interrupter and distributor.

Fig. 4A. Top view of Remy interrupter (contact-breaker) as used on the Studebaker.

To time spark on cars with Remy equipment get mark "AD-SP" opposite the pointer when No. 1 piston is coming up on compression and see that the distributor is assembled to drive so that the distributor segment will point directly to the rear. Then loosen clamp screw (Fig. 4) and make an accurate adjustment by rotating the distributor housing about the cam, with the advance arm at extreme forward position so that the points are just in the act of breaking the segment directly under No. 1 distributor terminal. Tighten the clamp screw to hold the housing in this position. Replace the revolving segment and distributor cover.

To test accuracy of adjustment, make sure that electrical connections from battery to coil and distributor are complete. Disconnect from the coil the high-tension cable leading to the center terminal of the distributor. Place the point of a wooden-handled screwdriver on a convenient part of the engine and have it held so that the metal part of the screwdriver is about ⅛" from the high-tension terminal of the coil. Fully advance the spark lever on the steering wheel and turn on the ignition switch. Crank the engine over slowly by hand until the spark jumps from the coil terminal to the screwdriver. The mark "AD-SP" should now be directly opposite the pointer.

The adjustment of the spark-control rod will govern the retarded adjustment. This should be adjusted so that it will move the distributor arm against the stop for advanced and retarded positions.

Timing the Spark on Mitchell "F"

The ignition system used on this six-cylinder model of car is the Remy. The instructions are as follows:

Ignition timing: With the circuit-breaker in full retard position, the circuit-breaker contact points should just start to separate or open when the engine is turned past dead center.

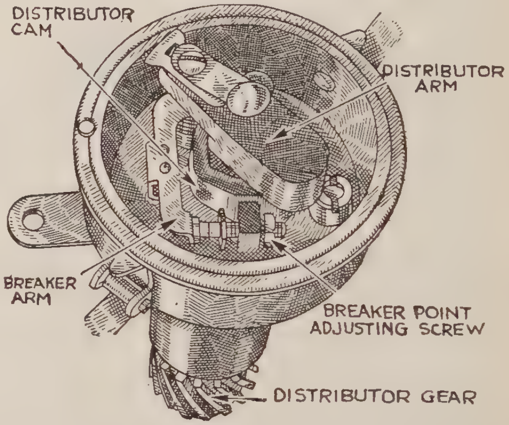

Fig. 5. Top view of Remy interrupter (contact-breaker) as used on the Mitchell "F".

If it should ever be necessary to retime the ignition distributor, proceed as follows: Open all compression cocks and turn the engine by hand till the intake valve of cylinder No. 1 (next to the radiator) opens and closes, and till the mark "D.C. 1-6" on the fly wheel is in top center position. When this has been done the piston of cylinder No. 1 is just starting down on its working stroke.

Next place the spark lever in **full retard position.** Remove the distributor segment by pulling it up off from the shaft, disclosing the nut that locks the cam. Unscrew and remove this nut. Loosen the cam from its snug fit on the taper of the shaft by prying up, rapping it at the same time. Use care not to mar the smooth surface of the cam.

Reset the cam by moving it in the direction in which it rotates until the circuit-breaker contact points just start to separate, and the cam is in such a position that when the segment and cap are replaced, the metal blade of the segment will be nearest the extension in the distributor cap connected to the spark plug in No. 1 cylinder. Rap the cam down in this position, and tighten the nut. The next distributor-cap terminal in a counter-clockwise direction from the terminal connected to cylinder No. 1 is to be connected to the spark plug of cylinder No. 5, the next to No. 3, the next to No. 6, the next to No. 2, and the next and last to No. 4.

Spark plugs: Failure of spark is sometimes due to the gap in the spark plug becoming clogged with carbon or oil. This gap should measure .022".

Too large a gap may cause missing on a hard pull or when accelerating at very low speeds. With **too small a gap,** the engine may operate unevenly at idling speeds and miss at higher speeds. With spark plugs having more than one gap, the shortest gap should be as stated.

Timing the Spark on Essex Model "A"

Timing the ignition: The ignition system is carefully timed when the car leaves the factory, and, under ordinary conditions, will not require any attention; but should it become necessary to re-time the ignition for any reason, it can be done as follows:

1. Place the spark lever on the steering-wheel sector in the **fully advanced position.**
2. Turn the engine with a hand crank until No. 1 piston starts to come up on the compression stroke. The marking of the fly wheel should then be observed through the hole in the fly-wheel housing on the right-hand side of the engine until the marking "D.C. 1-4" appears at the pointer on the fly-wheel housing.
3. Loosen the timing adjustment screw in the center of the distributor shaft and turn the breaker cam so that the rotor button will be in a position under No. 1 high-tension terminal, or that which leads to No. 1 cylinder, when the distributor

head is down in place. Locate the breaker cam carefully in this position so that when the slack in the distributor driving gears is rocked forward, the contacts will be opened by the breaker cam, and when the slack in the gears is rocked backwards, the contacts will just close.

4. Tighten the adjustment screw, securing and replacing the rotor and distributor head.

Adjusting spark plugs: The gauge on the distributor wrench marked "Spark Plug" should be used for adjusting the spark plugs. This gauge is approximately thirty thousandths of an inch thick (.030"). On spark plugs having more than one gap, all but one gap should be made very wide, and the closest gap should be adjusted to this gauge. An exceptionally wide **adjustment** may cause missing at the higher speeds. **Too close an adjustment** will cause the ignition to be very poor at very low speeds and when idling.

See Index for Delco ignition and Essex wiring diagrams.

On the Cole, "870 Series" car, using Delco ignition, the spark lever is fully advanced, and the piston is placed within 1½" of the top of the compression stroke.

Timing the Spark on the Maxwell "25"

This car uses type "CC" Atwater-Kent ignition system.

Procedure: Turn the crank shaft with a hand crank until No. 1 piston is 1/32" past top dead center, or 1¼" past on the fly wheel, on compression or firing stroke. Then turn the vertical shaft until the distributor arm is under the terminal on the cover leading to No. 1 cylinder. Assemble the unit to the engine.

Loosen the screw which locks the advance and retard on the timer to the timer head. Turn the timer head in whichever direction is necessary so that the points just start to open when the cam is revolved, in clockwise direction. Holding the timer head in this position, push advance and retard lever in the retard position, and tighten the lock screw. Replace the distributor cover and connect the terminals in proper firing order of the engine, viz., from left to right, or clockwise, No. 1, 3, 4, 2.

The breaker points should be set to open between .006" and .008", or about twice the thickness of this paper.

Timing the Spark on the Chevrolet "490"

Remove the distributor cover and the distributor arm, and with a special wrench supplied with the car, remove the lock nut holding the igniter cam to the shaft (Fig. 6); slip the hooked end of the wrench under the cam (Fig. 7) and pry it loose from the shaft (the igniter shaft is tapered and the cam is held to this taper by friction so that it should not require a great effort to loosen it).

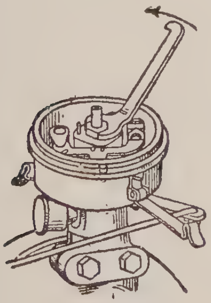

Fig. 6

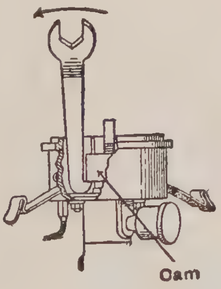

Fig. 7

Fig. 6. Remove lock nut.

Fig. 7. Slip hooked end of wrench under cam and loosen from tapered shaft as shown.

Insert the starting crank and turn until the intake valve on No. 1 cylinder begins to open; remove the spark plug on that cylinder and insert a screwdriver or rod; continue to turn the engine until the piston has traveled downward and has again returned to its uppermost position. By holding the screwdriver or rod firmly, the position of the piston at which no further upward movement takes place can readily be determined. The piston is then on "top dead center" of the compression stroke, and the gases have been compressed ready for firing.

Next turn the cam on the igniter, so that the driving pin assumes the position shown in Fig. 8, then turn the cam in the direction of the arrow until the two contact points begin to open. By the term "begin to open" we mean that point at which the two contact surfaces no longer touch each other.

The lock nut can then be slipped on the shaft and can be securely tightened against the cam; however, in doing this use care not to disturb the position of the cam. The distributor arm and cap can now be put in place and the car operated.

The sequence of firing is 1, 2, 4, 3, the No. 1 wire being the one immediately above the small slot on the edge of the distributor case. This slot fits over the locating pin on the rim of the igniter body. The rotation of the igniter is called "clockwise," that is, it turns in the same direction as the hands of a clock; therefore in the same direction will come the No. 2 wire, then No. 4, and lastly No. 3.

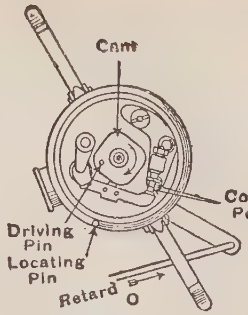

Fig. 8. Rotate the cam so that the driving pin assumes position shown. Retard the spark. Then turn the cam in the direction of the arrow until contact points begin to open when No. 1 cylinder is on top dead center of compression stroke. Replace the lock nut and tighten securely.

Timing the Spark on the Lexington Series "S" Model Six-Cylinder Engine

The Connecticut closed-circuit ignition system is used as an illustration.

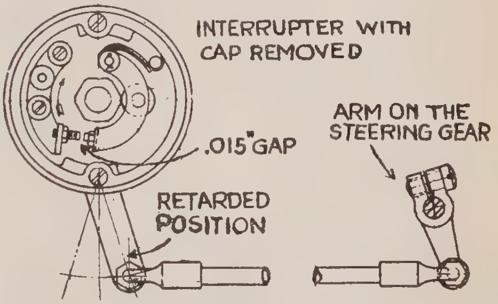

Fig. 9. Top view of the Connecticut interrupter (contact-breaker) as used on the Lexington "S."

To time the ignition, open the pet cock on No. 1 cylinder (next to the radiator), by means of the starting crank; turn the motor slowly until you get compression, determined by holding the finger on the pet cock. Be sure not to pass upper dead center. This is determined by the mark on the flywheel, "D, C-1 and 6," seen through the opening on the top flywheel housing exposing the pointer or indicator.

Retard the spark lever on the steering column fully (Fig. 9); remove the distributor cap; note the position of the breaker points. They should be just ready to open or separate. By advancing the spark lever on the steering column slightly, a spark should jump if the current is turned on.

Note that the spark is set to occur on top dead center of the compression stroke with the spark lever in full retarded position.

The breaker-point adjustment should be .015" air-gap when the cam separates the points fully.

The spark-plug point gap should be .020".

Other Ignition Timing Information

By referring to the Index for Delco, Atwater-Kent, Connecticut, Remy, and other systems of ignition, detailed explanations of each can be found, as well as of other cars.

See page 220 relative to the "Timing of Delco ignition."

Timing the Ignition of a Vibrator-Coil and Commutator Ignition System

Before passing from the subject of ignition timing, it is well to mention the timing of the high-tension vibrator-coil system, as also the "make-and-break" low-tension ignition.

The old-style coil ignition system, with "vibrators" and "commutators," requires a greater advance than magneto ignition. The reason for this is the time required for contact of the commutator, contact of the vibrator, and a possible loss of time for the vibrator to start operating.

Owing to the lag and inertia of a coil trembler, **considerable range of advance is required** to obtain the spark at the most effective position of the piston.

The usual method is to **place the spark lever midway between advance and retard** position, so that it will have half of the motion to advance on, and half to retard on (see Fig. 10).

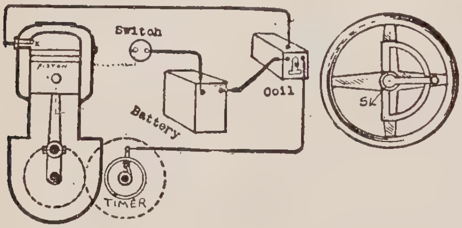

Fig. 10. (1) place piston on top of compression stroke; (2) place spark lever in center position of quadrant (SL); (3) set contact on commutator so that it will make contact with No. 1 cylinder. This will allow for a range of advance and retard in either direction from the center.

Timing Ignition of the Ford

The Ford ignition timing is explained in the Ford instruction.

Timing "Make-and-Break" Ignition

Timing the low-tension magneto[1], with make-and-break type of igniter: The armature of the magneto must be positively driven off the engine by means of a chain or of gear wheels. On engines with cranks at 180°, where the ignition has to take place at 90° relative to the cam shaft, the armature has to be driven at crank-shaft speed.

In the low-tension "make-and-break" system, the contact-breaker is not fitted on the magneto; a connection from the outer end of the armature winding joins up to the terminal of the hammer-break device inside the cylinder.

The general practice, when timing (see Fig. 11), is to arrange for the mechanism of the break to "trip" when the piston is just completing the compression stroke, or a little earlier, say ⅛" (or an amount determined by experiment to give the best results), the armature being, as in the case of the high-tension system, in "maximum" position.

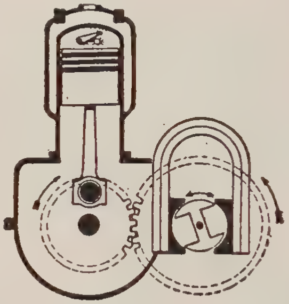

Fig. 11. Illustrates the principle of timing a low-tension magneto using a "make-and-break" ignition. The armature is in one of the maximum positions just as the piston is completing the compression stroke, and the "break" or "igniter" mechanism has just tripped or broken the circuit. This system is seldom used.

SPARK CONTROL AND OVERHEATING

As few motorists really understand just how the power efficiency of an engine is affected by the spark timing (which is generally under the control of the operator), the following may be of interest:

When a combustible mixture has been compressed in a cylinder by the rising piston, and the spark occurs, a very small portion of the mixture in the immediate vicinity of the spark is ignited; and if the mixture is of the proper proportions and suitably compressed, the flame propagation throughout the entire combustion chamber will be rapid.

This is as it should be. When combustion takes place, intensely heated gases are formed, which in their effort to occupy a larger volume of space exert great pressure on the walls of the combustion chamber and upon the piston head.

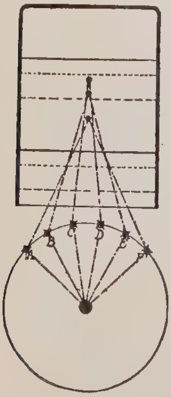

Fig. 1

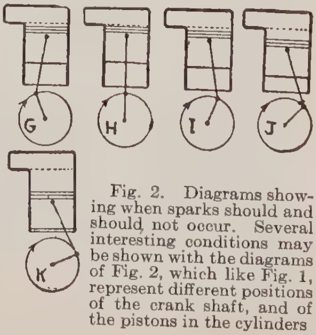

Fig. 2. Diagrams showing when sparks should and should not occur. Several interesting conditions may be shown with the diagrams of Fig. 2, which like Fig. 1, represent different positions of the crank shaft, and of the pistons in the cylinders

As a gas or gaseous mixture is compressed, it becomes heated, and the greater the pressure, the greater the heat.

If a mixture is of proper proportions, the greater the pressure, the more readily will it ignite, and the greater the speed of flame propagation or combustion.

On the other hand, as the pressure of a combustible mixture is reduced, it loses its heat, and its speed of ignition and combustion is also reduced.

Thus it must be understood that to get the utmost efficiency out of a combustible charge **it must be ignited at or near the point of maximum compression.**

Let it be assumed that a car is being driven at a speed of about 30 miles per hour, and that the engine is necessarily turning over at a speed of about 1,200 revolutions per minute, with the spark lever advanced so that sparks occur when the piston is ascending as at (G) (Figs. 1 and 2).

Ignition, we will assume, is complete at (**H**), and combustion at (I), at which point the maximum pressure of the expanding gases is being exerted. Under these conditions the engine runs smoothly and cool.

Now, by retarding the spark and advancing the throttle lever, it is found that the speed of 30 miles an hour can still be maintained.

The engine is generating the same amount of power, but with the spark retarded and the throttle advanced; but after about 30 minutes' running the radiator begins to steam, and we see that the engine is overheated. What is the cause?

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[1] When setting the time of the spark on a **stationary engine,** the spark is set to occur, when retarded, slightly after the compression stroke to prevent kicking back. This type of engine is usually equipped with a "make-and-break" igniter system.

It is this: The spark is retarded, so that now it occurs when the piston is at (I); compression is already reduced, so that ignition is slower and is not complete until the piston is at (J), and combustion is still incomplete at (**K**).

The explosive mixture is now richer in fuel, so that more heat is given off than under the first-mentioned condition; therefore the expansive force is greater than before, so that the speed of the engine is the same. But note the area of wall surface of the cylinder at (**K**), which now is exposed to this more intense heat.

The water in the jackets has not only to take care of the heat absorbed by the walls of the combustion chamber, but also of an excessive amount absorbed by the cylinder walls.

Range of Spark Advance and Retard

Fig. 1 is a diagram showing the range of spark advance and retard, representing different positions of a crank shaft and the relation of the piston in the cylinder at these different positions.

Referring to this diagram, we find that if an engine is running at an extremely high rate of speed the spark might be advanced so as to occur in the cylinder when the throw of the crank shaft is ascending and at the point (**A**); thus combustion might be complete or so nearly complete, by the time the throw reached the point (**D**), that a very strong pressure would be exerted upon the piston, which is as it should be.

If the engine were being subjected to an extremely hard pull, as in ascending a hill on high gear, so that its speed is considerably reduced, and ignition were to take place at (**A**), combustion might be complete at (**B**) or (**C**), and the pressure or power-impulse on the piston head would tend to turn the crank shaft in a reverse direction.

If the car were traveling at a very low speed, or if there were not sufficient momentum in the flywheel or the car itself, the engine would be stalled, or killed, as the expression is.

Of course, if the car or engine were traveling at a sufficiently high rate of speed to carry the crank and piston over this dead center, a large percentage of the power would be applied in the right direction, but considerable would nevertheless be lost; there would be what is known as an "ignition knock," and the strain on the bearings would be quite severe.

On the other hand, if the engine has been slowed down considerably under a hard pull and the ignition is retarded so as to occur at about (**C**) or (**D**), combustion might be complete at about (**E**) or (**F**), or perhaps even a little farther down where the leverage on the crank shaft is greatest, and thus the greatest amount of the downward pressure on the piston is utilized.

It must be remembered that the greatest power is dependent upon the momentum or torque of the flywheel.

An engine always should be run with the spark advanced as far as possible without causing it to knock or lose power, and it will overheat if caused to run for any great length of time with a retarded spark.

Verifying the Ignition Timing

It occasionally happens that cars turned out of the factory hurriedly, to meet pressure of orders, are not as well adjusted in the setting of the ignition timing as they might be, with the result that the car may fail to idle properly, due to the setting being slightly too far advanced when the contact-breaker is retarded.

On magneto ignition it was a common practice to set for either "slow idling," or "for speed" or just between. In other words, if slow idling was desired, then extreme high speed was sacrificed. On the other hand, if very high speed was desired, the engine would not idle properly. Thus an average setting was made by meshing the timing gears driving the magneto.

Testing Ignition Advance

If the ignition is suspected of being set too far advanced, and idling speed is desired, then test as follows:

(1) Place No. 1 piston on top of compression, or its firing stroke. This can be found by following out the wires and noting when the cylinder to be tested will fire.

(2) Place breaker-box in "retarded" position.

(3) Note if the contact-points are just separating when the piston is on top. If so, the setting is about right for the magneto.

If, however, the points have already separated, then it is likely there is too much "advance," the amount being determined by the distance the spark occurred before top.

If a vibrator coil system, then the contact on the segment ought to be made when the piston is, say, ⅛" over the top of compression stroke with retard-spark lever.

If a change is made in the setting, then a trial should be made with the engine running, and a note should be made as to how the speed responds to the advance-and-retard movement. Variation in the setting should be made if found necessary.

QUESTIONS AND ANSWERS RELATIVE TO THE ADVANCE AND RETARD OF SPARK, EXPLAINING WHY THE ADVANCE OF SPARK INCREASES THE SPEED OF ENGINE

Question 1: How can the spark be made to vary as to the time at which it takes place?

Answer: By movement of the hand-spark lever on the steerng wheel, as in Fig. 4, page 287, which connects with the circuit-breaker housing on the magneto, or, if a coil and battery system, by connection with the advance arm of the interrupter housing and distributor (Figs. 3 and 4, page 302).

Movement of the interrupter housing in the direction of rotation of the cam causes the break to occur later, or retarded; movement in the opposite direction to that of rotation causes the spark to occur earlier, or advanced. See also Figs. 3 and 4 on this page, showing a commutator as used on a vibrator-coil ignition system.

Note in Fig. 3 that the contact arm (instead of a cam) is moved in the direction of rotation of the rotating segment with which it makes contact; thus, the spark occurs late. In Fig. 4,

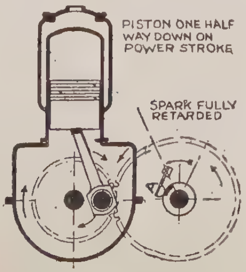

Fig. 3

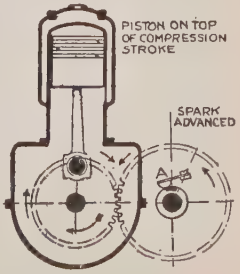

Fig. 4

the arm is shown moved back, or in the opposite direction to that of the rotation of the segment; therefore the spark will occur earlier.

Where an automatic advance of the spark is provided, as explained on page 203, the same action takes place but by means of a governor instead of by the hand-spark lever.

Question 2: Suppose the throttle is open, and the engine is speeded up, and the spark lever is not advanced but left at full retard position, what happens?

Answer: The gas would not be compressed as tight because the piston would be part way down on its power stroke, as seen in Fig. 3, with the result that there would be very little force exerted on the head of the piston. The engine would waste part of its power stroke and would not be as powerful as if the spark was properly timed or advanced. Excessive heat would also result, because the gas would continue to burn, not only during the rest of the power stroke, but also during a part of the exhaust stroke. For instance, with a retarded spark and an opened throttle, if the exhaust manifold was removed, a long red flame would be emitted from the exhaust ports; whereas, if the spark was properly advanced, there should be no flame at all, as the gas is supposed to ignite and cool before it passes through the exhaust valves. When running with a retarded spark a greater throttle opening is needed to develop the same power or speed. Thus a retarded spark generates greater heat and greater gasoline consumption.

Question 3: Why does advancing the time for the spark to occur increase the speed of the engine? For instance, suppose the engine is running with a certain throttle opening and the spark is advanced, the speed of the engine increases. Why is this?

Answer: The reason why **the advance of the spark causes an increase of speed** in the engine with the throttle open is principally the fact that when the spark is retarded, the power stroke is much shorter. In other words, suppose that the piston is half-way down on power stroke before the retarded spark occurs, as in Fig. 3. Note that when it sparks the gas at this position, the space between the head of the piston and the head of the combustion chamber is so great that there is not much force exerted on the head of the piston when the spark occurs; whereas, if the spark occurs advanced, or when the piston is near the top of the compression stroke, as in Fig. 4, the compression of gas is greater, and hence greater force is exerted on the head of the piston when the spark occurs advanced. Consequently more speed results.

In other words, with a retarded spark the piston travels well down on its power stroke without doing any work, whereas, with an advanced spark the piston works all the way down.

Question 4: What occurs if the spark is advanced when the engine runs slowly?

Answer: There will then be a fierce struggle inside the engine: the piston fighting to complete the compression stroke, and the explosion, which has occurred too soon, trying to force it back again. And which wins? If the engine is working fairly briskly, the piston overcomes the explosion; otherwise the explosion drives back the piston, and stops the engine. This is why, when an engine is cranked, it frequently "kicks back"; the spark has been advanced too far, and the piston can not overcome the early explosion. In order words, the spark occurs and combustion takes place before the piston reaches the top of stroke. Fig. 4 shows the spark advanced so that it occurs on the top of the stroke. It is not full advanced; if it were, the spark would occur before the piston reached the top. See pages 291 and 292.

Question 5: How can I tell when the spark is too much advanced?

Answer: There will be a sound in the engine as of a hammer striking the top of the piston. The engine will be said to "knock;" and the more the spark is advanced, the louder will be the knock. This is termed an "ignition," or "spark knock."

Question 6: And what should make it knock? Does the piston strike the top of cylinder?

Answer: We have already pointed out that this is impossible, as the length of the stroke is invariable; neither does it appear that it is caused by a general looseness throughout the parts of the engine, since new engines knock in this instance as much as old ones.

The ignition knock thus produced is caused by a "piston slap." When the piston is going up on the compression stroke, it is riding hard against one side of the cylinder, and as it passes over dead center the piston jumps to the other side of the cylinder wall, owing to the compression pressure, or compressed charge, which would be from 62 to 125 lbs. to the square inch. Such a charge would produce no noise in an engine with properly fitted pistons. However, if this compressed charge should be ignited considerably before top dead center, by the time top dead center was reached, which is the position where the piston "slaps," or is transferred from one wall of the cylinder to the opposite wall, the pressure would probably be 300 lbs. or 400 lbs. to the square inch, which would cause a very decided noise in the piston. See page 292 explaining the relation of the speed of the engine to the spark.

An engine should not be slowed by retarding the spark. If it has been noticed by the reader during the last few paragraphs that it is possible to slow an engine by retarding the spark, let him at once understand that this is the last method by which it ought ever to be done. It is not only unscientific, but is also wasteful of fuel, causes unnecessary work for the engine, and results in rapid pitting of the exhaust valves, the gases passing through them in an incandescent form. Engines even of the same make may vary as to the exact position of the spark lever. Thus the best plan is to experiment as to what position of spark makes the engine run best.

The correct method of slowing down or increasing the engine speed is to shut or open the throttle valve, which is situated between the carburetor and the inlet valve, by which the amount of fuel supplied to the engine may be regulated (see Fig. 11, page 33). Then as the engine varies its speed slower or faster, the spark should be retarded or advanced accordingly.

The rule therefore is to **let the engine speed follow the throttle and make the spark follow the engine speed;** or, to put it in another way, in order to drive economically, keep the throttle valve closed as much as possible and the spark advanced as far as possible, short of knocking or of a tendency to knock.

Retarding the spark too much produces heat. See page 304: "Spark control and overheating."

AVERAGE ADJUSTMENT OF LEADING IGNITION SYSTEMS. INTERRUPTER AND SPARK-PLUG CLEARANCE

MAKE OF IGNITION SYSTEM	MODEL OF IGNITION SYSTEM	CLEARANCE INTERRUPTER	TIMING POSITION	SPARK PLUG GAP
Atwater Kent	**Open Circuit**	.010"	T-R	.025"
Atwater Kent	**Closed Circuit**	.006"	T-R	.025"
Bosch	**Closed Circuit**	.016"	T-R	.025"
Conneticut	**Closed Circuit**	.016"	T-R	.022"
Delco	**Open Circuit**	.010"	T-R	.025"
Delco	**Closed Circuit**	.018"	T-R	.025"
Splitdorf	**Closed Circuit**	.015"	T-R	.020"
Westinghouse	**Closed Circuit**	.008"	T-R	.025"
Remy	**Closed Circuit**	.020"	T-R	.025"
	Magneto			
Berling	**High Tension**	.015"	T-R	.030"
Bosch **	**High Tension**	.016"	T-R	.020"
Dixie †	**High Tension**	.020"	T-R	.020"
Eisemann ††	**High Tension**	.012"	T-R	.025"
K. W.	**High Tension**	1/64"	T-R	1/64"
Remy	**Low Tension**	.020"	T-R	.025"
Ford	**Clearance between magnets and magneto coils. .031 or 1/32"**			1/32"

The air-gap clearances and position in which to place the spark lever (advanced or retarded), given on the left may vary on different engines and with different models or types of ignition systems or magnetos, as made by the different manufacturers mentioned. But in the absence of definite instructions by the manufacturer, the clearances and position of the spark lever are near enough to produce fairly good results. See page 220 for Delco average timing instructions; and page 208 for Remy instructions.

Average ignition timing: After placing the piston on top and retarding the timer housing, the interrupter points should just be opening, if a "closed-circuit" type of timer, or just closing if an "open-circuit" type of timer. It is difficult to see this; therefore a good plan is to use a 6-volt lamp in the low-tension circuit (between battery and timer). In this way one can tell when the circuit is closed or opened at the timer points, by the light going out or on (see page 221). See Index for Atwater-Kent, Connecticut, Remy, and Delco timing instructions.

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†On 4, 6, and 12-cylinder engines the spark-plug gap is .025" and 8-cylinder engines .020". On 4, 6, and 8-cylinder engines place the piston 1/16" before top with interrupter retarded. On 12-cylinder engines place the piston on top with the interrupter retarded.

†† Eisemann new-style spring contact breaker requires .012"; others .016".

T, means to place piston at top of stroke.

R, means interrupter is retarded.

**NU4 Bosch spark-plug gap is .016".

FINDING POSITION OF PISTON

In the preceding pages we have discussed placing the piston on top of the compression stroke. How to tell when the piston is on top of the compression stroke is explained on page 70, but the following pointers will no doubt be of interest.

There are two possible firing orders on a four-cylinder engine, that is 1, 2, 4, 3, and 1, 3, 4, 2. In either case, cylinders 1 and 4 fire one revolution or half a cycle apart, so that at the instant that No. 1 cylinder needs the spark, the exhaust valve of No. 4 cylinder is just closing.

Refer to Fig. 1, and note that the cylinders are numbered, beginning at the radiator. The last valve away from the radiator is usually the No. 4 exhaust valve. In order to tell when it just closes, it is well to slide a piece of paper (P) between the valve stem and the tappet or push rod, and then to crank the engine over by hand, until the tappet is seen to rise and pinch the paper and lift the valve.

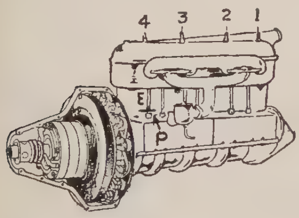

Fig. 1

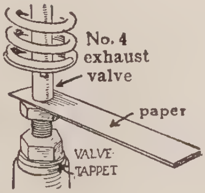

Fig. 1A

Continue to crank the engine, with one hand held on the piece of paper. At the instant that the paper **just gets loose, the spark for No. 1 cylinder should occur.**

In magnetos and most battery systems this will be the instant at which the interrupter points just begin to open, and in a Ford system using vibrating coils it will be the instant at which the timer just begins to make contact (see the Ford instruction or the discussion of "Valve timing"), which can most easily be determined by the use of batteries, and by listening for the first buzz of the coil.

In six-cylinder engines there are two common firing orders, as follows: 1, 5, 3, 6, 2, 4, and 1, 4, 2, 6, 3, 5; in each of these it will be noticed that cylinders No. 1 and No. 6 are half a cycle apart, just as No. 1 and No. 4 were half a cycle apart in the four-cylinder engine. We can then use the same rule for the six-cylinder engine as for the four, except that we look at the No. 6 exhaust valve, which is still the last valve down the line, the one farthest from the radiator.

It sometimes happens that the valves are inaccessible, as, for instance, in a sleeve-valve engine, in which case it is necessary to check by the compression, in order to get the proper top dead-center position, and then to check the exact piston position by feeling with a piece of wire inserted at the spark-plug opening.

If the firing order is not known, it can be determined by the order in which the valves lift or by opening the pet cocks and putting wads of paper in them. If the engine is now cranked by hand, the wads will blow out in the same order in which the engine fires.

To determine the end of the compression stroke, in any cylinder (Overland is taken as an example): turn the crank until the exhaust valve in that cylinder, which is the one directly beneath the priming cup, has just reached its seat; and then turn the flywheel approximately one revolution, stopping when the mark "1-4 UP" (or "2-3 UP") is at its highest position and in line with the guide mark on the back end of the crank case. Another method is to turn the engine while the hand is held over the open priming cup and identify the compression stroke by the escape of air. See also Index under "Finding position of piston."

INSTRUCTION No. 29

CARE AND REPAIR OF THE MAGNETO

Care of the Magneto

Distributor parts: The distributor plate should be removed occasionally for inspection as to the presence of the carbon dust that wears off from the carbon brushes. This dust may form a connection between the distributor segments, and as a consequence may cause a spark to occur in the wrong cylinder. Carbon dust that has collected on the distributor should be wiped out with a cloth, the cloth being moistened with gasoline in case the carbon has become caked. After cleaning with gasoline, the inside of the plate should be given a very light film of oil to prevent excessive wear of the brush and the distributor plate.

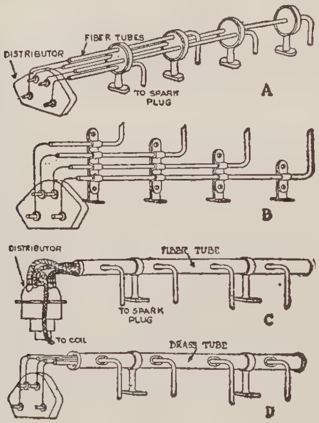

Fig. 1. **A**, method by which the wires can be separated from one another to avoid static effects; **B**, another method of separating wires to avoid static effects; **C**, with this arrangement static effects are sometimes felt; **D**, running wires through brass tubing does not avoid static effects.

Cables: Use only the best insulated wire for all electrical connections and especially those leading to the plugs. The wires running from the distributor to the spark plug are called secondary cables, and should be protected from static[1] electricity. (See Fig. 1; **A** and **B** are best arrangements.)

Terminals: Scrape off about 3/16″ of the insulation from both ends of the cable; clean the copper wire, and screw it into the tube of the terminal (it will not do to push it in only), in order to connect the two parts thoroughly. Spread out inside the tube the portion of the wire which has been stripped of its insulation, and screw in the little screw supplied for the purpose.

Many a case of ignition trouble has been hard to locate due solely to one of the strands of wire short-circuiting. Therefore, if special connections are provided, use them; otherwise solder the ends.

Interrupter Adjustments

Among the most important parts of the magneto is the interrupter and it is advisable to inspect it from time to time. An inspection of the interrupter requires the removal of the cover which is usually secured to the interrupter housing by means of a spring ring that permits it to be snapped on and off. The interrupter lever should be moved for assurance that it is free on its pivot, and a test should be made of the distance between the platinum points.

Adjustment: When the lever is depressed by one of the steel segments or the cam, the distance between the platinum points should be about .015″ to .020″ or about 1/64″. This distance may usually be adjusted by the movement of a platinum-pointed screw.

Should it be necessary to replace one of the platinum points, or to attach a spare part, the interrupter may be more completely exposed by turning the lock ring a quarter of a turn to the right or to the left, and removing it and the interrupter housing. The interrupter itself may be removed by unscrewing the interrupter screw.

When replacing the interrupter, care must be taken that the key on the interrupter disk fits exactly into the keyway on the armature shaft, and care must also be exercised when replacing the interrupter housing, to make sure that it is placed back in exactly the same position as it was in when it was taken off.

The platinum points on the interrupter "pit" in time, but not so badly as the points on a vibrator coil. The alternating current of a magneto does not cause pitting of the points as much as the direct current. However, in time the points are bound to become worn and new ones must be fitted, or the old ones dressed down. (See Index under "Dressing platinum points.")

A defective condenser will cause excess sparking at the interrupter points. See Index under "Condenser."

The Safety Spark Gap

In order to protect the insulation of the armature and all other parts from injury due to excessive voltage, a safety spark gap is provided, to permit the passage of the current to ground without injury. The current will pass across the safety spark gap in case a high-tension cable is disconnected, if the spark gap is too great, or if for any other reason the spark-plug circuit is open. Discharge should not be permitted to pass through the safety spark gap for any great length of time, however. This should be particularly guarded against if the engine is operated on a second or auxiliary ignition system. When the engine is operated on such a system, the magneto should be grounded in order to prevent the production of high-voltage current. See Index under "Safety spark gap."

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[1] Static electrical discharge means jumping of high-tension current from one wire to another when the wires are together, even though fairly well insulated.

Oiling the Magneto

The over-oiling of the magneto should be guarded against in order to prevent the entrance of oil to the interrupter parts. Each of the oil holes is to be given a few drops of fine machine oil every two weeks, or every 1,000 miles. The interrupter is designed to work without lubrication, and the presence of oil on the platinum points will give unsatisfactory results, inasmuch as it will cause sparking at the points and possible misfiring.

Vaseline is suitable for lubricating the ball bearings, but never use oil on the interrupter in such a manner as to permit it to reach the platinum points.

Cutting Off the Magneto Ignition

To cut off the ignition, the **primary current must be "grounded,"** which will prevent the breaking of the circuit by the opening of the interrupter, and consequently prevent the production of the secondary current. The primary current may be grounded by making a connection between the grounding nut and the engine ground, this circuit usually including a switch. One terminal of the switch is connected to the engine or frame, the other terminal leading to the grounding terminal. When the switch is open the magneto will produce a spark, but the closing of the switch will ground the primary circuit and will prevent the production of the ignition spark.

MAGNETO IGNITION TROUBLES

In case of defective ignition it must be determined whether the fault is in the magneto or in the plugs. Generally, when only one cylinder misses, the fault is in the plug.

Defects of Spark Plugs

(1) **Short-circuit at the spark gap,** due to small metallic beads which are melted by the heat of the intense spark and form a conducting connection between the electrodes. This defect is easily ascertained, and may be remedied by removing the metallic beads.

(2) **If the gap between the spark-plug electrodes (point) is too great,** the spark will jump across the safety gap on the magneto. In such a case, when the plug is unscrewed from the cylinder the spark will jump across the electrodes of the plug, and not across the safety spark gap. This does not signify that the distance between the electrodes is correct, for it must be borne in mind that open air has a lower resistance than the compressed air or gas existing in an engine cylinder. The distance between the electrodes when under compression in the cylinders must, therefore, be less than is required in the open air. The correct gap should be approximately 1/64″ or .020″.

(3) **Fouling of the plug:** If fouling should occur, the parts exposed to the burning gases may very readily be cleaned by removing the plugs from the cylinder. This exposes the plug core, and it may be cleaned with gasoline.

The spark plug used with a magneto should have the point set closer than with a battery and coil ignition, because, when the magneto runs slow, the current is not as strong as when running fast. With a battery as a source of supply, the current is constant at all times.

The spark-plug cables must be tested, and special attention should be paid to ascertaining that the insulation is not injured in any way. The metal terminals of the cables must not come in contact with any metal parts of the engine or with any metal parts of the magneto, except the proper binding posts.

Diagnosing Magneto Troubles

(1) Engine balks—no spark.

(2) Misses at low speeds.

(3) Misses at high speeds.

(1) **Engine balking** may be due to broken connections, short-circuit in primary circuit, or between coil and distributor brush. Timing may be wrong or breaker points too far apart.

(2) **Missing at low speeds** may be due to spark-plug gaps too far apart, or too close; breaker points too far apart; loose connections or short-circuits; weak magnets.

(3) **Missing at high speeds** may be due to breaker points set too close; breaker arm not working freely, loose connections, or short circuit.

If ignition fails suddenly: A sudden failure of ignition **indicates a short-circuit** in the low-tension cable, either through a defect in the cable, through a faulty connection of the switch, or through the presence of dirt or moisture. This may be tested by removing the grounding cable from the binding post on the magneto and endeavoring to start the engine on the magneto. If the engine runs with this wire disconnected, but stops when the wire is connected, it may be taken for granted that there is a fault in the insulation or some other defect through which the low-tension current escapes to "ground." It is also advisable to examine the carbon distributor brush to ascertain if it is in good condition. This brush may be exposed by removing the distributor plate.

Irregular firing: Irregular firing is usually caused by the **improper working of the interrupter,** and this part should be examined. It should be seen to that the interrupter lever moves freely on its pivot, and that the center screw is properly tightened; see also that the steel segments or cams, as well as the two platinum screws, are properly secured in position. Furthermore, the platinum points should be inspected for the correctness of their adjustment, and they should be so set that they are about 1/64″ apart when the interrupter lever is depressed by one of the segments. The platinum points should be clean, flat, and true to one another, and any oil, grease, or dirt that is deposited on them should be removed. If they are uneven or in bad condition—but only then— they should be trued by means of a fine flat file. If the interrupter lever does not move freely on its pivot (as is occasionally the case, particularly with new magnetos), the hole through the fiber bushing that forms the bearing should be reamed out. This work should be very carefully performed, however, and excessive reaming must be guarded against.

Starting the engine: To start the engine it is sufficient to give a sudden pull to the starting handle at the moment when a spark is to take place in one of the cylinders. If the engine does not start off at once, this may be caused by either or all of the following: (1) by the setting not being done in a proper way; (2) by the points of the plugs being too far apart; (3) by the cables being faulty, or the connections being badly made. Very often the carburetion is faulty.

In any case, care should be taken, when stopping the engine, to short-circuit the magneto, and to cut off the supply of gasoline (by closing throttle) when the engine has ceased running. In this way the cylinders are prevented from being filled with air. If the cylinders contain gasoline, the starting of the engine is always easy. If on the contrary, the supply of gasoline (throttle) is cut off while the engine is running, the cylinders get filled with air, and on restarting it has to be driven out and replaced by gasoline.

Coil: If on turning the magneto no high-tension current is produced, it may be that the coil is damaged (this applies to a low-tension magneto with a separate coil, or with the secondary winding on the high-tension armature), and should be returned to manufacturers in order to have it repaired or replaced.

Magnets: Remagnetizing will not be necessary unless the magnets have lost their magnetism through having been taken off and left, for a long period, without their bases having first been bridged by a piece of iron; or unless, before taking out the armature, no piece of iron or steel has been placed on the pole pieces. This piece of iron or steel should remain there until the armature is replaced. It often happens that on remounting the magnets, a mistake is made in placing them in the wrong order, whereby their magnetic power is completely neutralized.

When it becomes necessary to take the magneto apart, you will do well to draw a chalk line across one side of all the magnets. Be careful that the same marks stamped on the magnets appear all on the same side. All north poles are to be replaced on one side, and all south poles on the other.

Difficult starting is in many cases caused by the fact that upon stopping the engine, the supply of gasoline is cut off, while the ignition only should be stopped. In this way the cylinders are filled with air only, without any gasoline, and no explosions are possible. After opening the throttle about one-quarter of the way, draw in a "mixture" of air and gas; then the engine will start.

By cutting out the ignition only, there will be gasoline vapor in the cylinders instead of air, and the engine can be set in motion by a half-turn of the starting handle, i.e., by a sudden pull at the moment of highest compression.

Springs: Examine from time to time whether the safety contact spring sliding in front of the cam presses sufficiently against the cam; as soon as the steel bosses are rather worn, the spring should be replaced by a new one. By putting some oil now and then upon the steel parts, too rapid wear will be prevented.

Carbon brushes: The low-tension carbon brush, as well as the high-tension distributor, will wear off in the course of time and have to be replaced by new ones, i.e., in the first case, as soon as the spring presses down on the metal holder of the carbon, and in the second, as soon as the spring of the carbon comes out of its case.

When the magneto armature rubs against the pole-piece, it is probably due to worn bearings or to a broken ball, to loose screws on the armature head, or to gears meshed tight causing undue wear on one end of the shaft.

Magneto Trouble Indications—Condensed

Failure of magneto to give the proper spark may be due to:

Armature: weak current; open primary; open secondary; shorted primary or secondary.

Condenser: short-circuited; open circuit (see Index).

High-tension circuit: brush on collector spool cracked or punctured; loose connection to collector spool; defective distributor brush.

Spark plugs: improper gap; fouled.

Magnets: weak; reversed.

Contact breaker: points worn; points too close or too far apart; weak spring.

Assembly: gear bearing worn or dry; armature rubbing on pole pieces and end play in armature, due to loose screws in armature head or worn bearings.

Procedure of Diagnosis

If missing continues to occur and the cause cannot be located, then **begin the diagnosis as follows;** being sure that the—

(1) Spark-plug gaps are correct—about .020″ gap.
(2) Magnets are not weak.
(3) Interrupter points are clean and the correct distance apart—about 1/64″.
(4) Connections from magneto and switch are tight.
(5) Magneto is properly set.
(6) Carburetor adjustment is correct.
(7) Armature is in perfect alignment.

Determine whether missing occurs when running slow or fast.

First Determine if Trouble Is Due to Magneto

This should be done by first **running the engine on the battery and coil system of ignition;** then switch on to the magneto side. If the engine begins to miss, yet runs on the battery side, this will indicate that the trouble is in the magneto.

Quite often, however, this test is made when the engine is running slow. If the engine misses only on slow speed, try setting the plug points closer together and adjust the interrupter or clean the interrupter points. Look for a loose wire or strand of wire short-circuiting. If everything else, including carburetion, is apparently in proper order, and the engine runs on the coil and battery, but misses on the magneto, then the trouble is likely to be due to weak magnets or to punctured or short-circuited insulation.

Before deciding that it is the magneto winding giving the trouble, be sure magnets are strong. See test below, and **test the magneto,** as directed in pages 311 to 315.

To Test Magneto on Engine

First test to find out **which cylinders are missing,** as directed on page 238. If all miss, then the trouble is probably in the magneto or the carburetion. If missing is found in one regularly, the trouble is then probably due to the spark plug or wiring.

Run the engine slowly; advance and retard the spark; note if there is any missing; **then speed the engine up** and advance and retard, and notice if there is still any missing. This will enable you to determine if missing is on low or high speed.

If the engine is running and the spark jumps ⅜″, and is blue and has volume, and spreads when blowing on it, then it is not likely that the magneto winding is defective. If it will not jump this far regularly, and is thin and yellow, and the cause is not elsewhere, then test the armature winding, as directed on pages 313, 314.

Note. The magneto could continue to give a weak spark, even though the winding was defective, as only part of the winding may be cut out.

MAGNETO MAGNETS AND REMAGNETIZING

Magnets Made of Steel

The magnets used on both low and high-tension machines are of special tungsten steel made as hard as it is possible to obtain them, so hard that a sharp file cannot make any impression on the metal. Much depends on the class of steel used—a special grade known as magnet steel is now being adopted. The retention of magnetism by steel is a very curious and interesting property. It resides only on the surface of the steel and it is found that a much stronger magnet is obtained, weight for weight, by making it in sections, one placed over the other, than in using a massive single magnet. Magnetos have two magnets placed side by side; some have a single large magnet—they were formerly two—made of superimposed parts.

Soft steel is easier to magnetize than hard steel, but the former loses its magnetization quickly if subjected to vibration. The hard steel magnet loses its magnetism very slowly, although the magneto has, as a matter of course, to withstand much vibration from the engine, etc.

Weak Magnets

After the magneto has been in use for approximately two years, the magnets may have become weakened. The length of time a magneto retains its magnetism is governed by the quality of steel used in the magnets.

Misfiring will be the result of weak magnets. There are other conditions, however, to determine before blaming the magnets. For instance, the missing may occur from spark-plug points not being set equal distances apart.

The best remedy for trouble from this source is obtained by having the magnets of the magneto recharged; but temporary relief often may be obtained by adjusting the points of the spark plugs so that all are brought a little closer together, and all equally distant apart; that is, the gap between the points should be the same on all plugs. If the gaps are not all the same, then the plug with the widest gap generally will be the first to misfire, as a result of weak magnets.

When running a car slowly on the high-speed gear, the engine may be turning over so slowly that the magneto will not generate the required current and misfiring accompanied by a jerky action of the car will take place. When this occurs, one should either shift to a lower gear, or switch over to the battery. The better plan is to shift to the lower gear, if in congested traffic when the car speed cannot be increased; for by so doing one speeds up the engine and magneto; more current is generated; a hotter spark results, and missing is eliminated.

Remagnetizing Magnets[1]

In charging by the use of an electro-magnet, one of which is shown in Fig. 1, unlike poles must be placed together. That is, the north or N pole of the magnet should be in contact with the S or south pole of the electro-magnet, and the south pole of the magnet with the north of the charging device. The electro-magnet has polarity because the fields are wound in opposite directions. It is easily determined whether the magnet is in its proper position, even if the poles are not marked. Since like poles repel and unlike attract each other, when the magnet is placed in contact with the electro-magnet cores they should hold fast. If there is a repulsion, then the magnet should be reversed.

After charging has been completed and the magnets are assembled on the magneto, it is necessary that **like poles be in contact.** That is, if the magneto has three magnets the north poles of these must be in contact, as shown in Fig. 2. Often some figure is painted upon the magnets, such as is shown, and when this figure is made by the assembly of the magnets, the poles are properly facing. It is best then to determine the proper polarity by the attraction and repulsion methods; like poles repel each other, and unlike poles attract each other.

Another method to find N and S poles: The S pole of the magnet will attract the N pole end (**N**) of the compass needle (see Fig. 3).

Keeper: When magnets are disassembled, place an iron bar (called the "keeper") across the ends to retain magnetism. This should be done instantly on removing magnets, and after remagnetizing.

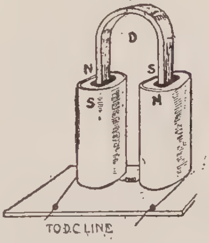

Fig. 1

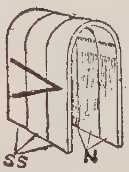

Fig. 2

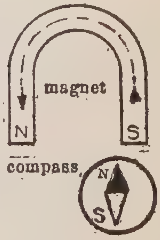

Fig. 3

To test if magnets need recharging: A good way to test, is to place a steel bar or a pair of pliers across the bottoms or the sides of the magnets on the magneto. If they pull fairly strong, you may know that they are in fairly good condition. You can ascertain whether or not they are pulling fairly strong by testing some other magneto which you know is all right. In doing this, however, turn the armature so that the points are just separating.

Another method is to turn over the armature of the magneto by hand, as shown in Fig. 3A, and when the armature gets to a certain position resistance will be felt. This resistance is due to the breaking of the lines-of-force by the armature. Since weak magnets produce a weak field, little resistance will be felt in cases of weak magnets. The magnitude of the resistance will not be known to the repairman unless he has tried previously to turn the armature when the magnets were in good condition, or unless he tries another magneto and compares the results.

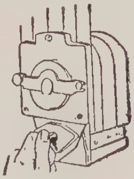

Fig. 3A

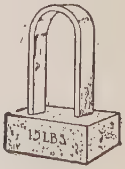

Fig. 3B

Another test is to test the magnet's capacity for lifting 15 lbs. as shown in Fig. 3B. On small magnets 10 lbs. would suffice.

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[1] A. L. Dyke, Granite Bldg., St. Louis, Mo., is in a position to remagnetize magnets and to repair magnetos, coils, etc.

A good plan is to test the ability of a new magnet of the same size, etc., to lift, and to **compare** the results with those of the one just charged, or which you know is charged.

How Poor Compression Weakens Magneto Magnets

If the engine has good compression, the piston will stop on quarter and not dead center. Result, a free path for magnetic lines-of-force forming virtually a complete magnetic circuit, as in Fig. 4.

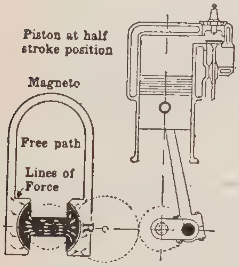


Fig. 4

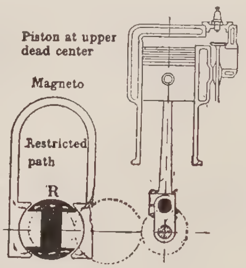


Fig. 5

Fig. 4. Left, position of magneto armature with piston of engine at midstroke showing free path for magnetic lines-of-force between poles of magnet.

Fig. 5. Right, position of magnetic armature with piston at upper dead center showing restricted path of lines-of-force through armature.

If the engine has poor compression, even in one cylinder, the piston will stop on dead center. (Fig. 5). Result, the path for the magnetic lines from one pole-piece to the other is very poor and the result is the same as when a horseshoe magnet is allowed to lie around without its keeper—the magnets will gradually lose their magnetism (from *Motor World,* by Thurston W. Turner).

One Reason Why a Magneto Fails to Spark at Times

A high-tension magneto secondary winding insulation may in time become hardened and leaky from heat, caused by the strain of running with too wide a spark plug and safety gap.

A wide-open throttle increases compression, and the plug gap offers resistance which increases the voltage in the winding, with the result that the spark jumps the insulation internally instead of at the plug gap.

When running on a level with an almost closed throttle, compression is less, with the result that the spark, although weak, may jump the plug gap. This accounts for a magneto armature requiring rewinding, yet producing a spark at times.

Remagnetizing Magneto Magnets

The device[1] shown in Fig. 6 is an electromagnet designed to remagnetize the permanent magnets which are used on magnetos.

A fully charged **6-volt storage battery** of the lighting or starting type should be connected to the terminals of the Magnetizer, using short heavy wires.

On closing the switch on the base of the device, a current of 25 or 30 amperes will flow, and the Magnetizer becomes a powerful electromagnet of such strength that a magnet placed across its poles will be magnetized to its maximum strength.

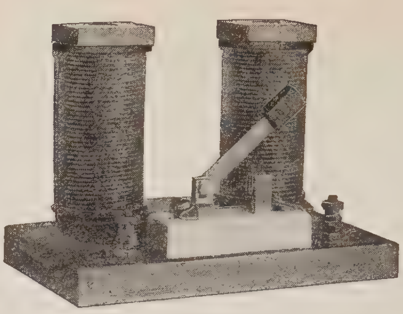


Fig. 6. Electromagnet[1] for remagnetizing magneto magnets of all kinds. For remagnetizing Ford magnets without removing from car, the attachments shown in Fig. 8 are provided.

In order properly to remagnetize magneto magnets it is necessary to remove the magnets from the magneto. Before doing so, one side of the magneto, that is, the pole-piece and the legs of the magnets on one side, should be chalk-marked. The magnets should be magnetized so that the chalk-marked poles have the same polarity. This is done by chalk-marking one pole of the Magnetizer and placing the chalk-marked pole of the magnet to be charged, on the marked pole of the Magnetizer.

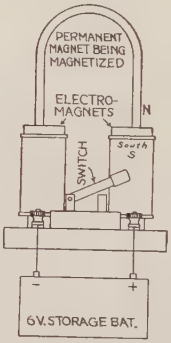
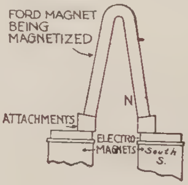


Fig. 7



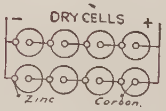


Fig. 8 (upper)
Fig. 9 (lower)

The magnets are placed, one unit or section at a time, so as to span the poles of the Magnetizer, as shown in Fig. 7. Switch the current on and off several times. The current need only flow a few seconds at a time. While the current is flowing, the permanent magnet to be charged should be rapped a few times with a piece of wood. This will assist the magnet to absorb the magnetism easier. It is well to place a piece of soft iron as a keeper across the poles of the magnet before removing it from the Magnetizer so as to preserve the full strength of the magnet until it is put on the magneto. When sliding the magnet on the magneto, the soft iron "keeper" will slide up and may then be removed. See that the magneto is put together exactly as before.

Do not allow the current to flow longer than a short time, as it will cause the coils to heat and will also drain the battery. The Magnetizer may be used on a **12-volt battery or two 6-volt batteries in series.** This will cause it to be twice as strong as if used on a 6-volt battery. It is then suitable for very large magnets.

It is possible to use **dry cells** in case a storage battery is not available. Six or eight fresh cells should be used and connected in two groups in parallel, the groups to be connected in series. See Fig. 9.

If it is desired to magnetize the magnets with a certain polarity, it is necessary to observe the following:

The polarity of the Magnetizer will be as shown in Fig. 7, provided it is connected so that the plus (+) terminal of the battery is connected to the right-hand terminal of the Magnetizer when facing the side with the switch. Place the marked or north pole (N) of the permanent magnet on the south pole (S) of the Magnetizer. When magnetizing this way the marked leg of the permanent magnet will then be the north pole.

The polarity of a magnet is easily determined with a magnetic compass. The north (N) pole of the magnet attracts the (S) pole end of the compass needle. The north pole of a magnet is sometimes called the plus or positive pole. Like poles repel each other; unlike poles attract.

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[1] Can be secured of A. L. Dyke, Electrical Dept., Granite Bldg., St. Louis, Mo. Price $8.50 (add $1 if Ford attachments are desired).

Remagnetizing Ford Magnets

The magnets in a Ford magneto may be charged as described above, but by attaching the special pole pieces, as shown in Fig. 8, it is not necessary to remove the flywheel from the engine. Remove the transmission-case cover so that the ends of the magnets are available.

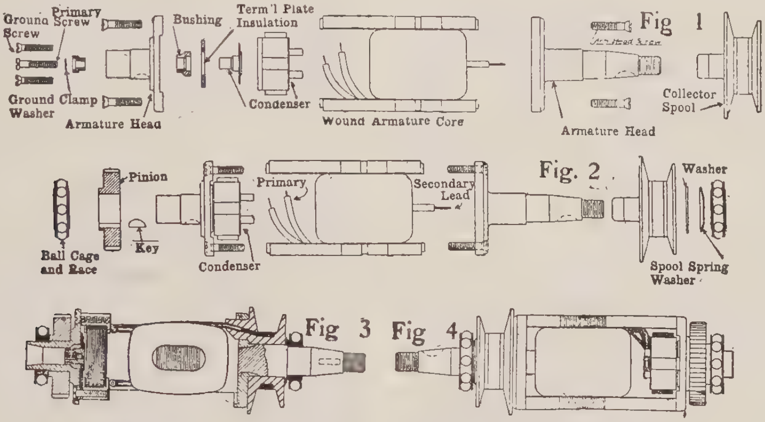
With the aid of a small magnetic compass, the north poles of each one of the magnets should be chalk-marked. Also chalk-mark the south pole of the Magnetizer.

Now place the pole tips of the Magnetizer so as to touch the ends of one of the magnets, taking care that the chalked end of the Magnetizer touches the chalked end of the magnet. By turning the flywheel over, each magnet should be magnetized, one at a time.

It is advisable to check up the polarity of all the magnets with the compass, when they are charged.

DISASSEMBLY, ASSEMBLY, AND TESTING OF A MAGNETO (BERLING AS AN EXAMPLE)

The parts of the armature on the type "E" and "F" Berling magneto are disassembled as shown in Figs. 1 to 4. The interrupter, which was first removed, and the magnets, distributor, etc., are not shown. On most magnetos there is but one primary connection to the condenser, the other primary terminal being grounded, also one terminal of the condenser. Here the primary leads are connected to the condenser and one terminal of the condenser is grounded, which gives the same results. The primary leads are soldered to the condenser.



Figs. 1 to 4. Parts of the Berling "E" and "F" high-tension magneto.

Fig. 2 shows the armature parts being assembled.

Figs. 3 and 4 show a sectional and top view of the completed armature.

It is not advisable to take the magneto apart, unless you know it is defective. Before taking apart read pages 309 and 310 carefully.

To Disassemble the Magneto

Remove interrupter, distributor block, gear housing, magneto and bearings. This will leave the armature as shown in Fig. 5. Be sure and place a "keeper" on the magnets the instant they are removed, as directed on page 311.

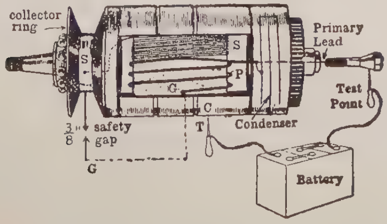


Fig. 5. Testing a magneto armature.

To Test Armature Primary Winding

Use a 6-volt battery[1] and test points, as shown in Fig. 5. Connect one test point with the primary lead, and touch the other test point (T) to the armature core at (C) for an instant. The current then travels through the primary winding and condenser, and is induced into the secondary winding.

If a spark occurs at the test point, and at the same time it jumps the secondary gap of 3/8", then we know the armature has tested out properly.

If there is no spark at all, then we know that there is an open circuit in the primary winding.

If there is a heavy spark at the test point when touching the core, then there is a short-circuit in the condenser or primary winding, and it is necessary to disassemble the armature. This, of course, would mean a dead short-circuit on the battery.

To Disassemble Armature

Remove the screws, armature heads, collector spool, etc., as shown in Fig. 2.

To Test Secondary Winding

A single wound primary coil with a vibrator and condenser fitted internally can be used for this test. A Pfanstiehl[2] coil, is excellent for this purpose; or a Heinze coil unit as used on a model "N" Ford, with the secondary winding short-circuited, could also be used.

Only the primary winding in connection with the vibrator is necessary, as the secondary winding on the armature is used instead; hence the reason for shorting the secondary terminals.

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[1] Secondary is grounded. On some magnetos it connects to two collector rings.

[2] This coil can be supplied by A. L. Dyke (Elect. Dept.), Granite Bldg., St. Louis; price $7.50.

If the secondary winding is in order, then on touching test point (T) to the armature core (Fig. 6), the spark will jump the ⅜″ gap.

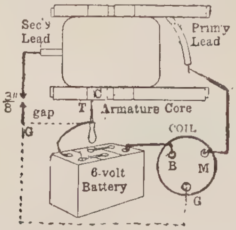

Fig. 6. Testing secondary winding of armature with a battery and a coil.

If the secondary winding is short-circuited, the secondary spark on this test will arc from secondary winding to armature core, but will not jump the gap.

If the secondary winding is open, a spark could occur, as it could jump the open gap internally, but it would be weak.

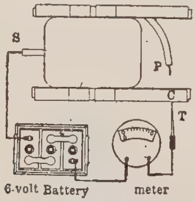

Fig. 7. Testing the secondary winding of an armature with a battery and voltmeter.

To tell positively if a secondary winding is open, about the only plan is to put a very low-reading sensitive voltmeter, connected with a 6-volt storage battery, across the winding, as shown in Fig. 7. If the circuit is open, the meter needle will not move at all. If it moves at all, this circuit is in good order.

Note. Never run current through armature when magnets are on the magneto; it may be run through in the wrong direction and tend to demagnetize them.

Magneto Spark-Plug Gap

The correct gap is .020″ to .031″. If too wide, starting will be hard, and there is a danger of breaking down the high-tension insulation of the winding. If too close, the points are more likely to become shorted, due to carbon collecting on the gap points.

Compression of an engine determines the type of magneto to be used. For instance, if the magneto is used on a high-compression engine, then the points must be closer than on a low-compression engine. If, however, the magneto is made of sufficient capacity for the high-compression engine, then the gap could be normal, or .020″ to .025″.

Contact Breaker Tests

Usual troubles are: dirty points; platinum worn off; arcing at points; gap too far apart or not far enough; points not genuine platinum.

To test platinum points, use nitric acid. If it eats the points, they are not genuine platinum. The best test is to use a jeweler's stone test (ask any jeweler). Platinum or platinum-iridium is generally used for points on magnetos, and tungsten (which is very hard) for points on battery and coil-system interrupters. See also Index under "Platinum points."

MAGNETO TESTING APPARATUS

When considerable testing is done, a countershaft with pulleys, and used in connection with a 1/6 h.p. electric motor, can be used to run the magneto at various speeds to test the length of gap and volume of spark at various speeds (see Fig. 8).

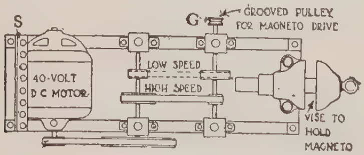

Fig. 8. Counter-shaft, pulleys, vise and motor for driving magneto for testing.

An adjustable gap arrangement can easily be made as shown in Fig. 9. Note that the length of the gap can be adjusted.

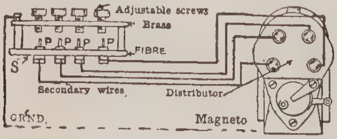

Fig. 9. An adjustable secondary spark gap for testing the secondary winding of magneto.

To test the magneto, place it in the vise (Fig. 8). Connect the secondary terminals to the stationary points (P) (Fig. 9). Place a grooved pulley on the taper shaft of the magneto and connect it with grooved pulley (G) (Fig. 8) on the second countershaft by means of a round belt. Then run the magneto and test as directed on page 315.

If the spark does not test out satisfactorily, then disassemble magneto and test armature and condenser as directed on pages 313, 314, and 315.

To Test Condenser

All high-tension magnetos and high-tension coils are provided with condensers.

A condenser usually consists of 161 layers of mica insulation material, between which sheets of tinfoil are laid so that each layer of tinfoil is electrically insulated from its neighbor (see page 191). In some coil condensers paraffined paper is used instead of mica, but this is not as efficient.

Condensers can be removed, but it is usually necessary to unsolder the primary armature winding connections to one of its terminals, the other condenser terminal being grounded to armature frame.

Usual troubles are due to the sheets of tinfoil becoming grounded, or to the fact that one of the connections is open. **Indication of a defective condenser** is excessive sparking at the contact-breaker points, which become pitted white.

How to test: Use 110-volt direct current with one or two lamps connected, as shown in Fig. 10. If

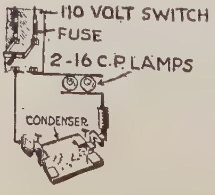

Fig. 10

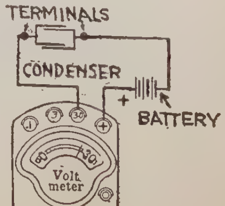

Fig. 11

the condenser is properly insulated and not grounded, the lamp will not light when the switch is closed. If it does light, then the condenser is grounded. If the ground cannot be removed, a new condenser is necessary.

Another test is shown in Fig. 11. Use a 30-volt range volt-meter and connect as shown. If the condenser is good, no indication will be obtained. If it is grounded, an indication will be obtained. See also Index under "Testing condenser."

A Home-Made Magneto Armature Tester

This device is similar to the one explained on page 230, for testing a high-tension coil.

To test a magneto armature, a hole, the diameter of the armature, is made in the sheet of copper, as shown in Fig. 12. The vibrator iron knob (V) on the spring (B) is placed close to the side of the iron core of the armature. This vibrator blade will vibrate when current is passed through the primary winding of the armature if the iron knob (V) is close to the iron armature core.

The primary winding of magneto is connected as shown. One end is grounded to the armature core; the other end connects with the vibrator blade at (**F**).

Note. The armature core should fit tight in the hole so that it will act as a ground.

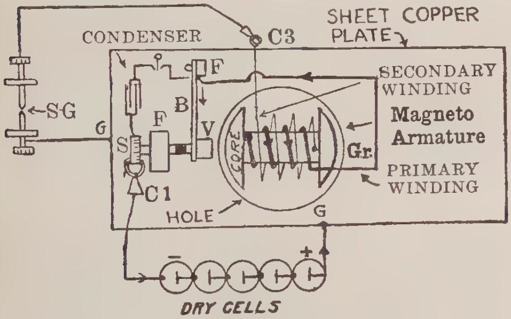

Fig 12. Magneto armature tester.

The primary circuit would then be from (+) of the dry cells to the ground plate (use six dry cells), through ground of primary winding on armature core, through primary winding to vibrator blade at (**F**), through points, to clamp (C1), to (−) terminal of battery, completing the primary circuit.

By adjusting the vibrator screw, the blade (**B**) will vibrate, thus causing a spark at the secondary spark gap (SG), which consists of fiber blocks with very fine brass wires sharply pointed and adjusted to a gap of about ¼″ or 5/16″.

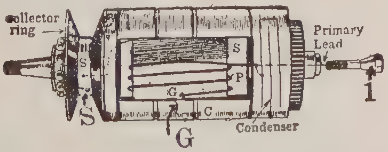

Fig. 13. Showing the winding and parts of a magneto armature.

The secondary winding is wrapped over the primary winding, as shown. One end is grounded to the iron core (usually grounded to the primary wire which is grounded to the iron core); the other end is connected with the insulated slip ring (S) (Fig. 13). Thus the secondary circuit would be from clamp (C3, Fig. 12) which would connect with the slip ring (S, Fig. 13) to the spark gap (SG), to ground (G) on the plate, to ground of the secondary on the armature.

A condenser is shown connected on the outfit to be used for testing purpose. This condenser can be taken from a magneto which is known to be in good condition, and should be so connected that it can be used by means of a plug switch.

The idea is to test the secondary spark, to see if it will produce a spark continuously—at least one hundred steady sparks without missing. The width of this gap at (SG) should be about 5/16″, or slightly less than the length the safety spark gap is set for on the magneto.

First test with the condenser which is used with the magneto armature, and note if there is sparking at the points of the vibrator interrupter; if so, try the good condenser on the outfit and see if the sparking disappears. If it does, the condenser in magneto is defective and can be tested separately with test points (pages 227, 230) to see if shorted. There should be no circuit between terminals of a good condenser. The condenser, of course, should be across the interrupter points, or the vibrator points.

If the condenser in the magneto is in such a position that it is not across the points, then test with condenser on the test outfit, and then unsolder the leads from the condenser on the magneto and test separately with a 110-volt test lamp similar to test on pages 314, 230. By reading the directions for testing a high-tension coil with a similar outfit, on page 230, the explanations will probably be clearer.

Other Methods of Testing a Magneto

Testing high-tension magneto: Oil the magneto; connect the distributor wires to the spark plugs and set the points at about a 3/16″ gap; then run the magneto 40 minutes at 1,500 r.p.m. with interrupter full advanced and for 10 minutes at 3,500 r.p.m. full advance, and 10 minutes at 150 r.p.m., noting that it runs equally well during last run in either advanced or retarded position.

During the runs the contact points should not spark or flame excessively. There should be no excessive noise or stray sparks about the magneto. The safety gap in the magneto should be 5/16″, and should not spark at any of the speeds mentioned, if the spark-plug gaps are not over 3/16″ during the test. The spark should jump the safety gap when the armature revolves at 60 r.p.m. with the spark plug or distributor wires removed.

One method of driving a magneto on a test is by an electric motor. Another method is from a line

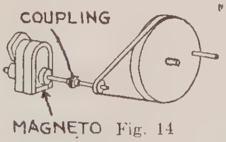

Fig. 14

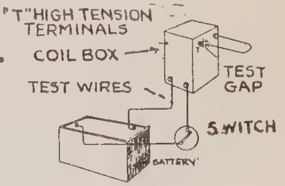

Fig. 15

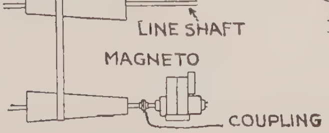

Fig. 16

Fig. 14. A method for determining the condition of the spark produced by driving the magneto at high speed.

Fig. 15. A battery, switch and test wires to test a coil.

Fig. 16. A variable-speed arrangement for driving a magneto from a line shaft.

shaft and a pulley (Figs. 14 and 16). Fig. 16 shows a variable-speed pulley arrangement. When testing a magneto or coil, run until heated up.

Be careful that the armature is in perfect alignment. If a ball is broken, the armature shaft will be out of line and permit the armature to rub against the pole-piece; or the armature heads may become loose, or the drive shaft may be worn unduly on one end of the armature by the gear driving it meshing too tight.

Usually, **the cause of the armature being out of alignment** is worn bearings, or a broken ball, or loose screws on the armature head.

Testing a High-Tension Coil Used with a Low-Tension Magneto

Connect the low-tension circuit of the coil with a good battery of the same voltage as is used on the car, and provide a spark gap of suitable size on the high-tension side.

For 60 lb. compression the gap should be ¼″ in the atmosphere and for 90 lb., ½″. Fig. 15 shows the conventional arrangement which may be used when the coil is not on the magneto armature.

The coil primary circuit is closed and then quickly opened, and if the coil is in good condition a spark should occur at the high-tension gap (Fig. 15).

There is no necessity for removing the coil box from the car to do this work if the test wires are long enough to be attached with the coil in place.

Unless the internal wiring of the coil is known, some experimenting will be required in order to connect up with the right terminal. Probably the simplest method of procedure is to note the terminals to which the low and high-tension wires are attached, and to attach the test wires accordingly.

Testing a Dixie Magneto

The windings of a Dixie magneto armature can be tested by disconnecting the primary winding from the stationary insulated contact point (S) and connecting this primary lead (W) to one terminal of a 6-volt battery. (This primary lead is clearly shown in Fig. 26, page 276). The other terminal of the battery should then be connected to the stationary contact point (S), the circuit then being as shown in Fig. 17. Then turn the armature so that the contact points will open and close, and watch to see if the spark jumps the safety-gap. The safety-gap points should be set about 5/16″ apart. In such a case, the winding is probably in good order.

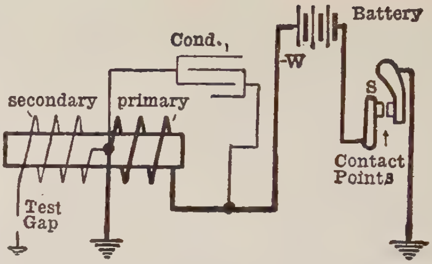

Fig. 17. Testing a Dixie magneto. The same principle applies to the armature type of magneto.

A good plan is to test a winding that you know is in proper condition, and to compare the suspected defective one with the spark of a good one.

The test described above may also be used on the armature type of magneto, the principle being the same, that is, to connect the battery between the primary winding and the **insulated** contact point.

If the points rotate, do not give the armature many revolutions, as the battery leads will wrap around it.

Changing Direction of Rotation

If the direction of rotation of a standard revolving armature-type of magneto armature is changed, a contact-breaker, housing and a cam must be obtained for the opposite rotation.

It will also be necessary to change the meshing of the armature gear and distributor gear teeth, so that the spark will occur at the proper plugs according to the firing order.

Magneto Gear Tool

A specially made tool for removing magneto gears is shown in Fig. 18 at (W). The prongs of the fork are tapered. By using two such tools, the gears can easily be removed without damage.

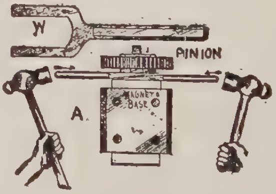

Fig. 18. Magneto gear tool.

INSTRUCTION No. 30

ENGINE STARTERS: Ignition; Priming; Compressed Air; Gasoline and Air; Electric

Ignition Starting

The first form of self-starter was the ignition starter. It is still used, but to no great extent, in connection with the priming systems and gas systems of starting, as explained on page 268. A special form of switch, is sometimes provided which causes a spark in all cylinders simultaneously.

It is possible to start any engine occasionally on the switch, if the cylinder in which the spark is made at the time happens to have a charge of gas and the ignition is a battery and vibrator-coil system, either as an auxiliary or regular system. If, however, the magneto system and breaker are used in connection with a non-vibrating coil, then the chance of obtaining the spark is not so good. The breaker points will not permit the opening and closing of the circuit when the engine is idle.

Therefore a special connection is usually provided on the non-vibrator type of coil in the form of a button switch. This applies to engines of four or more cylinders. The principle: there is always a certain amount of unexploded gas remaining in one of the cylinders when the engine stops, especially if the driver has taken the precaution to open his throttle before the engine stops. Therefore, if a spark occurs in the cylinder, this unexploded gas will combust and give enough momentum to start the engine.

As stated, if a coil system is used, the switch can be thrown on and a quick movement of the spark lever for its full length will cause contact to be made on the timer or commutator, thereby causing a spark in one of the cylinders.

Naturally the cylinders must be in good condition. The piston rings must be tight so that the compression will not be lost by leakage. When stopping the engine the throttle ought to be opened part way, so as to admit a full charge of gas to the cylinders, to make starting easier. The engine must be speeded up, but by holding the clutch out.

Priming Starter

The priming method of starting was the next method. Instead of depending on the pistons to draw in a charge of gas, a special pump was devised as in Fig. 1. This pump forced a charge of carbureted gas into the cylinder, as explained below.

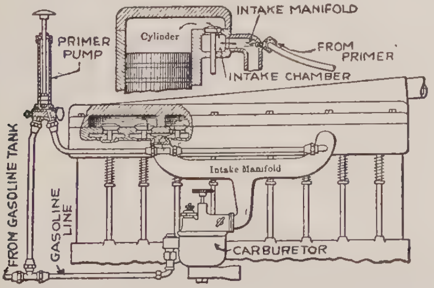

Fig. 1. A primer starter. Cylinder primers are all operated very much along the same lines, the fuel being injected into either the cylinders themselves through special priming cocks or into the intake manifold. A hand-operated pump is usually used to draw the gasoline from the supply tank to the feed pipe. The gasoline is brought into the primer cylinder from the carburetor supply pipe. It is then forced into the intake manifold through a special form of spray nozzle. An upward stroke of the handle fills the primer cylinder, and a downward stroke forces it into the valve chambers of the engine. With all priming systems it is necessary to have a spark at the correct time. See Index under "Starting on the switch."

Gas Starter

The acetylene gas idea of starting developed from both of these systems. The Prest-O-Lite Co. worked out a very satisfactory system for starting, as explained in Fig. 2. This system also employed a special electric connection for igniting the gas.

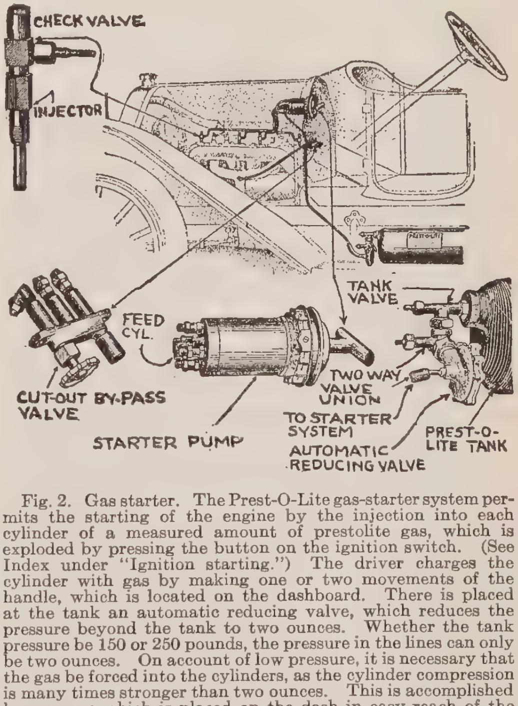

Fig. 2. Gas starter. The Prest-O-Lite gas-starter system permits the starting of the engine by the injection into each cylinder of a measured amount of prestolite gas, which is exploded by pressing the button on the ignition switch. (See Index under "Ignition starting.") The driver charges the cylinder with gas by making one or two movements of the handle, which is located on the dashboard. There is placed at the tank an automatic reducing valve, which reduces the pressure beyond the tank to two ounces. Whether the tank pressure be 150 or 250 pounds, the pressure in the lines can only be two ounces. On account of low pressure, it is necessary that the gas be forced into the cylinders, as the cylinder compression is many times stronger than two ounces. This is accomplished by a pump which is placed on the dash in easy reach of the driver. In cold weather the driver can press a by-pass valve button and cause the gas to pass from the tank directly to the intake manifold. (Prest-O-Lite Co., Indianapolis, Ind.)

Compressed-Air Starter

The compressed-air system was first used by taking pressure from the exhaust, storing it in a tank, and then distributing it to the cylinders. The compressed-air starter is divided in two classes: (1) the type which uses a pump, operated mechanically from the engine to store fresh air in the air tank (Fig. 3); (2) in the other type, the exhaust gases are stored in a tank.

This last-mentioned method was a type of starter formerly used on the Winton several years ago. Part of the exhaust gases from the engine was stored up in a tank, during the exhaust stroke. This gas was then used to force the piston (which was ready to commence its power stroke) down. Fig. 3 shows the method, using a mechanically driven air pump to store fresh air in a tank under pressure.

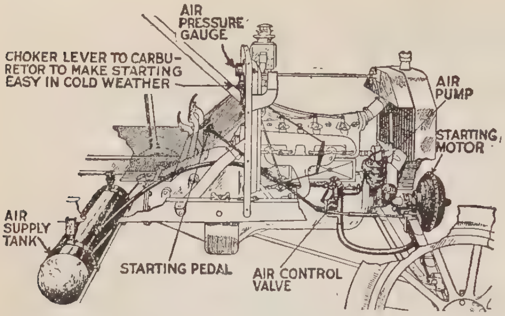

Fig. 3. Compressed-air starter. The Stewart starter for the Ford cranks the engine from the front end of the crank shaft in exactly the same manner it would be cranked by hand. To start the engine, it is only necessary to press the pedal which is installed on the footboard.

The starter motor, or cranking unit, is an air-tight chamber, circular in form and replaces the crank handle. Passing through this is a shaft which engages the engine shaft, the same as the crank handle formerly did. Within the cylinder is a stationary head; also a revolving valve.

This valve is attached to a collar through which the starter shaft passes. In operation, the charge of air is admitted into the starter motor at a point between the stationary head and the revolving valve. This air pressure forces the revolving valve to make almost one complete revolution.

Inside of the collar, attached to the revolving valve is a pawl which engages the grooves or teeth in the starter shaft. A "driving" clutch is attached to the end of this starter shaft.

A "driven" clutch is installed on the end of the engine crank shaft. The "driving" clutch engages with the "driven" clutch in the same manner as formerly, when the car was started by the old crank handle. (Stewart-Warner Speedometer Corp'n., Chicago, Ill.)

Gasoline and Air Starter

The Christensen gasoline and air starter (Fig. 4) is used on aeronautical engines, such as the Thomas, Sturtevant, Roberts, Duesenberg, Hall-Scott, Curtiss, Wisconsin, and others; also on motor boats, trucks, tractors, and automobiles.

Principle: This starter does not crank the engine, but starts it as follows: The engine, when running, uses gasoline and air, properly mixed, as its fuel. When not running it cannot be started ordinarily only by cranking by hand or some other starter. The Christensen starter supplies this mixture to the engine in ready-made form, under compression, to each of the cylinders in firing order so that the engine is started on the first touch of the button.

The parts are shown in Fig. 4 and consist of **the compressor; a clutch** for engaging and disengaging the starter; **a carburetor chamber** (independent of the engine carburetor) and **a distributor,** timed with the firing order of the engine; **a control valve,** which is used for starting the engine and for engaging the air compressor; **a tank** for holding the air, and **a gauge** telling how much air the tank contains.

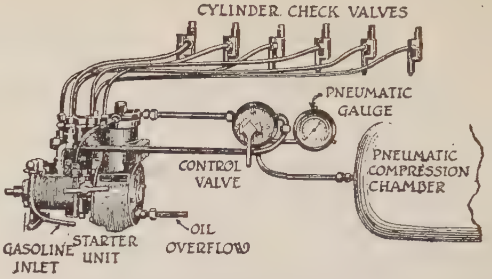

Fig. 4. Gasoline and air starter.

Into each engine cylinder a **starter check valve** is screwed (usually in the priming cup opening), and a pipe runs from the check valves to the distributor.

Method of attaching: The starter unit is usually driven by Oldham coupling from the crank shaft or cam shaft, and is mounted in the most convenient place. (The Christensen Engineering Co., Milwaukee, Wisconsin.)

Mechanical Starter

The mechanical starter is made in many and varied forms, one being shown in Fig. 5.

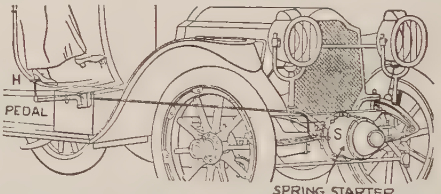

Fig. 5. A mechanical starter. This device (S) is attached to the front of the car in place of the ordinary starting crank. It is about the size of an ordinary automobile headlight, and looks like one reversed. There are two powerful springs in the device which are released by a very slight pressure on a pedal (H) which is located near the driver's seat. (American Ever-Ready Works, Long Island City, N.Y.)

Electric Starter

The electric starting motor has many advantages over other systems, in that the motor is easily applied and manipulated. The source of electric supply is derived from a storage battery which is kept recharged by an electric generator (dynamo).

Summary

Thus, we have the several types of self-starters classified as follows: Ignition or switch starter; primer and ignition; acetylene gas; compressed air; gasoline and air; mechanical, and electric.

Electric Starter Most Used

The electric starter is the system in general use and will be treated in the next instruction.

INSTRUCTION No. 31

THE ELECTRIC STARTING MOTOR: Principle of an Electric Motor; Windings

The electric starting motor is an electric device or motor for turning over the crank shaft of a gasoline engine. The electric motor is a device for transforming electric power into mechanical power. The electric motor receives its electric current for its motion from an electric storage battery.

The storage battery receives its charging current from an outside source, or an electric generator, usually run from the gasoline engine. Quite often this generator (also called a dynamo) is made a part of the starting motor, as will be explained under "Generators."

APPLICATION OF THE ELECTRIC STARTING MOTOR TO THE ENGINE

By referring to Fig. 1, different methods employed for cranking or starting the engine by means of the electric starting motor will be noted. We might classify the methods under two headings as follows:

1. **Flywheel** application (**A** and **B**, Fig. 1).
2. **Crank-shaft** application (**C**, **D**, **E**, and **F**, Fig. 1).

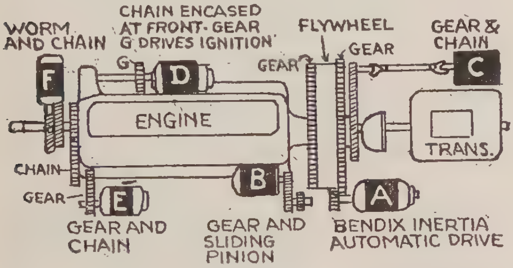

Fig. 1. Various methods of applying the starting motor to an engine. The application shown in **A** is used most.

The flywheel drive methods can be classified as "mechanical" and "automatic." For instance, (**A**) (Fig. 1) the teeth of the pinion or gear on the end of the motor armature shaft automatically engages with the teeth of the flywheel and automatically disengages after the engine is started. This method is known as the "Eclipse-Bendix inertia gear drive," and is illustrated in Fig. 2.

Eclipse-Bendix "Automatic" Inertia Gear-Drive Application to Flywheel

The Bendix "automatic" shifting pinion, as used on a large percentage of the different makes of electric starting motors, also called the "inertia" gear shift, is pictured in Fig. 2. This illustration is not exactly as the device appears today, but explains the principle clearly.

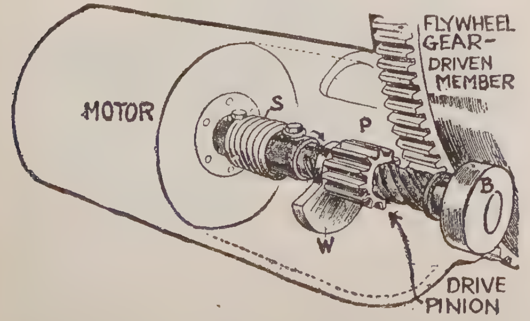

Fig. 2. The Bendix inertia gear drive is the type in general use. Note that the drive pinion automatically engages the driven gear on the flywheel.

The armature shaft has a screwed extension provided with an outer bearing (**B**), and carries the pinion (**P**).

A weight (**W**) is solidly attached to the pinion, and the latter is loose enough on the shaft always to occupy the position shown, with the weight underneath when the shaft is idle. The leading screw has a triple thread.

On starting the motor, the inertia of the weight (W) causes it and the pinion to be carried quickly along the shaft into mesh with the teeth on the flywheel, where it remains performing the operation of cranking until the engine commences to fire, when the direction of the drive is reversed, coming from flywheel to pinion, and throwing out pinion.

The spring (**S**) is provided simply to ease the shock of starting by permitting a slight play between the motor shaft and the screwed extension. The teeth of both flywheel and pinion are beveled on the entering side for easy engagement.

The action is easy to understand. But a query will naturally arise as to what would happen if the starting switch is not released and the motor continues spinning. It would seem that the pinion would return and either get into mesh or continue chattering at the edges of the teeth. Neither happens. The pinion simply continues to rotate out of mesh until the switch is released. This is due to a secondary function of the weight (**W**). Immediately the pinion is thrown out from the flywheel the speed of the motor is such as to cause a binding of the pinion on its shaft, due to the one-sided position of the weight. The action involved is that of the center of gravity of the weight attempting to get into the central plane of rotation of the pinion, and the slight necessary looseness of pinion on shaft allows a temporary binding as a result.

This type of gearing would be termed a "single reduction" of gearing.

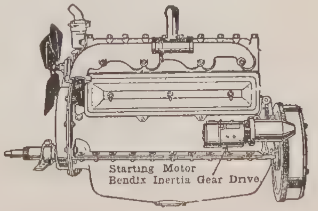

Fig. 3. Illustration showing how the starting motor using the Bendix inertia gear drive is connected to the engine (Studebaker "Light-six," as an example).

Bendix Construction

A modern construction of the **Bendix automatic gear shift** is shown in Fig. 4.

The gear (A) shifts, which meshes with flywheel gear (D). The action is as follows: When the starting button of the switch is pressed down, the connections are made between the storage battery and the electric motor, which causes the armature to rotate rapidly. This causes gear (A) to travel towards the motor on the coarse-threaded sleeve (B) and to mesh with gear (D) on the flywheel. (B) is connected to the armature shaft through spring (C), which allows a certain amount of flexibility and prevents too sudden application of the gears.

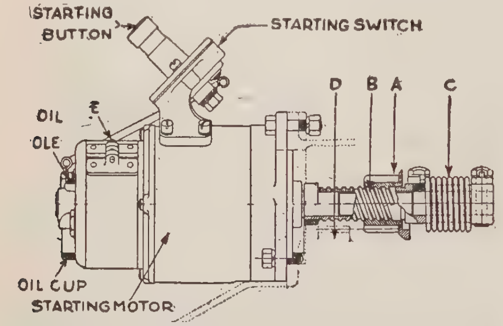

Fig. 4. Bendix drive as used on the starting motor of the King car.

As soon as gear (A) is fully engaged with flywheel gear (D), it comes up against a stop and is locked firmly to sleeve (B), thus rotating with the starting motor armature shaft and allowing the starting motor to crank the engine.

When the engine starts under its own power and the starting button is released, the small inertia gear (A) is thrown out of mesh with the flywheel gear (D), and the starting motor comes to rest.

Note. In the Bendix type of drive shown in Fig. 3, the spring is positioned at the inner end of the sleeve and gear (A) travels in the opposite direction. The principle however is exactly the same. In this construction, the counter-weight on gear (A) is in the form of a flange.

Pointers on the Care and Repair of the Bendix Drive

In case the starting motor fails to start the engine when the starter button is pressed, the following suggestions will be found helpful in tracing the trouble: (1) ignition switch in "off" position; (2) throttle closed; (3) carburetor not choked; (4) loose ignition wire connections; (5) interrupter breaker points out of adjustment; (6) no gasoline in main tank; (7) no gasoline in gravity tank. Remove the carburetor float chamber cover, and if no gasoline is present, see that the shut-off cock underneath the gravity tank is open. If there is gasoline in the main tank, and none in the gravity tank, see "Gasoline feed" instructions for remedy.

If the starting motor runs, but does not crank the engine: This trouble is likely to occur only in extremely cold weather when the oil congeals, causing the starter inertia gear to stick, and not to move into mesh with the flywheel gear. A slight tapping on the starting motor housing will usually overcome the difficulty, but if this fails, start the engine with the hand crank and when the motor is warmed up, it will operate properly.

If the starting motor does not run, this might be caused by any of the following: (1) loose connections at either starting switch, starting motor or battery; (2) battery discharged (test solution with hydrometer); (3) dirty starting motor commutator; (4) worn or loose brushes.

If the pinion goes into mesh with a "bang" and there is considerable noise while cranking, it is evident that the clamping bolts (R) (Fig. 5) have loosened. Be particular to line up the motor properly before drawing them up. By turning the threaded sleeve (B) with the fingers, the pinion (A) can be moved into mesh. Unless it meshes easily, it is not in line.

Starting switch: Good contact and a quick release are important. Examine the spring occasionally, as it must be in good order to prevent damage to the gear teeth. Keep the clamping bolts (that hold down the motor) drawn up snug at all times, otherwise the motor will shift out of line.

Occasionally a Bendix drive gear will stick in mesh, and will not release after the engine has started. This is often caused by improper alignment of a starting motor. In this case, or if the gear meshes harshly, or spins considerably without meshing, proceed as follows: (1) remove bolt (R), spring (C) and threaded sleeve (B); (2) wind a strip of emery cloth around a stick and clean inside of sleeve (B); (3) clean armature shaft; (4) apply small amount of light graphite grease to inside of sleeve (B) and replace parts; (5) do not grease any other part of this drive mechanism, as the action of the starter depends upon the inertia weight on gear (A), and this action is hindered if grease or dirt is on the threads of (B); (6) see that the starting motor is in perfect alignment. If not, place 1/64" shims under it.

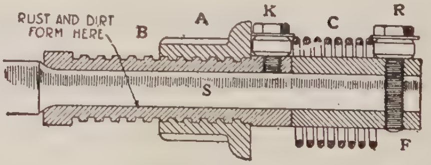

Fig. 5. Parts of the Bendix drive where trouble may likely occur.

Bendix drive troubles may develop from rust and dirt collecting on the inner drive shaft and sleeve (Fig. 5). This should be cleaned out by means of emery paper, being careful to see that no trace of emery is left.

Ratio of Gearing

Ratio of gearing using the Bendix drive: On the Ford, as an example, using this system, there are 10 teeth on the starting motor pinion and 120 teeth on the flywheel gear; thus the starting motor turns twelve times as fast.

On the King car (Fig. 4), there are 12 teeth on the pinion and 126 on the flywheel gear. The ratio is therefore 10½ to 1. The starting motor cranks the engine at a speed of about 150 to 200 r.p.m.

Care of Starting Motor

Lubrication: The bearing at the commutator (rear) end is fitted with a wick oil cup underneath the bearing. The wick dips into the lubricant and the upper end rests against the armature shaft, so that the oil is constantly fed to the bearing. The wick should be cleaned with gasoline and the oil cup filled with non-fluid oil or vaseline once every 3,000 miles. The oil hole is on top of the bearing bracket.

Commutator: The commutator and brushes can be exposed by unscrewing the screw in (**E**) and removing the band cover. Do not touch the commutator so long as the motor starts properly. If it becomes dirty, clean with a piece of canvas moistened with gasoline; if rough, polish with No. 00 sand paper while revolving. See Index, under "Care of starting motor."

BOSCH AUTOMATIC ELECTRO-MAGNETIC PINION SHIFT

Another "automatic" method of a flywheel drive application of the starting motor is where the gear or pinion on the end of the motor armature shaft is shifted electrically. This system, now known as the "Bosch," was formerly known as the "Rushmore," and is termed a "displacement type of armature" because the armature shifts endwise.

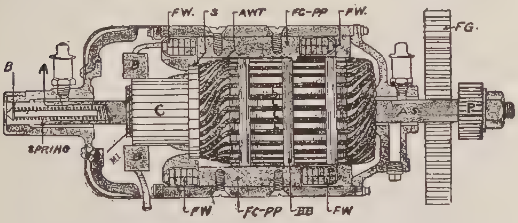

Fig. 11. **C**, commutator; **B**, brushes; **L**, laminated iron core; **AWT** armature winding terminals; **BB**, brass bands around armature to hold coils in place; **F, C,** and **PP,** field core, or pole pieces; **F, W,** field winding; **A, S,** armature shaft; **S,** segment of commutator, where armature coils connect; **MI,** mica insulation between the copper commutator segments; **P,** drive gear or shaft pinion; **FG,** flywheel driven gear.

Displacement Type of Armature

The armature is so arranged that it can be shifted endwise in its bearings, parallel to its axis.

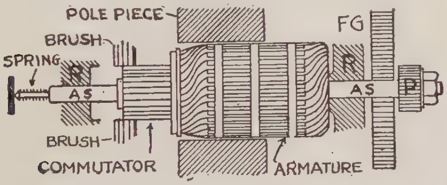

Fig. 12. Motor armature in non-operating position.

In the normal or non-operating position (Fig. 12), the armature is held out of electrical center, or out of line with the pole pieces, by means of a spiral spring in the commutator end of the armature shaft; therefore, when in the normal position (Fig. 12), the pinion (**P**) on the driving shaft of the starting motor is kept out of mesh with the gear ring (**FG**) on the flywheel of the engine.

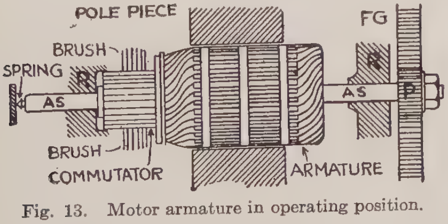

Fig. 13. Motor armature in operating position.

Fig. 13 shows **the motor armature in operating position.** Note that the armature has been pulled to the left under the center of the pole pieces and the gear (**P**) on the end of the armature shaft is now in mesh with flywheel gear (**FG**). Also note that the spring at the left end is now full up into the hollow armature shaft. In this position the gear (**P**) revolves the flywheel gear (**FG**), thus cranking the engine.

Other starting motor armatures, unless of a "displacement type," do not shift; instead, a Bendix drive, or other means for connecting the motor drive gear (**P**) with the flywheel gear (**FG**) is used.

Principle of Operation

The principle of the Bosch starting motor is as follows: Switch arm (**R**) is pressed down slowly by foot pedal (**D**), until connection is made across (**A**) to (**B**). Note that the current from the battery must then pass through resistance (**E**). The amount of current is thus limited. A small portion of the current will then flow through armature (**A**), while the greater portion flows through the motor field coils around pole pieces (**PP**), forming a strong electro-magnet of the field pole pieces (**PP**).

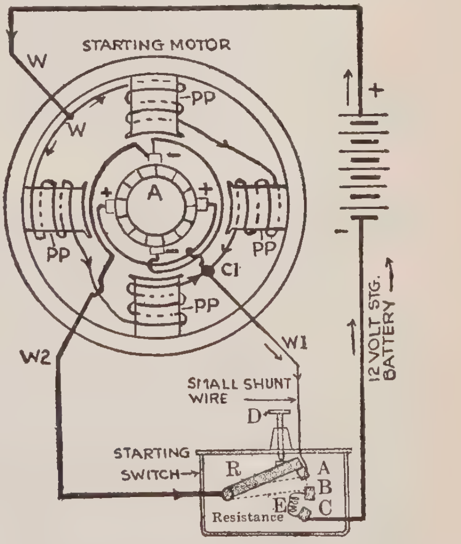

Fig. 14. Principle of operation of the Bosch electro-magnetic pinion shift.

The result is that the **armature is magnetically drawn endwise** against the tension of the spring (Fig. 13) into the magnetic center of the motor, or, in other words, into its working position between the pole pieces.

The passing of the small amount of current through the armature causes the armature to rotate slowly, and as the rotary motion occurs simultaneously with the shifting of the armature endwise, the meshing of the motor pinion (**P**) with the gear ring on the engine flywheel (**FG**) is accomplished quickly and positively.

Immediately after connection is made at (**A**) and (**B**) (Fig. 14), the switch pedal (**D**) is pressed down until (**R**) is in contact with (**C**); therefore the resistance (**E**) and the connection (**A**) and (**B**) and shunt wire or cable (**W1**) are cut out of the circuit and a straight "series-parallel" motor connection through the motor field windings is thus established. This allows the entire current to pass through the motor field windings and the armature windings.

The circuit would then be from (+) terminal of battery to terminal (W) on the motor, which connects with the field windings. The current divides, part going through two field coils in series on one side and through the two field coils on the other side, then from (C1) to (+) brushes on the armature, through the armature coils, out (−) brushes, to switch arm (R), to (C), to (−) terminal of battery, thus completing the circuit.

As soon as the engine starts, the starting motor is relieved of its load, and the current passing through it drops rapidly in volume, this being a characteristic of all series-starting motors. In consequence, the strength of the field magnets is lessened to a point where the spiral spring in the end of the armature shaft overcomes the magnetic attraction holding the armature, and returns it to the original or non-operating position. It is this action that automatically and positively throws the armature shaft pinion (P) out of mesh with the flywheel gear (FG).

Thereafter, until the starting switch is released, any current which continues to pass through the armature will merely cause the latter to revolve freely but without meshing with the flywheel, due to the fact that the amount of current utilized when the motor is running free and the shunt wire (W1) is out of the circuit, is not sufficient to overcome the tension of the spiral spring. The switch should be released quickly.

The system described was formerly used on the Marmon car.

WESTINGHOUSE STARTING MOTOR WITH AUTOMATIC ELECTRO-MAGNETIC PINION SHIFT

The Westinghouse starting motor with an electro-magnetic pinion shift was formerly used on the Pierce-Arrow, Locomobile, Mercer, Cunningham, and McFarlan, and is still used on some cars in connection with a magnetic starting switch.

The internal construction varies slightly on the systems used on the cars just mentioned, but the principle is similar on all.

As an example we will use the system (Fig. 16) as used on the 1919–20 Locomobile.

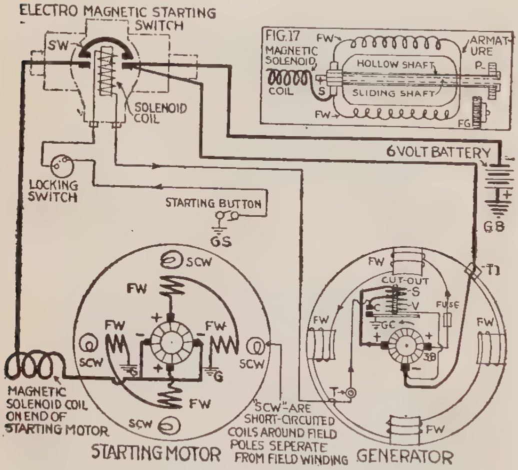

Fig. 16 (lower). Fig. 17 (upper right)

The starting motor is a series-wound, round-frame type, with four poles and with four brushes. It develops 0.7 h.p. at 5.25 volts. It turns the Loco "38" engine crank over at about 125 r.p.m., and the "48" model engine at 115 r.p.m.

On each field pole there is a short-circuited coil (SCW) for the purpose of preventing the starting motor from turning too rapidly as the first rush of current passes through the motor. It acts somewhat like an electric brake for a short period of time. These coils reduce the inductive effect temporarily around the field cores, so that the starting motor does not revolve fast, but permits a current of high value to build up in the magnetic solenoid. This short-circuit coil only affects the magnetism of the field cores temporarily, and the current soon builds up around the field windings (FW); thus the motor picks up speed.

The magnetic solenoid is mounted on the commutator end of the motor (Fig. 17). The armature is on a hollow shaft. On one end of the hollow shaft is the shifting pinion (P) which is splined to it, and thus can slide on this hollow shaft. A sliding rod runs through the armature hollow shaft which is attached to the pinion (P), and it is this sliding shaft which is drawn endwise into the magnetic solenoid, thus shifting the pinion (P) in mesh with the flywheel gear (FG).

It will thus be observed that the difference between this system and the Bosch (Rushmore) system (page 321) lies in the fact that instead of the entire armature being shifted, as in the Bosch "displacement type armature," to cause the pinion (P) to mesh with the flywheel gear (FG), the sliding or shifting rod (S, Fig. 17) is moved in the hollow shaft of the armature in the Westinghouse (Figs. 16 and 17).

When the engine starts on its own power, the starting motor is relieved of its load, or, in other words, the series-wound motor draws more and more current, the heavier the load; the lighter the load, the less current it draws. Therefore as the load has been relieved, when the engine starts to run itself, the current passing through the solenoid and field windings is reduced to such a point that the solenoid loses its magnetic pull and the spring (not shown) forces the sliding shaft (S) and gear (P) out of mesh with the flywheel gear (GP).

A return spring, not shown, forces the shifting rod back so that the gear (P) is out of mesh with the flywheel gear (GP) when the motor is not running.

When the starting switch is closed (which could be a foot pedal, but in this example is an electromagnetic switch, explained farther on), the circuit is from (+) ground (GB) of the battery, to ground (G) of the field coils (FW), to (+) brushes, through the armature, to (−) brushes, through the magnetic solenoid, through the switch, to (−) terminal of the battery.

The electromagnetic starting switch: This type of starting switch takes the place of a foot pedal and is operated by a push button placed on the gang switch on the dash.

Circuit: When starting, the push button (Fig. 16) is depressed. The circuit is from (+) of battery ground (GB), through the frame of the car to ground (GS) on the push button, through the locking switch, through a solenoid winding or coil of the magnetic switch, to generator terminal (T), to cut-out point (C), through cut-out series winding (S), to (+) generator brush, through the armature of the generator, through (−) brush, to terminal (T1), to contact on the electromagnetic switch, to (−) terminal of the battery.

When the engine commences to fire and to speed up, the voltage of the generator builds up.

Cut-out voltage coil circuit: The voltage is built up in the voltage coil (V) of the cut-out. The circuit is from (+) brush, through the series cut-out coil (S), through the voltage coil (V), to (−) brush. This causes the cut-out points (C) to close. Therefore the closing of the cut-out points (C) causes the circuit from the generator (+) brush to become grounded. Thus the electromagnetic starting switch has its solenoid coil grounded at (GC) and also at the push button (GS), with the result that its circuit is opened because its coil is demagnetized and the switch (SW) opens (by a spring not shown), thus opening the circuit between the starting motor and battery. This switch cannot be closed as long as the generator is running fast enough to maintain a voltage sufficient to close the cut-out points.

The generator: In this example a third-brush regulated generator is shown. The field poles are built up, or magnetized, by the (+) current from the armature passing through the third brush, to the four shunt field windings, to terminal (T1), thence to (−) main brush.

Charging circuit: When the generator runs at a speed corresponding to eight miles per hour car speed on high gear, the generator is generating sufficient voltage to close the cut-out points (C); therefore the generator will charge the battery.

The circuit is from (+) main brush, through the series cut-out coil (S), through the closed points (C—now shown open), through the frame of the cut-out, to ground (GC), to (+) ground of battery (GB), to the connection on the magnetic starting switch, to the generator terminal (T1), to (−) main brush.

MECHANICAL GEAR-SHIFT APPLICATION TO THE FLYWHEEL

A mechanical gear-shift arrangement for engaging the shifting gear or pinion (J) with flywheel gear (FG) is shown in Fig. 18, an **early Westinghouse system.**

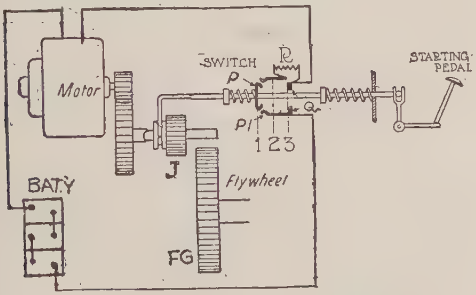

Fig. 18. **A mechanical gear-shift arrangement** for starting the engine with a starting motor and reduction gear drive.

The switch is operated by a foot pedal, which closes the electric circuit to the starting motor and shifts sliding gear (J) in mesh with flywheel gear (FG).

When the switch is at position 1 (Fig. 18), the starting motor switch is off and starting motor idle.

The starting pedal is depressed slowly, forming position 2. This causes contact to be made at (P) with (P1), at which time resistance (R) is in the circuit causing the armature to rotate slowly. This slow rotation allows pinion (J) to mesh easily with the flywheel.

In position 3, **the starting pedal is depressed fully.** This causes (P) to make contact with (Q), at which point the resistance (R) is cut out and the full voltage is applied to the starting motor terminals in order to crank the engine.

After the engine is started, the starting pedal is released and the spring de-meshes the pinion (J) from flywheel gear (FG), and the switch cuts-out and assumes position (1).

Gear Reduction

The connection of gears between the starting motor and flywheel can be either a **single reduction,** as shown in Fig. 19, or a **double reduction, Fig. 19A.** The single and Bendix drive are used most.

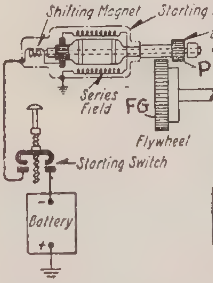

Fig. 19

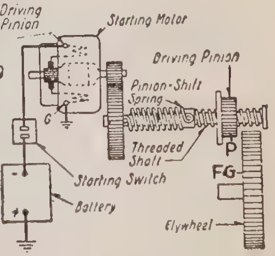

Fig. 19A

THE BIJUR DOUBLE-GEARED TYPE OF DRIVE—FLYWHEEL APPLICATION

This type of geared drive shift is the standard, as used on the Packard "Twin-six." It was also used on the Nash cars for 1916, 1917, and 1918.

The Bijur double-geared pinion shift (Fig. 20) for starting motors driving through the flywheel is similar in some respects to the Bendix (page 319), and can be attached to the armature shaft (A) of any starting motor with the shaft machined to fit it.

Names of parts: A, armature shaft; B, drive shaft; D, driving gear; E, clutch; H, sleeve; L, clutch spring; M, pinion which meshes with flywheel gear or pinion; O, light spring; X, pinion on end of armature shaft.

To start the engine: The driving gear (D) rotates the drive shaft (B) through the clutch mechanism (E and F). This causes pinion (M) to screw itself

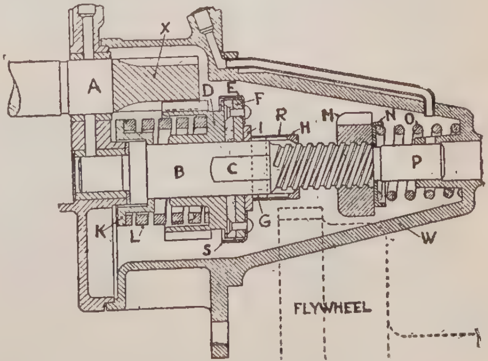

Fig. 20. The Bijur double-geared pinion shift.

to the left along the shaft (**P**), and after meshing with the teeth of flywheel (**M**), it continues to travel in mesh until (**M**) comes in contact with sleeve (**H**). It then pushes (**H**), the whole clutch assembly, and driving gear (**D**) in the same direction and compresses the clutch spring (**L**).

When the members are in this position there is sufficient pressure between the face of the driving gear (**D**) and the clutch member (**E**) to cause the clutch to transmit to the drive shaft the power required for cranking. This it continues to do until the engine begins firing.

When the engine starts the pinion (**M**) is rotated faster by the flywheel than by the electric motor. It therefore screws itself to the right and out of mesh with the flywheel teeth. On coming out of mesh the pinion is cushioned by the spring (**O**).

CRANK-SHAFT APPLICATION OF STARTING MOTOR

The starting motor can be connected with the crank shaft by means of gears or chains.

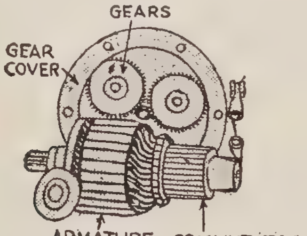

Fig. 21

When connected with the crank shaft by gears, there is usually a reduction of gears encased in the motor housing, as shown in Fig. 21, which permits a reduction of speed, as the starting motor speed is too great for connecting direct to the crank shaft.

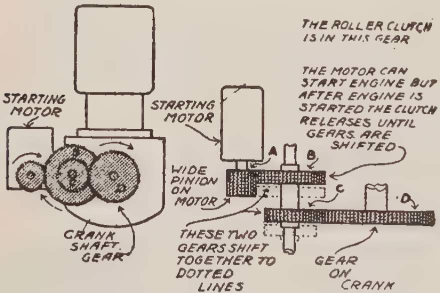
STARTING MOTOR
STARTING MOTOR
THE ROLLER CLUTCH IS IN THIS GEAR
THE MOTOR CAN START ENGINE BUT AFTER ENGINE IS STARTED THE CLUTCH RELEASES UNTIL GEARS ARE SHIFTED
A
B
C
D
WIDE PINION ON MOTOR
CRANK SHAFT GEAR
THESE TWO GEARS SHIFT TOGETHER TO DOTTED LINES
GEAR ON CRANK SHAFT

Fig. 22. Showing application of starting motor to crank shaft by gears. Note that the clutch is in gear (B). The gears are all out of mesh after the motor serves its purpose. (Westinghouse method formerly used on the Davis car.)

An application of a starting motor and generator, where the starting motor drives through a chain and sprocket and the generator is driven through a chain by means of a sprocket and an over-running clutch, is shown in Fig. 23.

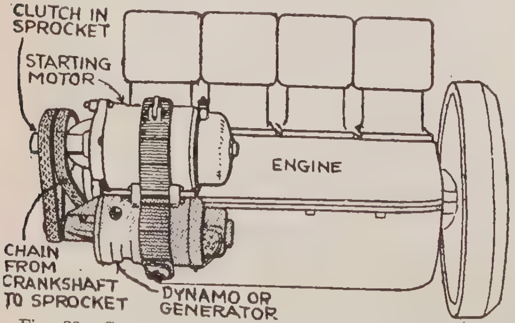

Fig. 23. Starting motor driving the crank shaft by means of a chain through a clutch in the sprocket.

Note that the clutch is in sprocket. Both chain and sprocket run with the engine, but the clutch in sprocket cuts out the motor after the engine is started. (This system was formerly placed by the Gray & Davis Co. on the 1914 Overland.)

The starting motor is started by current from a storage battery, thus starting the engine by means of a silent chain connected with a sprocket on the crank shaft of the engine. After the engine is started, the sprocket to which the starting motor chain is connected is then operated by the crank shaft of the engine. The action of the roller clutch permits the two sprockets to run free of the starting motor; thus the generator is operated from the crank shaft without operating the starting motor.

Just how this clutch permits this action is explained as follows.

Action of the Roller Clutch

The roller type of clutch is a popular type of clutch and its action should be studied carefully. In fact, this type of clutch is now used on a popular make of motor-generator, the Delco, as explained farther on; but it is used in a different manner from that shown with this Gray & Davis system.

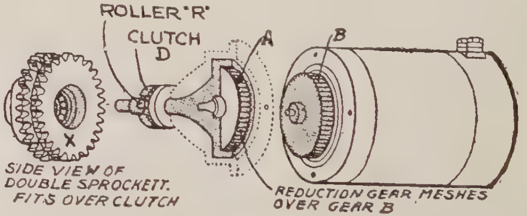
ROLLER "R"
CLUTCH D
A
B
X
SIDE VIEW OF DOUBLE SPROCKETT. FITS OVER CLUTCH
REDUCTION GEAR MESHES OVER GEAR B

Fig. 23A Fig. 23B Fig. 23C

Fig. 23A. Double sprocket on starting motor shown disassembled.

Fig. 23B. Roller clutch and gear **A** attached to clutch.

Fig. 23C. Gear **B** attached to starting motor armature shaft. Part shown by Fig. 23B fits over gear **B** and attaches to motor housing.

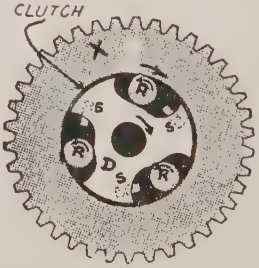

Fig. 23D

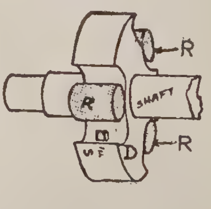

Fig. 23E

Figs. 23D (left) and 23E (right). Showing parts of the roller clutch.

A reference to Figs. 23A to 23E shows that the starting motor is geared, by means of reduction gears (A) and (B), to clutch member (D).

When starting the motor, the armature shaft is made to revolve by current from the battery; then (D) becomes the driving member and turns in direction shown by arrow point (D, Fig. 23D), causing rollers (R) to roll outward and clutch against the inner surface of sprocket (X), thus transmitting the power through (D) to (R), to gear (X), then by the silent chain to the crank shaft of the engine.

After the engine is thus started and the motor switch is off, then the engine drives sprocket (X), which becomes the driving member instead of (D). This reversed action causes rollers (R) to roll in an opposite direction and against spring stops (S), thereby releasing the clutching action to the inside of (X). The result is, the double sprocket over-rides clutch (D). Therefore when the engine is running, clutch (D) and gears (A) and (B) and the starting motor are idle.

Starting Motor Direct on Crank Shaft

On some cars, the starting motor is mounted directly on the crank shaft by having the armature built into the flywheel. This eliminates the necessity of gears or chains. The motor is a slow-speed machine.

An example of this construction is the U.S.L., as used on the Jeffrey (see Index under "U.S.L. motor-generator").

TYPES OF STARTING MOTOR SWITCHES

A foot-operated starting switch for the automatic "pinion shift" drive such as the "Bendix," is shown in Fig. 24. Contact is closed at (a) and (d) when (B) is depressed.

The foot-operated starting-motor switch is the one in general use, and while the construction may vary, the principle is much the same as in Fig. 24.

An electromagnetically-operated switch (Fig. 25) is used in connection with the "electrically operated automatic pinion shift" as shown on page 322. The operation of this switch is controlled by the push-button switch (Fig. 25A), mounted on the dash.

On many of the Delco systems the starting switch is eliminated by raising the starting motor brushes at the same time the gears are meshed with the flywheel (explained farther on, under the instruction on the Delco system).

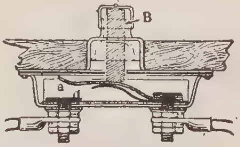

Fig. 24

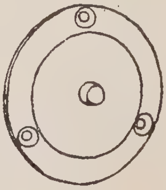

Fig. 25A

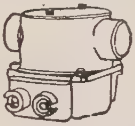

Fig. 25

Fig. 25. Electro-magnetically operated starting switch automatic pinion shift.

Fig. 25A. Push-button switch for magnetically operated starting switch.

RELATION OF THE STORAGE BATTERY TO THE STARTING MOTOR

The electric current is supplied to the starting motor from a storage battery. The voltage is usually 6 volts, but some systems use 12 or 18 volts, others 24 volts.

Direct electric current only, is used for starting motors.

The voltage of the storage battery can be ascertained, by counting the number of cells. For instance, if there are three cells, then the battery is a six-volt battery. If there are six cells, it is a twelve-volt battery. Each cell gives two volts—no matter how large or how small.

The amperage, or quantity of current consumed by a starting motor varies according to the condition of the engine. If it is cold and the oil is congealed, it will require more power to turn the crank shaft of the engine over, than if it is warm and flexible. The average length of time the starting switch is down is about 10 seconds. Therefore, with this great quantity of current being drawn from the battery, large heavy plates as well as large connections from one cell to the other are necessary. Large wire or cable for conducting the current to the motor is also necessary.

The average cranking current is 250 to 300 amperes when starting a cold stiff engine, and about 150 to 200 amperes when starting a warm flexible engine, for, say, one-half of a second, then 120 to 150 amperes after the engine flywheel is in motion. The voltage of a charged battery, when being used for starting, drops to approximately 5.4 volts. (This subject is further treated under the heading, "Storage batteries.")

The overload on the battery, it will be noted, is considerable. In fact, it is a temporary dead short-circuit for an instant, but, being only momentary, a good battery will stand it.

Charging the Battery

A starting and lighting storage battery, could be charged by removing it from the car and taking it to a charging station. But if this were done, owing to the great amount of current used, the size of the battery required, in order to last for a satisfactory period of time, would necessitate entirely too large a battery. Therefore a dynamo, also termed a "generator," is operated from the engine. When the engine is running the car at a speed of eight miles or more per hour, this generator generates electric current and charges the storage battery. The generator is treated in the next instruction.

Grounding the Battery

Sometimes the positive (+) terminal of the battery is grounded, and sometimes the negative (−) terminal is grounded. On many of the Westinghouse electric systems the (+) is grounded. On many of the Delco electric systems the (−) is grounded; that is, if the wiring system is a "single-wire grounded" system instead of a "two-wire insulated" system.

If the negative (−) terminal of the battery is grounded, then the negative (−) brushes of the motor and generator must also be grounded.

If the positive (+) terminal of the battery is grounded, then the positive (+) brushes of the motor and generator must be grounded.

STARTING MOTOR WINDINGS

The construction of a starting motor is similar to that of a generator, with the following exceptions:

The windings on the field poles are "series," or "series-parallel," wound instead of "shunt" wound, as on a generator. This gives greater **starting torque.**

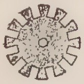

Fig. 1A

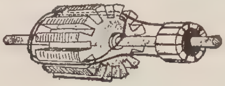

Fig. 1

The armature on a starting motor consists of many coils of very heavy wire, and is of a drum-wound type (Fig. 1). The core of the armature is made of laminated iron with slots for the coils (Fig. 1A). The armature winding on a two-pole starting motor is usually a "lap winding" with one coil per slot. The winding on a four-pole starting motor is usually a "wave winding."

The commutator has as many segments as there are coils. There is usually one coil for each slot on starting motors, and two coils per slot for generators.

The brushes rest on the commutator and conduct the current from the battery to the armature coils. The brushes are in series with the battery, field, and armature circuit.

Field poles: Starting motors usually have four poles and four brushes. A two-pole motor or generator is said to be of the "bi-polar" type, and a four-pole, of the "multi-polar" type.

When the multi-polar field is used the conductors on the armature, revolving between them, cut the magnetic lines-of-force many more times in one revolution, so that as the size of the machine increases the speed decreases—which is an advantage.

A Remy four-pole round-frame type of starting motor, with "series" field winding is shown in Fig. 2.

The circuit is from (+) of battery, through starting switch, through four field coils, to (+) brushes, through the armature, out (−) brushes, to (−) terminal of battery. This would be termed an "insulated," or "two-wire" circuit.

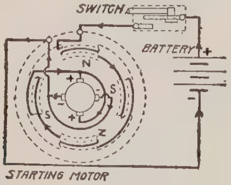

Fig. 2

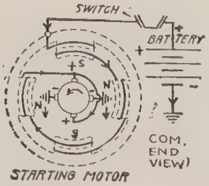

Fig. 3

Practically the same circuit is shown in Fig. 3 as in Fig. 2, except that the return circuit from (−) brushes to (−) grounded terminal of the battery is through a grounded return through the frame of the car.

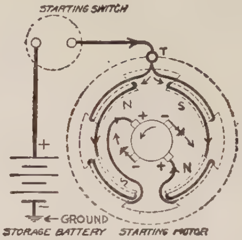

Fig. 4

A Remy four-pole starting motor is shown in Fig. 4, with a "series-parallel" field winding. The circuit is from (+) of the battery, through the starting switch, to (+) field terminal (T) on the generator. The current divides here; part going through the two-field coils on the left and right respectively, to (+) brushes, through the armature, out (−) brushes, to ground through the frame of the motor and car, to (−) terminal of the battery.

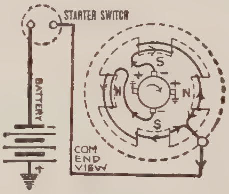

Fig. 5

The same "series-parallel" field winding is used in Fig. 5, but in this example, the (+) of battery is grounded instead of the (−). **The circuit is then** from (+) ground of battery, to grounded (+) brushes, through the armature, out (−) brushes, through the two-field coils on left and right, to the starting switch, to (−) terminal of the battery.

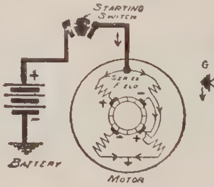

Fig. 6

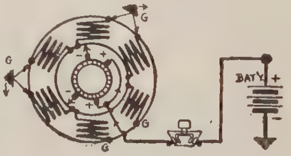

Fig. 7

A Delco four-pole round-frame type of "series-parallel" field winding is shown in Fig. 6. The circuit is from (+) of battery, through the starting switch, to the two-field coils, to (+) brushes, through armature, out (−) brushes, through the two-field coils, to ground to motor, through ground of the frame, to (−) grounded battery terminal.

A Simms six-pole round-frame type of "series-parallel" field winding is shown in Fig. 7. There are six field poles and six field windings and four brushes. One end of each field coil is grounded to the frame of the motor; the other ends connect to a (−) brush ring which connects to two (−) brushes.

The circuit: From (+) of battery, through the starting switch, through (+) brushes, through the armature, out (−) brushes to (−) brush ring, through the six-field windings in parallel, to ground (G), to the frame of the motor, to (−) grounded terminal of the battery. This is the type used on the 1920 Maxwell.

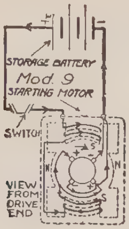

Fig. 8

A Remy rectangular frame "series" field-wound motor with two "active poles" with field windings on them and two "dead poles" without windings is shown in Fig. 8. Note the polarity of the poles.

The circuit: From (+) of battery, to the switch, to the top field coil, to the lower field coil, to (+) brushes, through the armature, out (−) brushes to (−) of battery.

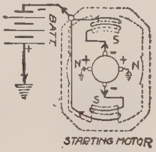

Fig. 9

A Remy rectangular frame motor "series-parallel" field wound is shown in Fig. 9.

The circuit: From (+) of battery, to ground, to (+) grounded brushes, through the armature, out (−) brushes, through the field coils, to (−) of battery; series-parallel circuit.

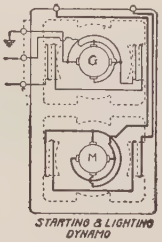

Fig. 10

A Remy "double-decker" motor and generator is shown in Fig. 10. The top circuit is that of a "shunt"-wound generator. The lower circuit is that of a starting motor "series" wound.

A motor-generator differs from Fig. 10, in that both the generator and motor field windings are on the same field poles, and only one armature is used. See Index under "Motor-generators."

Polarity of Field Poles

The polarity of the field poles of a motor is the same as that of the field poles of a generator. See Index.

PRINCIPLE OF A STARTING MOTOR

We will assume that there are two field poles wound as shown[1] in Fig. 14, so that the (+) current from the battery flows to series field winding (**F**), which would make a N pole of it, because the current from the battery flowing through the wire causes magnetic whirls in a direction which would make it a N pole (see Index under "Electro-magnets"). The battery (+) current is then to field winding (**F1**), which would make a S pole of it. Thus we have the main magnetic field flowing from N to S pole.

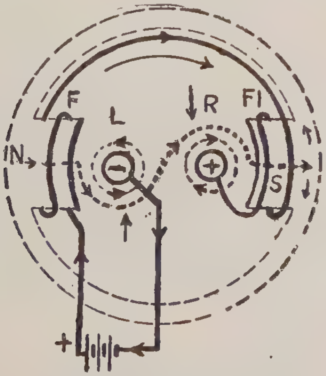

Fig. 14

The battery (+) **current** is then to field winding (**F**), to (**F1**), to armature coil (**R**), and the current is going in. Note that the magnetic whirl around this armature wire coil is the same direction at the top as the main magnetic field which is passing from the N to S pole, but at the bottom of (**R**), it is in the opposite direction.

After (+) battery current passes through this (**R**) side of the armature coil, it comes out at the wire (**L**) side, and the magnetic whirl at the top of (**L**) is in the opposite direction to the main magnetic field (from N to S pole), and at the bottom of wire (**L**), it is in the same direction.

Therefore we have two magnetic fields to deal with, one, the "armature magnetic field," which is set up around the armature wires (**L**) and (**R**), and the "main magnetic field," from the N to S pole.

Magnetic lines-of-force cannot flow in opposite directions in the same space at the same time. Thus the main magnetic field or lines-of-force from the N to S pole, pass under wire (**L**), and being in the same direction as the armature coil magnetic field lines under (**L**), they add to and strengthen the field below (**L**), and thus give a lifting effect to wire (**L**).

The main magnetic field then passes over wire (**R**), because the lines at the top of (**R**) are in the same direction, and thus the strength of the main magnetic field is added to that of the armature coil (**R**) field, giving a push-downward effect.

The lines-of-force can be considered as elastic bands that are always trying to shorten. Thus we see why the left side of the coil will be pushed upward and the right side will be pushed downward, which of course acts to produce rotation of the coil if it is pivoted and free to rotate. Thus in Fig. 14, we should have a clockwise rotation as indicated by the arrow.

---

[1] In this example we will omit the brushes and use only one coil of wire which is supposed to be wrapped around the armature, with end of coil (R) connecting with (+) brush, and the (L) end of the same coil with (−) brush. Also note that on Fig. 14 the (N) designating the North-pole end of the left field pole should be on the inner end instead of next to the frame, as the magnetic lines-of-force flow out of the N end, across the air gap, to the S pole end, through the frame, to the N pole end again. The magnetic circuit is treated farther on; see Index.

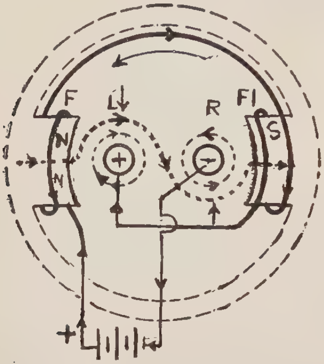

Fig. 15

Note that the wires are reversed from battery to armature coil in Fig. 15. Therefore the direction of the current flow from the battery in armature coil (**L** and **R**) is reversed, but not the main magnetic field. Thus the direction of rotation of the armature is reversed.

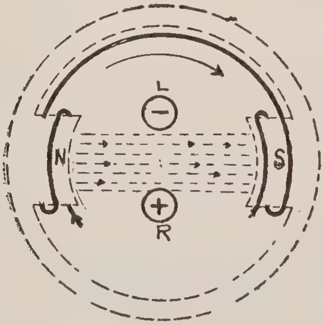

Fig. 16

If there was but one coil on the armature, as in Fig. 16, when (**L**) and (**R**) reached a vertical position, the main magnetic field or lines-of-force would pass directly across from the N to S poles, and if the coil should stop in this position there would be no effect of rotation, no matter how much current was in the coil, or how strong the magnetic field.

If two coils of wire (Fig. 17, **L** and **R** and **L1** and **R1**) are used, with their four terminals connected to a four-segment commutator (**17A**), then by placing the brushes (**B**− and **B**+) as shown, it is possible to obtain a continuous rotation. This is true because the sides of the coil (**L**) and (**R**) are in a horizontal position and are in the path of the main magnetic field and connected in the circuit by the brushes, whereas the sides of the coil (**L1**) and (**R1**) are in a vertical position and are disconnected from the circuit; but as rotation starts, then (**L**) and (**R**) would be disconnected from the brushes and (**L1**) and (**R1**) would be connected, thus establishing a continuous rotation.

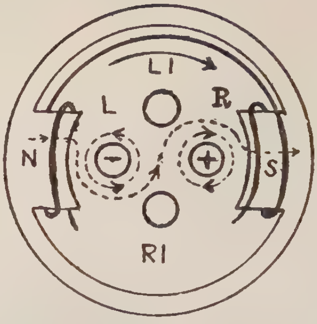

Fig. 17

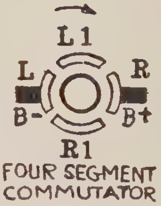

Fig. 17A

By using a number of coils and equally as many commutator segments the magnetic force acting on the coils will be more continuous.

This armature would be termed an "open-circuit" armature and would not be satisfactory for direct current, as only the coil connected by the brushes is in use.

A closed-circuit type of armature is more efficient, because all of the coils are used, one side being negative and the other side positive, or, in other words, the (+) brush would connect with the coils on one side of the armature and the (−) brush with the coils on the other side.

If a four-pole type, there would be four sections of coils connected to four brushes, two sections and two brushes being (+), and the other two sections and brushes being (−).

A generator can be operated as a motor, but is not as powerful because its field winding is of small wire and the same quantity of current would not pass through it as in a starting motor. It is wound for about 20 to 25 amperes.

A starting motor could be used as a generator, but would be of very low voltage, in fact impractical, because the wire is very large and intended for a very high quantity or rate of flow of current. It is wound for about 100 amperes or more.

To Reverse the Direction of Rotation of a Motor

From the explanations in connection with Figs. 14 and 15, it is seen that if the direction of either the magnetic flux or the current through the armature or field is reversed, the motor will revolve in the opposite direction. In order, then, to reverse the direction of rotation of a motor, we can **interchange** either the **field leads or the armature leads.**[1]

STARTING MOTOR BRUSHES

Thus two brushes are used on a two-pole motor or generator, and either four or two, on a four-pole.

If two brushes are used on a four-pole motor or generator, then they are placed 90° apart.[1] It is the usual practice however to use four brushes on a four-pole motor, owing to the heavy current they carry.

Brushes used on motors are made of a composition material something like carbon and graphite. Copper gauze brushes are also used on some of the starting motors, for reasons stated farther on. Generator brushes are made of carbon and have more resistance than motor brushes (see Index, under "Generator brushes").

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[1] See also, Index under "Generator brushes."

[1] A. L. Dyke, St. Louis, Mo., is in a position to furnish books giving data for testing starting motors, generators, etc., of all makes. Write for circular.

Remy Instructions on Starting-Motor Brushes

Copper gauze brushes are used on starting motors because they give the lowest contact resistance on the commutator and allow the maximum current to flow through the motor at a given voltage. This permits the motor to develop its maximum torque. Two brushes on each motor are impregnated with petrolatum to provide lubrication. Under normal conditions this should be sufficient for the life of the car. Copper gauze brushes should be fitted to the commutator by tapping them lightly.

It sometimes happens that a motor is operated under adverse conditions; perhaps the brushes are not properly seated or the rocker ring is not set in the position which gives the best commutation. In any of these cases there will be excessive sparking at the brushes and the commutator will become hot. This will cause the lubricant to melt and run out of the brushes. When this occurs there will be a cutting and burning action that will materially shorten the life of both commutator and brushes.

In order to take care of these conditions it is advisable to use **brushes made of a mixture of copper and graphite.** These may reduce the maximum torque of the motor, but the difference is so slight that it can scarcely be noticed. They will give better commutation and are self-lubricating.

When new brushes are required at short intervals by a starting motor, examine it carefully to make sure that the trouble is not due to a shorted field or a damaged armature. Remember that any kind of trouble in a starting motor will usually cause damage to the commutator.

Copper-graphite brushes should be ground in with sandpaper in the same way that generator brushes are seated. The brushes should be located approximately on electrical neutral, which will be found at the center line of the poles. Moving the brushes in a direction opposite to the rotation of the armature will improve commutation, but will decrease the torque of the motor.

Never undercut the mica in starting motor commutators. (The subjects of undercutting mica and seating brushes, etc., are explained under a separate instruction farther on.)

Setting brushes on motors. Motor brushes should be set at the position of least sparking when the machine is carrying full load. This position will be located a short distance back (in the direction opposite to rotation and the reverse of the direction for generator brushes) from the neutral plane.

To set motor brushes in the correct position, place the machine on block test and apply a load approximately equal to that which it is normally required to carry. (This load will be about 40 lbs. on a pulley of 6″ diameter, or 10 ft. lbs. for starting motors; see Index under "Torque test of a starting motor.") The speed of a motor is greatest when the brushes are at the neutral plane and decreases as they are moved away from that position.

The voltage of a generator and speed of a motor can be changed considerably by moving the brushes, providing the machine is not so heavily loaded as to cause it to spark badly.

PARTS OF A STARTING MOTOR (N.E. USED ON THE REO AS EXAMPLE)

As an example of **the internal construction of a starting motor,** the North-East "model R" starting motor, as used on the Reo "models T6 and U6" car is shown.

The starting-motor internal construction, so far as the armature, the commutator,the brushes, etc., are concerned, is very much the same on all starting motors. Thus Fig. 18 will give a good general idea as to the location and name of parts. Note the heavy coarse winding on the armature and field coils, which is necessary in order to carry the heavy current.

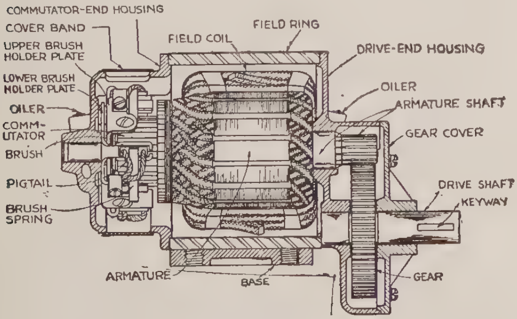


Fig. 18. Four-pole, straight series-wound starting motor

The drive method in general use is the "Bendix drive system," through the flywheel, as explained on page 319.

On the Reo starting motor (Figs. 18 and 18A), the drive method is through the transmission shaft, through the clutch to the flywheel. The gear-shift lever, of course, must be in neutral position.

The construction and action of the drive system used on the Reo is as follows:

The starting motor (Fig. 18) is mounted on the right-hand side of the transmission where it can be reached by raising the floor board. It cranks the engine through a chain drive operated in conjunction with a ratchet engagement (Fig. 18A) on the universal joint shaft.

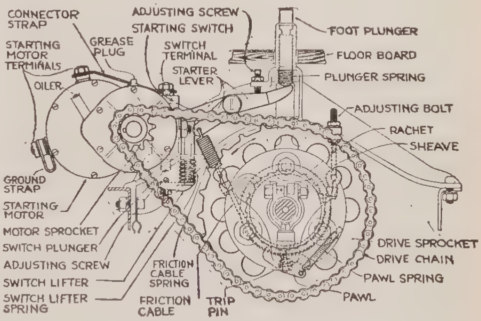


Fig. 18A

The ratchet is controlled by the starting switch pedal, so the motor is in action only during the actual period in which the starting switch is closed.

Under average conditions it will crank the engine at a crank-shaft speed of approximately 100 r.p.m., depending upon the condition of the battery. The cranking speed will of course be materially reduced in extremely cold weather, or in the case of a discharged battery.

Starting Action

To crank the engine by means of the starter, first make sure that the clutch pedal is in the driving position and the **gear-shifting lever is in neutral** (the starter cannot be operated with the gears in mesh), and **be sure to retard the spark lever fully.**

Next turn on the ignition and press down the starter push-rod. Hold the starting switch closed until the engine begins to run on its own power, and then release it at once. Finally, advance the spark to the running position and adjust the supply of gas as required.

Depressing the foot plunger (Fig. 18A) puts the starting ratchet into engagement and at the same time the switch is closed to complete the starting circuit.

The starting lever is forked, one arm operating the switch contactor and the other acting upon the friction cable.

When the starter push-rod is depressed by the driver's foot, the friction cable is thus tightened so as to retard the starter sheave. This allows the trip-pin to enter its slot in the sheave and cause the pawl to engage with the ratchet, whereupon the universal shaft and the starting sprocket are made to rotate as a unit. When the engine "picks up" and begins to run under its own power, the ratchet will be revolved faster than the sheave and sprocket, and the pawl will be thrown out of engagement. As soon as this occurs the starter push-rod should be released at once to remove the tension from the friction cable and also to open the switch contacts. This entirely disconnects the starting motor mechanically as well as electrically, and permits it to remain inoperative until the next time it is called upon to crank the engine.

The starter mechanism should be kept adjusted so that the friction cable has just enough tension to retard the sheave properly at starting and at the same time avoid holding the ratchet in partial engagement after the starter push-rod has been released. This adjustment is accomplished by modifying the tension on the friction cable by means of the nut and stud provided for the purpose. The need of adjustment will be evidenced by the starting motor tending to run without turning the universal shaft or by its starting the shaft with a severe pound, indicating that the pawl does not engage as quickly as it should.

The generator, a two-pole, third-brush regulated machine, and ignition are separate units. The generator is driven through a flexible coupling, similar to a magneto drive, on the left-hand side of the engine.

The ignition unit is mounted on the rear of the engine and is driven at cam-shaft speed from the cam shaft.

Delco Starting Motors

The Delco starting motor is treated under the Delco instruction.

STARTING-MOTOR TROUBLES

Starting-motor troubles, both "electrical" and "mechanical," are treated under "Digest of Troubles" (see Index). A few of the common starting motor troubles are given below.

If the starting motor fails to start, the trouble is usually due to one of the following causes:

1. **Battery almost or entirely exhausted,** the indications of which are that the lights burn dimly, especially when attempting to start the engine. Test battery for specific gravity and recharge from an outside source.

   Where a car is used a great deal in cases where frequent cranking is necessary, or where it is run at nights and very little in the day time, the probabilities are that the generator will not keep the battery fully charged. The generator should be adjusted for its highest charging rate under these conditions, and it may be necessary to have it recharged at an outside source occasionally, especially during cold weather when the engine is cold and stiff, since under these conditions it requires more current for the motor to start the engine.

2. **Loose connections or open circuit:** Loose connections would cause the motor not to operate at its full capacity, as the loose connection would cause resistance to the flow of current.

   Loose connections would include examination of such parts as the terminals of the battery, grounded battery terminal to the frame of the car, motor terminal, grounded connection inside of the motor where it terminates with a screw, and the switch connections.

   Loose connections at the brush terminals and brushes not seating properly, or worn short, are common troubles with starting motors which have been run for a long time.

   An open circuit would of course prevent the starting motor from operating at all.

3. **Starting switch not making proper contact:** The switch connections should be examined. When the switch connections are suspected, connect a jumper across the switch terminals. If the motor spins, the starting switch is defective inside. Should the motor fail to start, then you will know the trouble is elsewhere.

4. **Dirty or greasy commutator:** This would prevent the starting motor from working up to its capacity.

   See Index under "Commutator troubles." Oil or grease should never be put on the commutator.

5. **Inoperative motor:** Some of the causes would be, run-down battery, brushes not seating, open circuit at terminals or ground connections, or switch.

6. **The Bendix drive may be out of order.** See page 320.

Testing Starting Motors

Torque-test explanations and other tests can be found by referring to the Index.

INSTRUCTION No. 32

THE ELECTRIC GENERATOR: Construction and Principle; Armature Windings

PURPOSE OF THE GENERATOR

The purpose of the electric generator on an automobile **is to supply direct electric current for charging the storage battery,** for lights, for ignition, and also for the electric horn, when it is being run fast enough to generate sufficient voltage to close the cut-out points between the generator circuit and the battery circuit.

If the battery is a three-cell, six-volt battery, **the generator voltage** should be slightly more than the battery, or about 6.5 before the cut-out points would close. The generator generates this voltage, on an average, when the car is driven at about 8 miles or more per hour on high gear, and the current passes through the ammeter on the "charge" side.

When the generator is driven at speeds less than this, then the cut-out points remain open and the ignition, lights, and horn are dependent upon the battery for its electric supply. In this case the current passes through the ammeter on the "discharge" side.

The battery always supplies the electric current for the starting motor to crank the engine. The current is never taken from the generator for this purpose, for two reasons. One reason is that the engine is idle and not running when it is desirable to use the starting motor, and thus generator is not generating any current at all. The second reason is that the generator seldom delivers over 22 amperes at the most, whereas the starting motor requires from 120 to 250 or more amperes to start the engine.

The charging current from the generator to the battery is taken through the ammeter, but the current from the battery to the starting motor is never passed through the ammeter, because the ammeter on the cowl board seldom reads above 30 amperes, and thus would be burned out.

Water Analogy of the Electric System

In order to simplify the electric system on an automobile, a water analogy is given below.

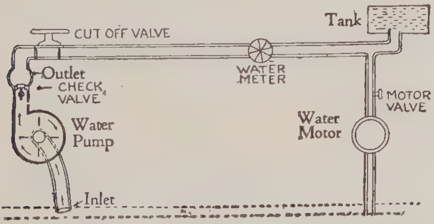


Fig. 1

The water pump (Fig. 1) is driven by some mechanical force and draws water from a source at the inlet. The water is forced through a check valve into and through the pipe, through the water meter to a tank. The check valve prevents the water flowing back to the water pump when it is not in operation, or when it is not running at sufficient speed to force water to the tank.

A water motor can be driven from the pressure of water from the tank.

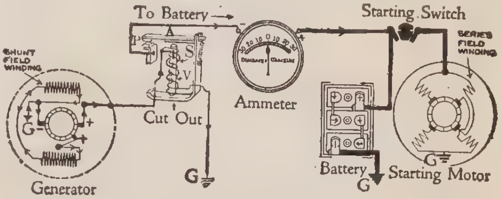


Fig. 2

The electric system (Fig. 2) is similar. The generator generates electricity from the magnetic lines-of-force at the field poles, around which are the shunt field windings; it then forces the electricity through the wires, through the cut-out (acting as a check valve), through the ammeter which shows the rate-of-flow of electricity in amperes, in the same manner that the water meter shows the rate-of-flow of water through the pipe, thence to the storage battery, which is similar to the tank.

The cut-out prevents the battery from discharging back into the generator.

The starting motor (like the water motor) can be operated by current from the battery (it cannot however be operated from the generator).

A point which must be considered, is **the speed of the pump.** If its speed was too great, it would produce a greater pressure, and consequently a greater rate-of-flow of water. This could be regulated with an automatic governor.

Just so with the generator. If the **speed of the generator** were increased, the e.m.f., or pressure, increases, and consequently the rate-of-flow of current in amperes is greater. The probabilities are that at very high speeds the voltage (e.m.f.) generated would be so great that the lights would be burned out. For this reason an action similar to a governor action is made use of on generators, in order to **regulate the output of the generator,** or to keep the voltage constant, or the amperage constant, or both, at various speeds of the generator, as it increases or decreases in speed, when the engine is speeded up or slowed down.

A mechanical governor was used on some of the early models of generators, but is now practically an obsolete method, and instead, a third-brush method is now more generally used, as will be explained farther on.

The regulation method as used in the generator (Fig. 2) is a third-brush method of regulating the output of the generator (see lower brush connecting with the field winding. This principle is explained farther on).

The subject of the regulation of a generator, or methods of governing the output at high speeds, is therefore one of considerable importance and will be treated farther on.

ELECTRICAL CIRCUITS; THEIR RELATION

Before proceeding farther, it is advisable that the reader clearly understand the circuits of the electrical system.

The circuit of a typical electric system is shown in Fig. 3. When starting to trace an electric system, always divide the system into the parts mentioned below.

When starting to trace one of the "eight" circuits, begin with the source of electric supply. For instance: the "generator field circuit," the "cut-out voltage circuit," the "battery charging circuit," would each begin with the (+) brush of the generator.

The "starting-motor circuit" would begin with the (+) terminal of the battery, and likewise the "ignition" and "horn" circuits, unless the engine was running at such a speed that the current for "ignition," "lights," and "horn" would be taken from the generator, in which instance, begin with the (+) brush of the generator.

The several circuits are:

1. Generator "field circuit."
2. Cut-out "shunt or voltage circuit."
3. Battery "charging circuit."
4. Battery "discharge circuit" back through cut-out.
5. Starting "motor circuit."
6. "Ignition circuit"; primary and secondary.
7. "Lighting circuit."
8. "Horn circuit" (not shown in Fig. 3).

Generator Circuits

Taking the generator field circuit first, always start with the (+) main brush of the generator. If the brushes are not marked (+) or (−), then look at the battery, as it usually indicates which terminal is grounded. And we know that the current from the generator to charge the battery must come from the (+) brush and pass into the (+) terminal of the battery, because direct electric current always flows from (+) or positive.

Therefore, if the (+) terminal of the battery is grounded, then the (+) brush of the generator must be grounded. In this example (Fig. 3), the (−) terminal of the battery is grounded at (G2); therefore the (−) brush of the generator is grounded at (G).

When tracing the field circuit, the regulation generator system is always included in this circuit. For instance, the generator in Fig. 3 uses a "third-brush regulation" system (explained farther on), and the third brush (lower brush on the right) always connects with one end of the field windings. The third brush may be connected with the (+) or (−) end. In this instance it is connected with the (−) end.

The field circuit therefore starts with the (+) main brush of the generator, through both shunt field windings (this is a two-pole generator), to the (−) third brush, through the armature to the (+) main brush (B). This completes the field circuit. The generator field winding is a shunt-wound generator.

Purpose and Principle of the Cut-Out

The cut-out shunt or voltage winding circuit is from the (+) main brush to the fine wire voltage winding (V), to ground (G1), to the frame of the generator or car, to the grounded (−) main brush (G).

This cut-out voltage winding (V) consists of very fine wire wrapped around a soft iron core (C). Its purpose is to magnetize the core (C) so that the core will draw the iron cut-out armature blade (A) to it, thus closing the points (P), so that the charging current can flow from the (+) brush of the generator to the (+) terminal of the battery.

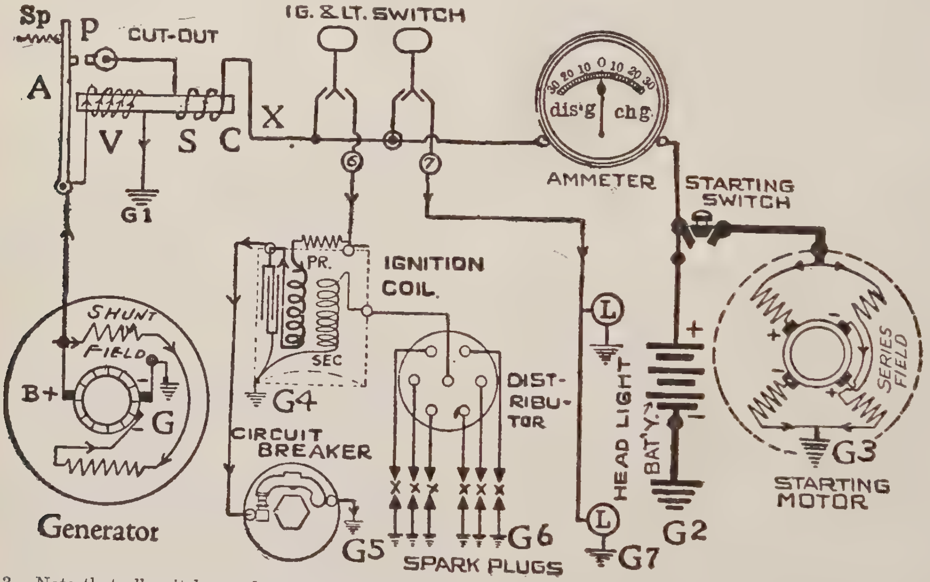
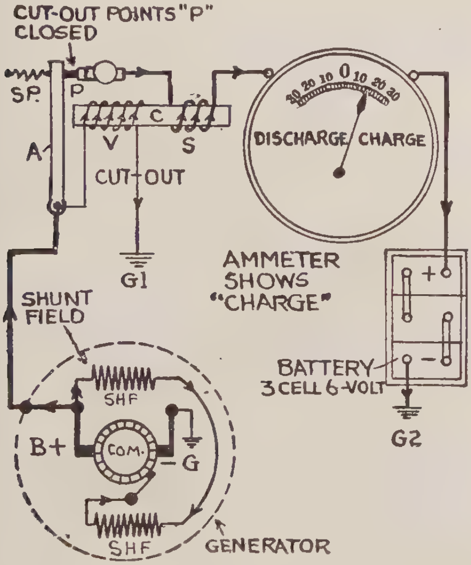


Fig. 3. Note that all switches and cut-out points (P) are open. The ammeter is at (O). Current is not flowing from the battery or generator. When current is being taken from the battery for ignition and lights, the ammeter needle goes to the "discharge" side. The ammeter is not connected with the starting motor circuit at all. When the generator is charging the battery, the current to the battery passes through the meter, and the needle goes to the "charge" side.

The cut-out voltage winding (V) is wound with such a size and number of layers and turns of wire, that it does not create enough magnetic force to draw the blade (A) against the tension of the spring (Sp.) until the generator speed is such that its voltage is higher than that of the battery, which is, in this example, about 6.5 volts.

Note that the current passes through this winding (V) whenever the generator is generating any current at all. Since the winding consists of very fine wire, however, the amperage is very slight.


CUT-OUT POINTS "P" CLOSED

AMMETER SHOWS "CHARGE"

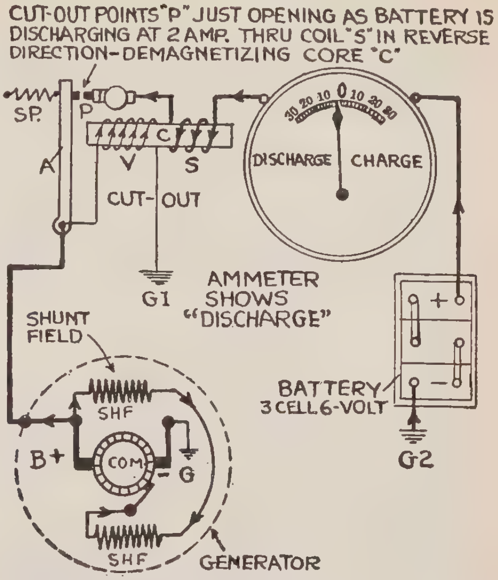
Fig. 4. Note that cut-out points (P) are now closed; therefore current from the generator is passing through ammeter to battery, and the needle is on the "charge" side of (O). About 10 to 15 amperes is usually the highest rate when the generator is running at 1,000 r.p.m. or more. 22 amperes is the extreme limit for which a generator can be adjusted, and with some generators 15 or 16 amperes is the limit.

Battery charging circuit: When points (P) on the cut-out are closed (Fig. 4), the path is from the (+) main brush (B) of the generator, through the closed points (P), through the series or current coil (S) of the cut-out, through the ammeter, which now shows the needle on the "charge" side of (O), to the (+) terminal of the battery, out to (−) terminal of the battery which is grounded (G2), to the (−) main grounded brush (G) of the generator.

Battery discharge circuit: If the generator speed drops to a point where the voltage of the generator is less than the voltage of the battery, the circuit would then be (see Fig. 5) from (+) of the battery, through the ammeter in a reverse direction to what it was in Fig. 4, thus causing the needle to go to the "discharge" side (showing about 2 amperes discharge), thence through series winding (S) of the cut-out in a reverse direction, through points (P), to the (+) main brush of the generator, through the armature to the (−) main brush, to ground (G), to the (−) grounded terminal of the battery (G2). The points (P) will instantly open when this circuit is completed.

The reason why the discharge through the series coil (S) of the cut-out is necessary, is to insure a quick demagnetization of the core (C).

Note in Fig. 4, that when current is flowing through the fine wire voltage winding (V) and the coarse series winding (S), the direction of the flow of current is in the same direction around the core. Thus a very strong magnetic pull is exerted by the core (C) with (A), and the polarity of one end of the core is N and the other end S.


CUT-OUT POINTS "P" JUST OPENING AS BATTERY IS DISCHARGING AT 2 AMP. THRU COIL "S" IN REVERSE DIRECTION-DEMAGNETIZING CORE "C"

AMMETER SHOWS "DISCHARGE"

Fig. 5. Generator speed is low, consequently the voltage of the generator has dropped to a lower voltage than the battery. The battery discharges for an instant through the ammeter and cut-out series coil (S) in opposite, or reverse direction, at about 2 amperes, thus demagnetizing core (C), and opening points (P). Note that the needle of the ammeter is on the "discharge" side of (O) during this operation. It will immediately go to (O) if the engine is stopped. If the engine is kept running (slowly) with ignition switch on, then the amount of current from the battery for ignition will be indicated on the "discharge" side. Or if the light switch is "on," the amount of current from the battery for the lights will be indicated on the "discharge" side. The generator, however, is cut out of the circuits at points (P).

When the current from the (+) terminal of the battery passes back through series coil (S) in a reverse direction, as shown in Fig. 5, this causes the series coil (S) to "buck," or oppose, the current flowing in the voltage coil winding from the generator, which is still flowing in its original direction. But, as the generator speed is low, the influence of the coil (V) is weak, with the result that coil (S) tends to change the polarity of the core (C), thus demagnetizing it, and causing a quick release of blade (A). For this reason the cut-out is often termed a "reverse current cut-out."

Starting-Motor Circuit

The starting motor circuit is never from the generator. The generator never delivers, at its highest output, over 22 amperes, and at times the starting motor requires from 150 amperes at normal conditions, up to 450 amperes or more if cold and stiff. This great overload on the battery is only momentary when first turning the engine over. After the engine turns over, the current is less, dropping to about 120 to 200 amperes.

Thus the starting motor never takes its current from the generator. The generator charges the battery and the battery supplies current for the starting motor.

Likewise the ammeter on the dash is never connected in the starting motor circuit, as it seldom reads higher than 30 amperes.

The starting motor circuit (Fig. 3) is from the (+) terminal of the battery, through the starting switch, through the "series-parallel" field windings, through the (+) brushes, through the armature, to the (−) brushes, to ground (G3), to (−) grounded terminal of the battery (G2).

Note that the field circuit of this starting motor is what is termed a "series-parallel" field circuit. There are four poles and four field windings. The current divides at the top and passes through two field coils, to the (+) brushes, through the armature to the (−) brushes, thence through the two lower field coils to ground (G3), to grounded (−) terminal of the battery (G2).

Ignition Circuit

Ignition: The ignition switch (6), which is shown open in Fig. 3, would first be closed. The circuit would then be from the (+) terminal of the battery (if the generator is running slow). In such cases, the ammeter would indicate a current "discharge" taken from the battery.

If the generator is running at a speed at which it is charging the battery, then the current for the primary ignition circuit would be taken from the generator, and the ammeter would be on the "charge" side.

The ignition primary circuit is, then, from the (+) terminal of the battery, or the (+) brush of the generator, to the closed ignition switch, to (6), to terminal on the coil, through the ignition resistance unit, through the primary winding (PR), to the coil terminal, to the insulated contact on contact-breaker, to the movable arm, to ground (G5), to the (−) ground of the battery (G2), or the generator (G).

The condenser is in the coil, and is connected across the grounded terminal (G5) and the insulated terminal of the contact-breaker.

The ignition secondary circuit is from the secondary winding of the coil (SEC), to the distributor, to the spark plugs, through the spark-plug gaps (X), to ground of the engine (G6), to ground of the coil (G4), to the secondary winding (SEC).

The lighting circuit is similar to the ignition circuit. The lighting circuit and ignition circuit almost always start at the (+) side of the ignition and lighting switch and circuits are traced from that point. The circuit would be (in Fig. 3) from the (+) terminal of the generator or battery, through the closed lighting switch, to (7), to the two lamps connected in "parallel," to ground, to (−) ground of the battery (G2), or (−) ground of the generator (G). See Index for "Wiring diagrams."

Floating a Storage Battery on the Line

This term refers to **the storage battery used in connection with a generator,** where the storage battery supplies current for lights, when the generator is running slow or not running at all, as explained heretofore.

The generator charges the battery and supplies current for lights when running at sufficient speed. If the speed of the engine is varied, the battery would be in use part of the time and part of the time the generator; the battery would then be "floating."

The "cut-out" would be changing from one to the other, owing to the variable speed of the engine.

Ammeter Indications

The ammeter is always placed in series with the circuit, and in Fig. 3 it would indicate on the "discharge" side of (O) when current is taken from the battery for ignition, lights, horn, or discharge back through the cut-out. When current is flowing from generator to battery, it would indicate on the "charge" side the amount of current flowing to the battery.

For instance, examples of the action of the ammeter will be given as follows:

If starting motor switch is closed: The ammeter would not be in this circuit at all, and is never placed in this circuit unless a "shunt" is used with it (explained farther on).

If the engine is idling, or not running at all, and lights and ignition switches are closed, and cut-out points (P) are open (Fig. 3): In this case the battery would be supplying the current and would be discharging. Thus current from the (+) terminal of the battery would flow through the ammeter to the ignition and light switches, through the circuits, to the (−) ground of the battery (G2), and in doing so, it would cause the ammeter needle to go to the left of (O), or the "discharge" side, and would indicate the amount of current being discharged or taken from the battery for ignition and lights. For instance, if the ignition consumed 2 amperes and the lights 5 amperes, the needle would indicate 7 amperes on the "discharge" side of (O).

Engine driving generator at a speed where generator is charging battery and cut-out points (P) are closed, and light switch open: We will assume that the maximum amount of current flowing to the battery from the generator is, at the rate of, say, 15 amperes. The battery would then be receiving a "charge" instead of "discharging"; thus the direction of the flow of current would be from the (+) brush of the generator, through the ammeter, to (+) of the battery in an opposite direction to what it did flow through the ammeter when discharging from the battery. Therefore, the ammeter needle would indicate on the "charge" side of (O) the amount of current flowing to the battery, or 15 amperes.

The ignition switch connection being at the left of the ammeter, the current required for ignition is, say, 2 amperes; therefore the actual amount of current taken from the generator would then be 17 amperes, but only 15 would show on the ammeter.

Note. All ammeters are constructed so that the (+) terminal of the ammeter is connected with the (+) terminal of the source being tested, and the needle will then move in one direction on the scale. If connections are reversed, the needle will read in the opposite direction. On ammeters used for testing purposes, the (O) (zero), is usually placed at the extreme left of the scale, and when connected properly the needle will pass to the right; if connected wrong it will pass to the left, thus indicating that the connections to the ammeter are not correct.

On dash ammeters, however, as shown in Figs. 3, 4, and 5, the (O) is placed in the center of the scale, so that it will indicate if a "charge" of current is going to the battery, or if the battery is being "discharged."

The "discharge" side on the dash-ammeter (Figs. 3, 4, and 5) is on the left, and the "charge" side is on the right of (O). This, however, varies, as some manufacturers reverse the order.

Engine driving generator at a speed where generator is charging battery, and cut-out points (P) are closed, and light switch is closed: In the previous example we assumed that the ignition switch was "on" and the light switch "open" and that 15 amperes was passing to the battery from the generator, after giving 2 amperes to the ignition, which would be indicated on the "charge" side of the ammeter. Therefore, if we throw "on" the light switch, and if the lights consumed, say, 5 amperes, then instead of the battery receiving 15 amperes, it would be cut down to 10 amperes. Thus 10 amperes would be indicated on the "charge" side as the amount of current flowing to the battery from the generator.

Take the case where the generator is running at sufficient speed to charge the battery, and cut-out points (P) are closed, and the ignition switch is closed but the light switch is open. Let us assume that the generator is running at sufficient speed to deliver 17 amperes. Then, the ignition switch being "on" and ignition consuming 2 amperes, 15 amperes would pass to the battery, and this would be indicated on the "charge" side of the ammeter.

If the light switch is now closed, and the lights take 5 amperes, then the rate of flow would be cut down to 10 amperes. Therefore 10 amperes would be indicated on the ammeter.

The point to grasp in connection with the foregoing explanations, is that when current is supplied from the battery, the more current that is taken from the battery for ignition, lights, etc., the greater the indications on the ammeter on the "discharge" side, because the battery is capable of giving a discharge supply, up to its capacity.

On the other hand, when current is taken from the generator, its output is limited by the speed of the generator, and if its maximum output is, say, 17 amperes, then as the different circuits are thrown "on," they reduce this maximum amount of current which would pass to the battery accordingly. Thus when lights are thrown "on," the "charge" side of the ammeter will indicate less current flowing to the battery.

The ammeter is placed, sometimes at one position and sometimes at another position, but is usually arranged so that as current is consumed from the battery for all purposes except the starting motor, it indicates the total amount on the "discharge" side of the ammeter and also shows the net amount of current flowing to the battery from the generator on the "charge" side. See Index for "Wiring diagrams"; see also the instruction on the Delco system for the location of the ammeter on various systems.

Suppose, however, that **the ammeter was placed at (X) on the left side of the ignition and the light switch.** What would the indications be?

Take the case where the **engine is idling and the cut-out points (P) are open,** with ignition and light switches closed. The "discharge" from the battery for both ignition and lights would not be indicated on the ammeter at all. The needle would stand at (O) because the circuit through the ammeter would be open at the cut-out points (P).

PRELIMINARY EXPLANATION OF THE CONSTRUCTION OF A GENERATOR

A round-frame, "bi-polar" (two field poles) **direct current** (dynamo) **generator** is shown in Fig. 6. The cut-out shown mounted on the generator is sometimes placed in the generator or on the inside of the dash.

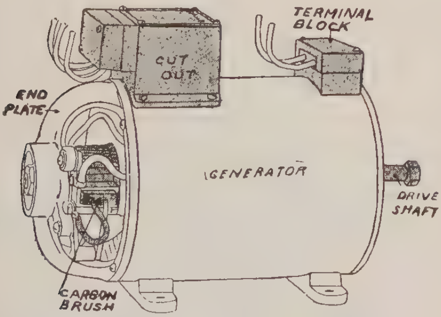


Fig. 6. A round frame bi-polar type of generator. Commutator and brush cover removed.

There are two "field poles" (PP) on the generator, shown in Fig. 7, and it is thus termed a "bi-polar" type. Around the field poles are windings. When the armature revolves, current flows through the field windings from the armature, and thus causes the field poles to become magnetized just like electro-magnets. Therefore the field poles (PP) are "electromagnetized."

When the field poles become magnetized, the lines-of-force pass from one pole to the other, and as the armature revolves between the poles, the lines-of-force are cut and current is generated.

The brush holders and brushes are mounted on the end of the generator, as shown in Fig. 8. The brushes rest on the commutator, as in Fig. 6.

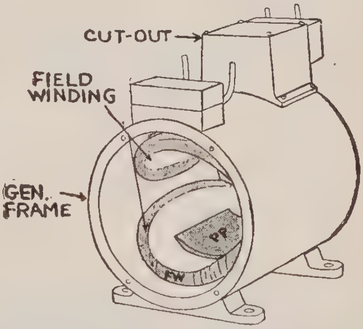


Fig. 7. End plate at drive end removed, showing field-coils or windings and one of the pole pieces (PP).

There are two carbon brushes on a bi-polar generator (placed 180° apart) and four brushes (or two brushes placed 90° apart) on a four-pole or "multi-polar" generator.

There are usually four field poles on a starting motor, due to the fact that considerable power is required and the pulling power of the "electro-magnetized" fields must be very strong.

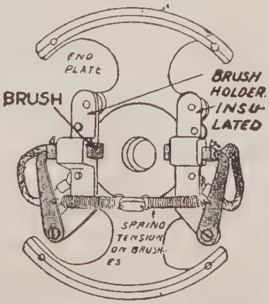


Fig. 8. The brush holder and brushes.

Armatures for generators are of "drum" type of construction. The "shuttle" type armature, as used on the magneto, cannot be used with a generator, as it generates and delivers "alternating" current, whereas only "direct" current can be used to charge a storage battery.

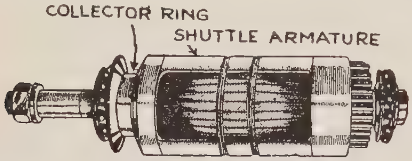


Fig. 9. A "shuttle" type of armature used on magnetos, which generates "alternating" current. Note that instead of a commutator, there is a "collector ring." Not suitable for a generator for charging a storage battery, used only on magnetos.

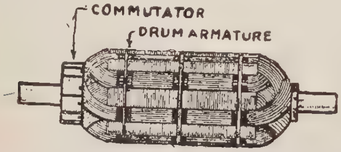


Fig. 10. A "drum" type of armature used on "direct" current generators which is suitable for charging batteries. All generators produce alternating current, but the "commutator" with two or more brushes direct the flow in one direction, thus establishing a positive (+) and negative (−) terminal at the brushes, whereas the current taken from a "collector ring" on a shuttle type armature alternates from positive to negative and vice versa.

All generators, generate alternating current, which is converted into direct current at the commutator.

The commutator has as many copper segments as there are coils on the armature. On many generators there are two coils wound in each armature core slot. There are thus twice as many commutator segments as slots.

Parts of an Electric Generator

A sectional view of a typical direct current generator is shown in Fig. 11.

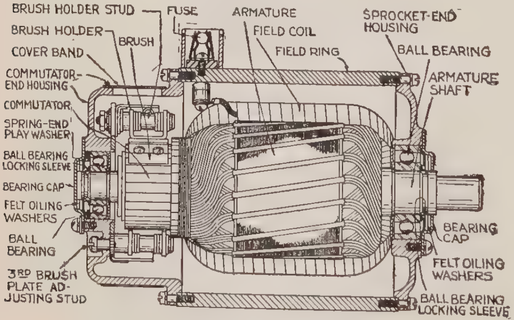


Fig. 11. Parts of the N. E. generator.

The parts are given in the illustration. A "drum" type of armature with a commutator is used.

Single-Unit, Two-Unit, and Three-Unit Electric Systems

A single-unit system (one type of the Delco system, as an example) combines a starting motor, generator (direct current), and ignition all in one machine. See Fig. 12.

The one armature and one set of field magnets serve for both the motor and generator. Thus it is termed a "motor-generator." There are two separate windings and two commutators, however.

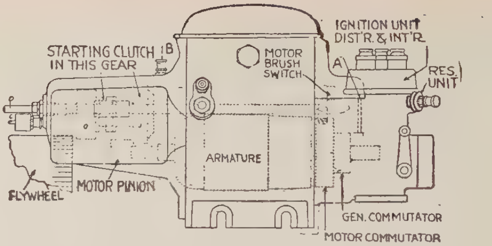


Fig. 12. Parts of the Delco motor-generator; a "single-unit" system.

Ignition timer and distributor are mounted with this unit, but the distributor-drive spiral gear is not attached to the armature shaft, as would naturally be inferred, but is connected to the pump shaft, or shaft driving the generator. In other words, if connected to the armature shaft the action of the clutch used in connection with the generator drive (not shown above) would affect the timing operation.

A two-unit system is where there are two units composing the electric system of starting motor, generator, and ignition, arranged as described below.

Where the starting motor and generator are combined in one unit and the magneto (or coil and distributor) for ignition in another, it is called a "two-unit" system; so also, when the starting motor is in one unit, and the generator and ignition in another, this is also a "two-unit" system.

The three-unit system is where the starting motor, generator, and ignition unit are separate from each other.

Methods of Driving the Starting Motor, Generator, and Ignition Unit

The generator must run when the engine runs, because it is necessary to recharge the battery and supply current for lights and ignition. Current for starting the motor, and also for the ignition to start the engine is provided by the battery.

The amount of current the generator supplies to the battery depends upon the number of lamps burning, and the speed of the engine.

Drive methods: The electric generator can be operated by belt, chain, shaft, or gear drive from the engine, and supplies electric current to charge the storage battery, as well as for lights, ignition, etc.

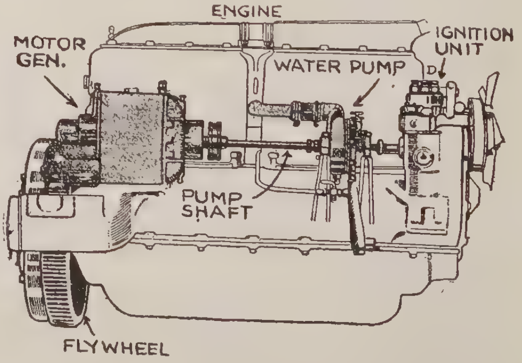


Fig. 13. Generator and motor combined. One armature serves for both. Generator driven from pump shaft, also distributor and timer. Starting motor drives through the flywheel. Delco system used on Hudson and others. This system would be termed a "two-unit" system, because the ignition unit is separated from the motor and generator.

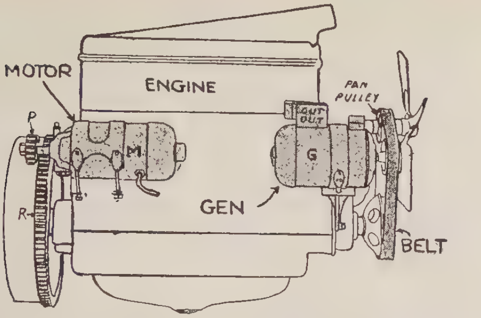


Fig. 14. **Generator driven by belt** which drives the fan. Starting motor is the "automatic Bendix drive," which drives through pinion (**P**) to flywheel gear (**R**). This system would be termed a "three-unit" system. The ignition is driven from cam shaft separately.

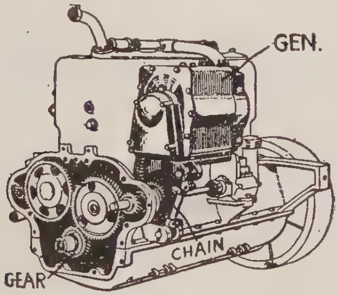


Fig. 15. **Generator, driven by gears and silent chain from crank shaft.** Ignition and starting motor (not shown) are separate units. This would be termed a "**three-unit**" system.

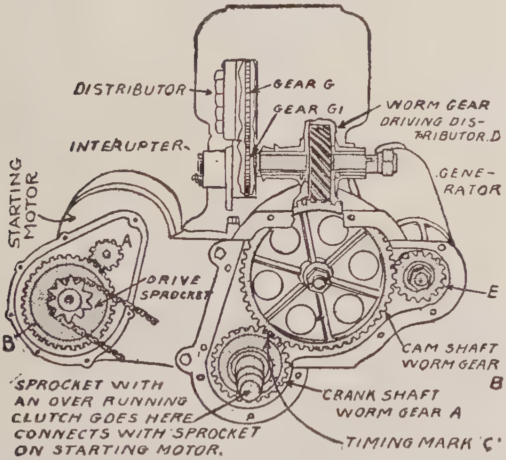


Fig. 16. Driving the generator from cam shaft, also distributor and "interrupter," but independent of each other. The starting motor drives "through the crank shaft" by a silent chain and an over-running clutch. This system is a "**three-unit**" system formerly employed by "Studebaker Six."

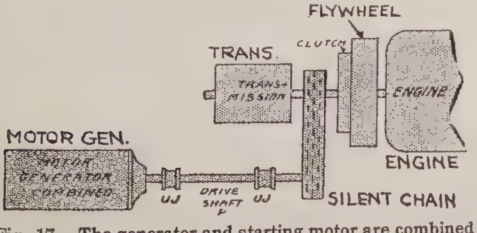


Fig. 17. **The generator and starting motor are combined in one.** Drive is through transmission shaft by means of a silent chain. The ignition is independent. This is a "**two-unit**" system, formerly used on the Chalmers.

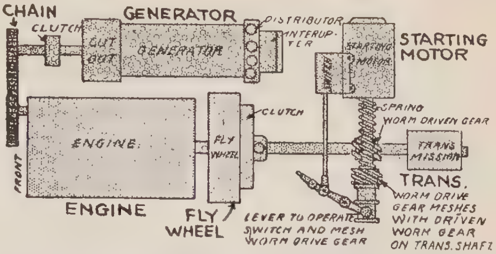


Fig. 18. **Generator driven by gear from crank shaft.** The starting motor drives through the transmission shaft. Ignition is the "interrupter" type mounted on the generator system formerly used on the Reo. A "**two-unit**" **system.**

Fig. 23, page 324, shows an early model Gray & Davis separate motor and generator, as used on the early model Overland cars. Note that the starting motor is mounted above the generator.

The generator is driven by a silent chain from the double sprocket on the starting motor shaft. This double sprocket with a "roller" type of clutch was a feature of this early system and is explained on page 324.

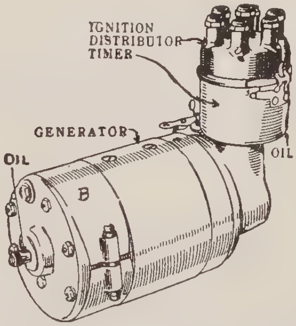


Fig. 19. **A popular method of mounting the ignition unit** on the generator. The generator drive end (end next to ignition unit in this illustration) faces the front of the car and is connected by means of a silent chain and sprocket to the crank shaft (Fig. 19A).

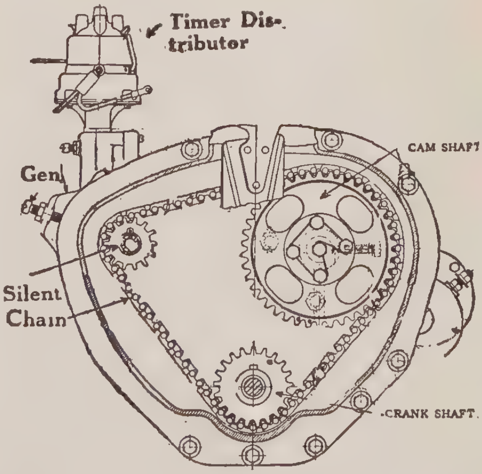


Fig. 19A. **Front end drive** of Studebaker engine. In this example the generator armature shaft is driven by a silent chain at 1½ times the engine speed and a vertical shaft (not shown) is driven by a worm gear from the armature shaft is so geared that the distributor and timer shaft turn at one-half the speed of the engine crank shaft. This would be termed a "two-unit" system, as the starting motor is a separate unit.

RELATION OF A GENERATOR TO AN ELECTRIC MOTOR

The electric generator is similar in many respects to an electric motor, the principal difference being in the winding. The motor field is usually "series"-wound, and the copper wire is heavy or coarse; in fact, it is in the form of copper strips on some motors. The generator field winding is usually a "shunt" winding and of smaller wire.

With a few minor changes the electric **generator can be run as a motor,** using the same winding. A motor-generator is an example of how one armature can serve both a motor or a generator, but there are usually two field windings, as explained farther on.

The series motor possesses great starting power, but under a light load may attain a dangerously high speed. **A series dynamo or generator,**[1] **to be used as a motor,** and run in the same direction as it does as a dynamo, must have the leads from the brushes interchanged.

A "series"-wound generator will rotate in an opposite direction to that in which it rotates when run as a motor.

A "shunt"-wound generator, when used as a motor, will turn in the same direction as when used as a generator.

The shunt-wound motor (seldom used for automobile work) has not such great starting power as a series-wound machine, but runs much more uniformly in speed under a varying load. Brush leads remain as in the dynamo for the same direction of rotation.

A "compound-wound" generator, when used as a motor, will turn in an opposite direction—providing that the "series" winding is more powerful than the "shunt" winding, and in the same direction. If the "shunt" is more powerful than the "series," this is called a differential winding, and will be explained later on, under "Motor-generators," where the same machine used for a motor or generator is described.

The compound-wound motor (used only in motor-generators) is about equal to the shunt motor in starting power, and runs at an almost constant speed under all loads. Brush leads for the motor remain as in the dynamo. To reverse the direction of rotation of the motor, the brush leads must be changed.

The generator is usually separate and distinct from the starting motor. The Delco, however (in some of their systems), employ two field windings (compound) and one armature with two windings and two commutators on the armature, one operating when used as a generator and the other when used as a motor.

The North East system, as used on the Dodge, is another example, but one armature with one winding and two field windings is used for both a generator and a starting motor (explained farther on).

GENERATOR PRINCIPLE

On page 181 we learned that if current is passed through a wire, magnetic lines-of-force in the form of magnetic whirls will be set up around the wire in a clockwise direction, if the current is going into the wire, and in a counter-clockwise direction if the current is coming out (see Figs. 6B, 6C, page 181).

We also learned that if magnetic lines-of-force cut a wire, generated electromotive force, abbreviated e.m.f. (volts or pressure), would be set up in the wire which would tend to move the electricity in the wire. How the electricity comes to be there we don't know. Electricity is in almost everything, but not in motion (see page 175). Therefore, in order to get work out of it, a force called "electromotive force" is generated in the wire by "electromagnetic induction." This force causes a current of electricity to be put in motion, or to flow, and when electricity is flowing or in motion, it is spoken of as a "current of electricity," or merely "current."

With a generator, the wires on the armature cut the "lines-of-force" as they revolve and thus e.m.f. is generated in the wires, which tend to move or conduct the current therein.

Therefore, in order to produce an e.m.f. in the armature wires which will cause the electric current in the wires to flow (if there is a closed circuit), the following is necessary:

1. **Moving wires,** forming a closed loop or circuit.
2. **Magnetic field** for the wires to move in and cut.

The strength of the current thus produced in the wires is dependent upon:

1. **Strength of the magnetic field.**
2. **Speed or rate at which the wires cut the lines-of-force.**

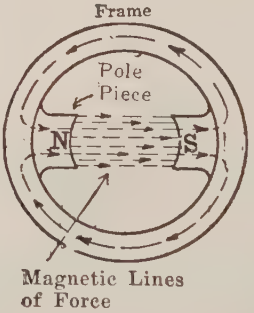


Fig. 8. Magnetic circuit in generator frame.

In Fig. 8 we have **a generator frame,** round pattern, with two pole pieces. Note that the lines-of-force flow from N to S outside of the frame, and from S to N through, or inside of the frame, thus completing a magnetic circuit.

For example: If we take two-bar magnets as shown in Fig. 8A, and bend them as shown by dotted lines, the magnetic circuit would be as shown, with lines-of-force flowing N to S outside of the magnet and S to N inside.

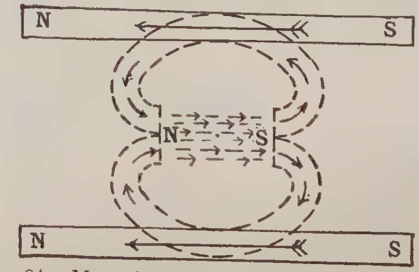


Fig. 8A. Magnetic circuit of a two-pole (bi-polar) generator with a round type of frame.

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[1] The words dynamo and generator are referred to as meaning the same thing.

In order to produce the magnetic field of lines-of-force, there must be wire wrapped around the field poles and electric current flowing through the wires, thus making "electro-magnets" of the field poles. See page 180 for an explanation of an "electro-magnet."

The direction in which the wire is wrapped around the field poles, and the direction in which the electric current flows in the field windings around the field poles, **will determine the polarity** of the field poles, just the same as in the electro-magnets described on page 183.

The next question is, if the field poles must first have current flowing through the windings around them, in order to produce magnetic lines-of-force for the wires to cut, and if this action generates e.m.f. in the wires, where are the original magnetic lines-of-force obtained?

The field poles are not permanent magnets, but are usually soft iron similar to the **electro-magnet** described on page 182. They lose their magnetism when the current stops flowing through the winding. On page 182, the lines-of-force were shown to be produced around the electro-magnet by current from the battery flowing through the windings, but in the field poles of the generator we cannot pass the current through the windings from a battery. Therefore we obtain our initial lines-of-force from "residual" magnetism, which may be explained as follows:

A slight amount of magnetism is left or remains in the iron field poles, even though it is supposed to lose its magnetism when the generator stops. This magnetism is termed **"residual" magnetism,** and even though it is very slight, there is sufficient magnetic lines-of-force in the iron which flows from N to S across from one pole-piece to the other for the wires to cut the moment the armature starts to revolve. Thus we obtain our initial lines-of-force to start with.

How Direct Current Is Produced from a Generator

Let us glance at Fig. 9, and assume that we have a N and S pole with lines-of-force passing from N to S. We will further assume that the two wires represent one coil of an armature wire, and are closed loops, and revolve in the direction shown by the arrow point above them.

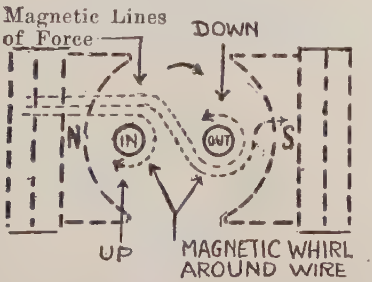

Fig. 9. Showing how the lines-of-force whirl around a wire when it is moved up or down in a magnetic field.

When the wire on the left moves up, it will **cut the lines-of-force up,** and the magnetic whirls will be clockwise around the wire, thus inducing in the wire an e.m.f. causing **current to flow into the wire,** or in the direction away from the reader.

The wire on the right, moving down, would **cut the lines down,** the magnetic whirls would be counter-clockwise, thus inducing in the wire an e.m.f. causing **current to flow out of the wire,** or in the direction of the reader.

If the direction of the lines-of-force is changed, or if the direction of the motion of the wires is reversed, the direction of the flow of current would likewise be reversed.

The strength or intensity of the e.m.f. generated under the conditions described would depend upon: (1) the strength of the magnetic field or the number of lines-of-force; (2) the rate of speed at which the wires cut the lines-of-force; (3) the number of wires cutting the lines-of-force.

The flow of current of any generator is an alternating flow inside the generator, that is, in one direction during one half-revolution, and in another direction during the next half-revolution.

For instance, let us refer to Fig. 10. If a wire loop is revolved between the poles of a magnet from which magnetic lines-of-force flow from N to S pole, and the wire is revolved in the direction shown by the curved arrow, magnetic whirls would be set up around the wire on the left, in a clockwise direction, due to the wire cutting the lines up, and thus causing an e.m.f. to be induced in this side of the loop which would cause current to flow from 1–2, into the wire. If a "collector-ring" was connected with the end of this wire to brush (**B**−), it would be negative (−).

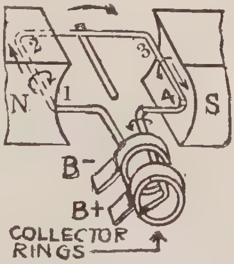

Fig. 10

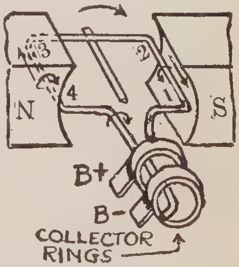

Fig. 11

Fig. 10. The outer brush is (+) and the inner brush (−).
Fig. 11. The outer brush is now (−) and the inner brush (+).

The wire on the right (Fig. 10) would cut the lines-of-force down, therefore the magnetic whirls around the wire would be in a counter-clockwise direction, and current would flow out from 3–4. The brush (**B**+) at the end of this wire would be positive (+).

Fig. 11 shows a half-revolution of the wire loop from the position at which it was in Fig. 10. Note that wire 2–1 is now cutting the lines-of-force down; therefore the brush which was (B−) in Fig. 10 and which is still connected with it, would be (+) instead of (−) as current is now coming out instead of going in.

Wire 4–3 is now cutting up, and current would flow in. Thus the brush which was (**B**+) in Fig. 10 and which is still connected with it, would now be (−) instead of (+).

Thus during a half-revolution the current would flow out of the same brush as (−) and during the next half-revolution current would flow into the brush as (+). This would produce an "alternating" flow of current which is used on magnetos but is not suitable for a generator which charges a storage battery which has a positive (+) and negative (−) set of plates and terminals.

Only a "direct" flow of current will charge a storage battery. Therefore some means must be employed to convert or commutate the "alternating" flow of current to a "direct" flow of current as follows:

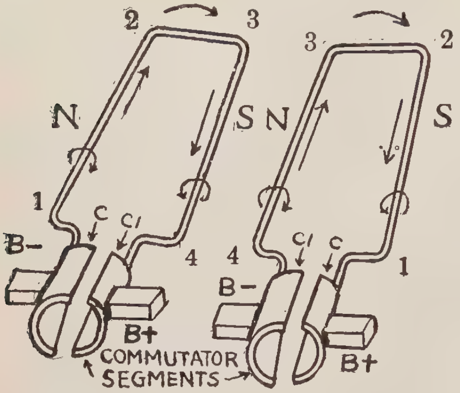

Fig. 12 Fig. 13

Fig. 12. The left brush is (−) and the right brush is (+).

Fig. 13. The left brush is (−) and the right brush is (+), the same as in Fig. 12.

A method of obtaining a direct flow of current at the brushes is shown in Figs. 12 and 13. Instead of having a round or endless collector-ring at the ends of the wires as in Figs. 10 and 11, we have substituted two half-sections of one ring, separated from each other, which we will term **the segments of a commutator.**

Now, when wire 1–2 on the left (Fig. 12), is cutting the lines up, current will flow in, and the brush on the left will be (−). The wire on the right (Fig. 12) will cut the lines down, and current will flow out, and the brush will be (+).

Fig. 13 shows a half-revolution of the wire loop from the position shown in Fig. 12. Wire 4–3 is now cutting up, and current would flow in, and the brush would be (−), just as it is in Fig. 12. Wire 2–1 would cut down, and current would flow out, and the brush would be (+), just as it is in Fig. 12.

Therefore, instead of the brushes being connected with the same end of the wires all the time, as in Figs. 10 and 11, the brushes connect with one wire, for a half-revolution, and with the other wire during the other half-revolution, and the flow of current from the brushes is always in one direct direction. This action is accomplished by the two-part commutator.

The current generated in all generators is an alternating flow of current and it is "commutated" **or changed to a direct flow of current at the brushes by means of a "commutator."**

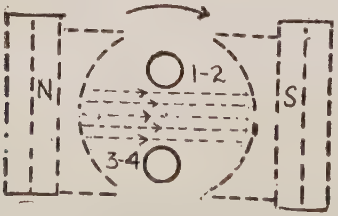

Fig. 14. Wires in a vertical position.

The strength of the current, as previously stated, is dependent upon the e.m.f. induced in the wires, and this in turn is dependent upon the number of magnetic lines-of-force cut by the coils of wire.

When the wires are cutting up or down across the magnetic field, the induced e.m.f. is greatest. When the coils reach a vertical position, as shown in Fig. 14, the e.m.f. induced in this position would be zero, as the magnetic lines are not cut (except perhaps a few stray lines), but flow freely through the coil from N to S pole-pieces.

Thus we have, at every half-revolution, when in position shown in Fig. 14, no current at all, or zero. But as the coils or wires are rotated, the number of magnetic lines cut will increase until it reaches a horizontal or 90° position (Fig. 9), where it reaches maximum. From this position (Fig. 9), traveling in the same direction, the number of lines become less until the vertical or 180° position is reached (Fig. 14), where the e.m.f. again becomes zero.

The e.m.f. induced in this simple dynamo would be called **a pulsating e.m.f.,** because it pulsates or changes from zero to maximum and back to zero at regular intervals or every half-revolution.

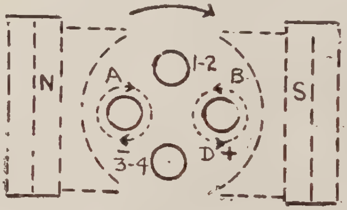

Fig. 15

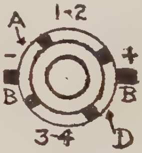

Fig. 15A

If we place two closed loops, or coils, at right angles to each other (Fig. 15) and use four commutator segments, as shown in Fig. 15A, the induced e.m.f. in one coil (**A** and **D**) will be maximum, when zero in the other (1–2, 3–4), if rotated. With the terminals of each coil connected to opposite commutator segments, the e.m.f. between brushes will never drop to zero.

By the use of more coils on the armature and more segments on the commutator, we should have more wires cutting the lines. Thus the e.m.f. would be made more steady with less pulsations.

This type of winding would be termed an "open-circuit" winding, and the coil or loop is connected to the external circuit only while the segments of the commutator to which the terminals of the loop are connected, are in contact with the brushes.

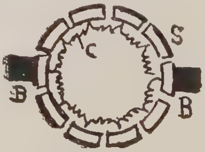

Fig. 15B

A closed-circuit winding (Fig. 15B) would be better, because the loops are connected together in "series-parallel," and thus all of the loops all the time are made use of except when the two commutator segments to which a loop is connected are in contact with a brush or with brushes of the same polarity.

GENERATOR ARMATURES

On a generator of the automobile type, the armature (which rotates and is driven by the engine) is made up of many coils and commutator segments, and various methods of winding and connecting to segments are employed. The principle, however, is very much the same in all cases, the idea being to have as many wires on each side cutting the magnetic lines-of-force as is possible. By adding more wires, the e.m.f. is increased.

A simplified "shunt-wound" generator[1] and its circuit are shown in Fig. 16. Note that the field windings are "shunted" to the brushes. Thus we have a "shunt field circuit" and a "main circuit," the latter being from the brushes to the battery, lamps, ignition, etc.

The armature, which is a "drum type," consists of a laminated iron core (Fig. 16A) with slots in the core for the winding of insulated copper wire.

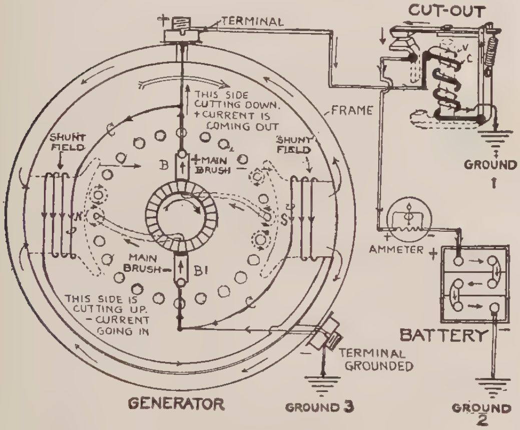

Fig. 16. Circuit of a shunt-wound generator.

The laminated iron core increases the total number of lines-of-force by collecting many stray lines from the surrounding air, and thus concentrating them.

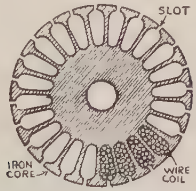

Fig. 16A. Laminated iron core of a drum-type armature.

The wire is wound around the core and in the slots and the ends are connected by soldering to the commutator segments.

An armature shaft passes through the core, which is supported by bearings. The shaft is driven from the engine, and the armature revolves between the pole pieces.

The commutator is made up of copper segments insulated from each other and from the shaft by mica insulation.

Brushes are usually made of carbon and rest on the commutator, and conduct the current from the armature. One brush will take current from wires which revolve on the side cutting the lines down, and the other brush will take current from the wires on the side of the armature which are cutting up; thus one side is (+) and the other (−). This is likewise true of the brushes. (This is true for open-coil armatures, but not for closed-coil armatures.)

The field circuit in Fig. 16 consists of two field poles (usually made of laminated steel and detachable by means of screws), with insulated wire wrapped around them in such a direction that when the armature is revolved in the direction shown by the arrow, the left pole is N, and the right pole is S, or vice-versa.

When the armature revolves the wires on the left cut the lines up, and therefore current flows in. The wires on the right cut down, and current flows out. The (+) side is connected with the (+) brush and the (−) side with the (−) brush. Current flows out to its external circuit from the (+) brush and comes back to the (+) brush, thus completing the circuit.

The shunt field circuit is supplied with part of this current thus produced (usually about 1½ to 2 amperes), and flows from the positive (+) main brush through the field coil on the left, giving this pole a N pole polarity (at the end of the pole next to the armature).

The flow of current is then continued to the other field pole which gives this pole a S pole polarity at the inner end of the pole. The field circuit is completed at the negative (−) main brush. The current flowing through the field windings makes electro-magnets of the field poles, and from them lines-of-force flow from N to S poles directly through the armature core.

As the speed of the armature increases, the rate at which the lines-of-force are cut by the coils on the armature increases. Thus a greater e.m.f. is induced in the armature wires, which causes a greater rate of flow of current through the field windings, thus in turn producing more lines-of-force.

The cut-out voltage circuit is from the (+) brush, to the fine wire voltage winding (V), around the cut-out core, to ground (1), to grounded (−) main brush (ground 3).

The battery-charging circuit from the generator: When the armature speed is such that the e.m.f. or voltage generated is slightly above the battery voltage, the fine wire winding (V) magnetizes the core of the cut-out and draws the cut-out armature to it. The effect of this is to close the points through which the current passes to battery, through the coarse wire or series winding (C) on the cut-out core, through the ammeter, to the (+) terminal of the battery, through the battery to (−) ground (2), to (−) grounded brush of the generator (ground 3). Note that current passes through (V) and (C) winding from the generator in the same direction around the cut-out core.

The action when the generator slows down and the cut-out points open is explained on page 333 (Fig. 5). Note that current flows in a reverse direction through winding (C) when the battery discharges back through it, as in (S) (Fig. 5).

The plain shunt-wound generator, as described, would not be satisfactory, because, as the speed of the armature increases, the e.m.f. increases, and at high speeds of the armature, the lines-of-force and also the rate at which they are cut would increase, and thus the output would be too great.

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[1] The "shunt field winding" connections of a generator are on the principle used on most generators. But owing to the fact that a shunt-wound generator builds up with speed, a "regulation of the field circuit" must be used in order to cut down the out-put at high speeds. This subject is treated under "Regulation methods," farther on.

In order to obtain a "constant voltage" or a "constant current" output, some form of "regulation," to cut down the lines-of-force in the field circuit is required. The subject of "Regulation of generators" will be treated farther on.

Direction of Motion of Armature Coils and Direction of Main Magnetic Field Governs the Polarity at Brushes

The direction in which the coils on the armature rotate and the direction in which the main magnetic lines-of-force flow govern the direction of the flow of current out of the armature wires into the brushes.

Simplified illustrations in Fig. 16 B show different directions of "motion" of the armature coils, and also different directions of the "main magnetic circuit" (lines-of-force). The field-poles are not shown wrapped with wire, but it is assumed that they are, and that they are so wrapped, that the main magnetic circuit (lines-of-force), passes from N to S pole. Only two wires are shown, as a matter of simplifying the explanation, although there are several coils of wire on the armature.

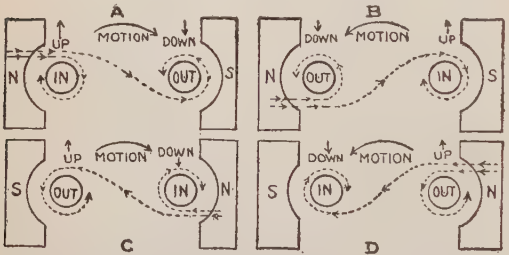

Fig. 16B. Explaining how the direction of motion of the wires on the armature governs the polarity at the brushes.

At **A,** the direction of motion of the armature is as shown by the arrow point. Main magnetic lines-of-force flow from N to S poles; therefore the wire coil on the left will cut up and the "magnetic whirls" will be clockwise around the wire. Thus an e.m.f. will be generated in the wire, causing current to flow into the wire, or away from the reader, and this current will be (−). The wire on the right (**A**), will cut down; therefore the "magnetic whirls" around the wire will be counter-clockwise, or out of the wire (+).

At **B,** note that the direction of "motion" of the armature coils is in the opposite direction to that shown at (**A**). Therefore the magnetic whirls around the wires on each side are reversed, and consequently the direction of the flow of current in the wires is reversed.

At **C,** note that the direction of the "main magnetic circuit" is changed. Instead of passing from N to S pole, from left to right, as at (**A**) and (**B**), they now pass from N to S pole, from right to left. We will assume this change was made by changing the direction of the winding on the field poles. Therefore, while the direction of the motion of the armature coils is the same as at (**A**), the main magnetic field is just the reverse. Thus the direction of the motion of the armature wires is such that the left wire (**C**), on going up, cuts the main magnetic field in such a manner that the magnetic whirls circle around the wire counter-clockwise, producing a generated e.m.f. in the wire, causing current to flow out (+), and on the other side, the wire cuts down, causing current to flow into the wire (−).

At (**D**), note that the direction of "motion" of the armature coils or wires has been reversed from that of (**C**). The main magnetic field (also called lines-of-force and main magnetic circuit) is the same as at (**C**). Therefore the change of direction of the motion of the wires produces a reverse effect to that at (**C**).

The purpose of these illustrations is to point out how the generated current flows **into** a wire when the magnetic whirls are clockwise around a wire, and how the generated current flows **out** of a wire when the magnetic whirls are counter-clockwise around a wire; and also that the direction of motion and the direction in which the main magnetic field or circuit passes from N to S pole, governs the direction of the magnetic whirls around the wire. A study of the illustrations will make these principles clear.

ARMATURE WINDINGS

There are a number of methods of winding an armature; so many, in fact, that armature winding is a trade in itself.

The repairman should not attempt to wind an armature because it requires a special equipment, and furthermore it is cheaper to turn in the old armature for a new one.[1]

The work on an armature that the repairman is usually called upon to do is to test it out, or to make such repairs as re-soldering the wires to the commutator segments, undercutting the mica, turning down or cleaning the commutator, fitting new brushes, etc., which is explained farther on. We shall not go further into this subject here, except to give an idea as to the construction of the armature.

Lap or Parallel Wound Armature

An armature in general use on two-pole generators and motors is shown in Fig. 17. It is termed a "lap" or "parallel" wound "drum" type of armature of the "closed-circuit" type.

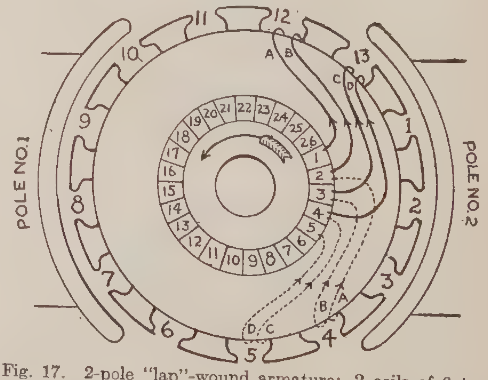

Fig. 17. 2-pole "lap"-wound armature; 2 coils of 6 turns per slot; 13 slots, 26 commutator segments.

In this example of a two-pole Delco generator armature, there are 13 slots in the core and 26 commutator segments. There are 2 coils per slot and 6 turns of double cotton-enameled wire per coil.

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[1] A. L. Dyke, Elect. Dept., St. Louis, Mo., can furnish armatures and parts of any make of generator or motor. From him can also be obtained a book on **Armature Winding,** price $5 prepaid.

The coils do not go directly from No. 1 commutator segment to No. 1 slot, but a "lead" of five segments, or bars, is given, to the right, from the slot where it enters.

The end of the first coil (A) would begin or "lead" from No. 1 commutator segment to slot No. 12, to slot No. 4 (spanning six slots), and end at commutator segment No. 2.

The end of the second coil (B) for the same slot, would begin or "lead" from No. 2 commutator segment, to slot No. 12, to slot No. 4, and end at commutator segment No. 3.

The end of the coil (C), for the next slot, would begin with commutator segment No. 3, to slot No. 13, to slot No. 5, and end at segment No. 4.

The end of the second coil (D), for the same slot, would begin at commutator segment No. 4, to slot No. 13, to slot No. 5, to commutator segment No. 5.

Thus the same procedure would continue around the core, with two coils of wire in each slot.

The main brushes on two-pole machines are placed 180° apart, or exactly opposite. Thus one brush would be on a near commutator segment No. 15, and the other on No. 2 segment.

Where a third brush is used for regulating purposes, the position would be on No. 5 or 6 segment, when the direction of the armature is as indicated. If the direction is reversed, the third brush would be on the opposite side. (The third-brush regulation is treated farther on.)

Many of the starting-motor armatures have the same number of slots in the cores as there are commutator segments, since there is usually, but one coil per slot.

Wave or Series-Wound Armature

An armature in general use on Delco four-pole generators and motors is shown in Fig. 18. It is termed a "wave" or "series"-wound "drum" type of armature of the "closed-circuit" type.

In this example there are 21 slots in the core, 43 commutator bars or segments, and 2 coils per slot with 5 turns of No. 15 double cotton-covered enameled wire per coil.

The coils do not go directly from No. 1 segment or commutator bar to slot 1, but a "lead" of 6 bars to the left of slot No. 1 is given to the first coil (A), and a "lead" of 7 bars to the left is given to the second coil (B).

Four-pole generators are divided into quarters. The "pitch" or span is from slot 1 to slot 6.

The first coil (A) for slot No. 1, would start with commutator segment or bar No. 6, to slot 1, to slot 6, to bar 28.

The second coil (B) for slot No. 1, would start with commutator bar No. 7, to slot 1, to slot 6, to bar 29.

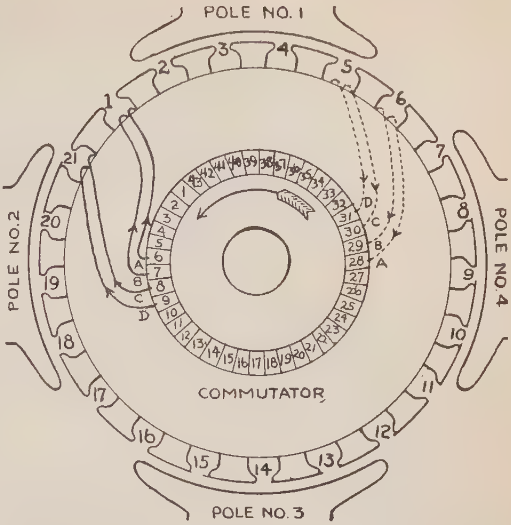

Fig. 18. 4 pole "wave"-wound armature 2 coils of 5 turns per slot, 21 slots, 43 commutator segments.

In order to fill up the remaining slots in this section, the next coil (C) would begin with bar 8, to slot 21, to slot 5, to bar 30.

The second coil (D) in the same slot would begin with bar 9, to slot 21, to slot 5, to bar 31, and thus proceed until all slots are filled up. Commutator bars 1 and 22 would be connected by a jumper.

On four-pole generators, using two main brushes, the brushes are located 90° apart.

The position of the third brush on a four-pole generator (when the regulation system is with a third brush) is somewhere between 130° to 160° from the main brush of opposite polarity.

A two-pole motor or generator usually employs what is termed a "lap winding," and four-pole "wave winding."

In the generator armature windings, one coil consists of four, five, or six turns of wire, depending upon whether the generator is to be driven at engine speed or at one-and-one-half times engine speed. One or the other ratio is generally used.

Motor and Generator Windings on One Armature

Diagrams of a Delco-Buick armature, where there are two windings on one armature, which is a "lap winding," are shown in Figs. 19 and 20. The generator is of the two-pole type.

The motor winding (Fig. 19) consists of one coil per slot. There are 19 slots in the armature core for both the motor and generator winding. There are 19 commutator segments for the motor winding. There are **two commutators**, one for the motor and one for the generator winding.

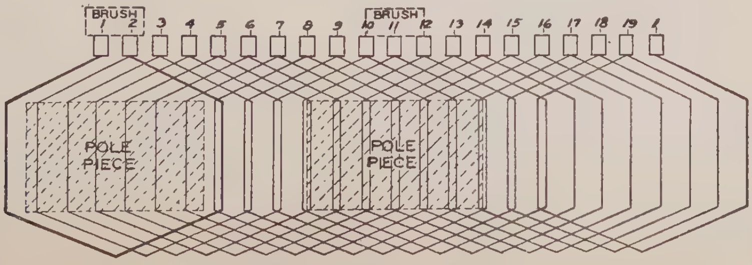

Fig. 19. Motor armature winding 19 slots, 1 coil per slot.

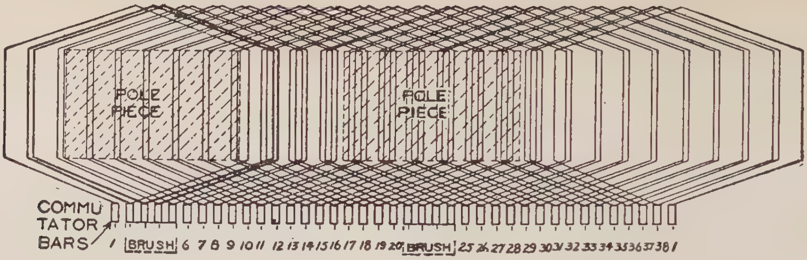

Fig. 20. Generator armature winding, 2 coils per slot.

The generator winding (Fig 20) consists of two coils per slot. There are 19 slots in the armature core (the same number of slots as for the motor). Thus, since there are two coils per slot for the generator winding, there are 38 commutator sgements on the generator commutator.

Meaning of Span and Lead

The "span" of coils on an armature refers to the number of slots, between those in which the two sides of a coil lie, plus the two slots in which they lie.

The "lead" of coils of an armature refers to the number of commutator bars to the right or left of the slot where the coil enters and where it comes out.

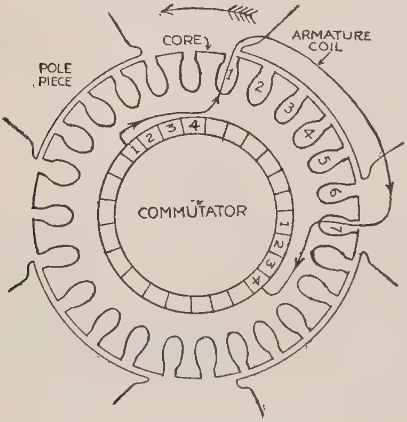

Fig. 21

For example, refer to Fig. 21. There are 25 commutator bars and 25 slots, and 1 coil per slot. The "span" is 1 to 7, and the "lead" is 4 left, 4 right, usually stated as 4 left, the beginning of the coil. Note that the armature coil leads from bar 1, which is the fourth bar to the left of slot 1, where it enters. The coil then "spans" from slot 1 to slot 7, and "leads" to bar 4, which is the fourth bar to the right of slot 7, where it comes out.

Refer now to Fig. 18, page 343. The "span" here is 1 to 6, and the "lead" is 6 to 7 bars left. Note that there are two coils per slot.

Therefore the "lead" of the first coil (A) is from bar 6, which is the sixth bar to the left of slot 1 where it enters. It then "spans" six slots, from slot 1 to 6, and ends at the sixth bar from under slot 6.

The "lead" of the second coil (B) is from bar 7, which is the seventh bar to the left of slot 1, where it enters. It then "spans" six slots, from slot 1 to 6, and ends at the fifth bar from under slot 6. As the winding progresses, the coils in this section are working to the left.

Refer next to Fig. 17, page 342. The "span" is 1 to 6, the "lead" is 5 to 6 to 7 bars right. Note that there are two coils per slot.

The "lead" of the first coil (A) begins with bar 1, which is the fifth bar to the right of the slot 12, where it enters. It then "spans" six slots (from 12 to 4), and ends at the sixth bar (2), to the right from under slot 12 where it entered.

The "lead" of the second coil (B) begins with bar 2, which is the sixth bar to the right of the slot 12, where it enters. It then "spans" 6 slots (from 12 to 4), and ends at the seventh bar (3) to the right from under slot 12 where it entered.

When the bars are connected to the bars opposite the center slots in the span, the lead is said to be "straight down" as in Fig. 17, just referred to.

INSTRUCTION NO. 33

GENERATOR FIELD-WINDINGS AND REGULATION METHODS

GENERATOR FIELD WINDINGS

Shunt winding: On all generators used for automobile work the magnetic field is produced by what is termed a "shunt" connection of the field winding, which is directly across the brushes, as shown in Fig. 1. Thus it is called a "shunt-wound" generator. Where there is a regulation system to the field winding of a generator, the regulation (such as an electric-magnetic principle or third brush) is placed in between the field winding and brush as explained farther on.

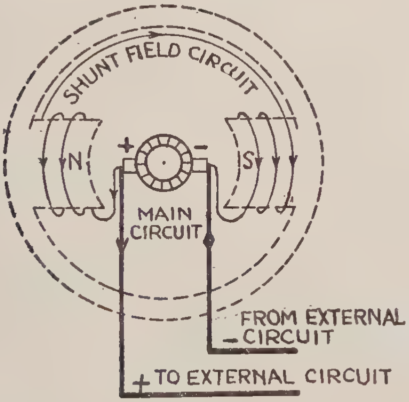

Fig. 1. Shunt field winding.

With a shunt-wound generator about 10 per cent of the total current generated by the armature passes to the shunt field windings. Therefore the strength of the main magnetic field depends upon the current passing through it, and the strength of the current depends upon the speed of the generator armature.

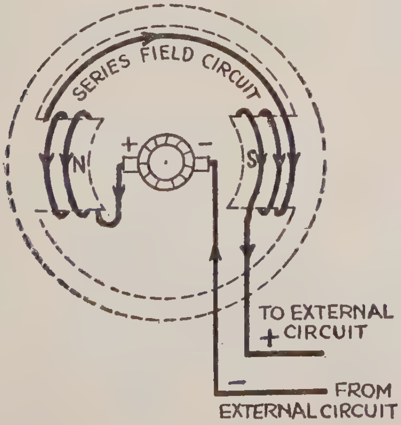

Fig. 2. Series field winding.

Series winding: This winding (Fig. 2) is used principally for starting motor field windings. In many instances the starting motor fields are connected "series-parallel," instead of in straight series. That is, where there is a four-pole starting motor, the field windings are often connected, two in series and parallel with the circuit, as, for instance, in Fig. 4, page 326.

It will be observed that all of the current would pass through the armature and field in series. This winding is not suitable for generator windings, if used alone.

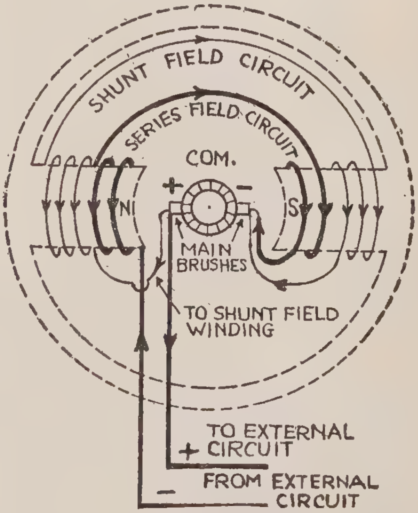

Fig. 3. Compound winding; shunt and series.

Compound windings: On some generators two field windings are used (Fig. 3). One winding is a "shunt" winding and the other a "series" winding.

If the two windings are wound in the same direction (as in Fig. 3), they assist each other in producing magnetic lines-of-force at the field poles, thus producing an **"accumulative" effect** or action.

If the two windings are wound in opposite directions, they oppose each other, thus producing a **"differential" effect** in action.

The shunt winding coils, in this instance, consist of a much greater number of turns of fine wire than the series coils, which are of coarse wire. The shunt winding determines the polarity of the field poles.

Motor-generators use a compound-winding, consisting of a "series" field winding and a "shunt" winding, which are wound in opposite directions on the field poles.

When used as a motor, the two windings have the "cumulative" effect of magnetizing the field poles, and when used as a generator, they have a "differential" effect (treated and discussed farther on).

Thus, in summing up the different windings of generators, motors, and motor-generators, we deal with two windings, a "series" winding and a "shunt" winding, either separately or combined.

If the two windings are combined, they can be wound in the same direction or in opposite directions, thus producing a "cumulative" or "differential" effect.

The two windings can also be connected in two different ways: as a "short shunt" connection, and as a "long shunt" connection.

GENERATOR REGULATION PRINCIPLES

Why Output of a Generator Must Be Regulated

The shunt-wound generator is used most. As stated, about 10 per cent of the current from the armature flows through the shunt field windings. This flow of current through the field windings "builds up" the magnetic lines-of-force in the field poles.

The lines-of-force then flow from N to S pole of the generator, and as the armature coils revolve between these poles, there is set up in the armature coils an induced e.m.f. (electric-motive-force, voltage, or pressure) which causes electric current to flow, as previously explained.

The e.m.f. voltage thus produced by a generator depends upon:

1. **The number of lines-of-force** cut by the armature wires.
2. **The number of the cutting wires** in armature coils.
3. **The speed at which the armature revolves,** or the rate of speed at which the wires cut the lines-of-force.

Thus it is clear that if the speed of the generator armature is increased, the lines-of-force will increase; consequently as the lines-of-force increase, the e.m.f. increases, owing to the greater speed at which the lines are cut by the armature coils.

For this reason, a plain shunt-wound generator will build-up its lines-of-force at high engine speeds (the engine drives the generator armature), and consequently the e.m.f. or voltage would increase to such an extent that the lamps would be burned out and too high a charging rate would pass to the battery.

Constant Current and Constant Voltage

To prevent the generator from increasing above its normal output at high speeds, methods for regulating the output are provided and can be classed as follows:

1. **Regulation of the voltage,** by maintaining a "constant voltage," with the current varying.
2. **Regulation of the current,** by maintaining a "constant current" (amperage), with the voltage varying.
3. **Regulation of both** voltage and current.

As a matter of fact, the number of magnetic lines-of-force and the rate at which they are cut by the armature coils, govern both the voltage and current. Conditions which affect one would affect the other. Some manufacturers, however, provide means for decreasing the lines-of-force through the voltage produced by the generator, and others through the current produced, or both.

Meaning of Constant Current and Constant Voltage

The generator output in watts is equal to the product of the current (amperes) multiplied by the volts (pressure). If there is no other pressure (voltage) in a generator circuit than that delivered by the generator, the current delivered by the generator is equal to the voltage divided by the total resistance of the circuit.

If the pressure (voltage) **generated in the armature remains fixed or constant,** the current supplied by the generator will vary according to the amount of resistance in the circuit, as, for example, a charged or discharged battery, lamps, etc. If, by way of illustration, the resistance is increased in the circuit (perhaps by the battery being fully charged), the current in the circuit will decrease, and if the resistance in the circuit is decreased, through a discharged battery in the circuit, for instance, the current will increase.

If the generated pressure or voltage in the winding of the armature is changed or varies, and the resistance of external circuit does not change, there will be an equal change in the output of current. For instance, if the pressure (voltage) increases, the amperage will increase, and if the pressure decreases, the amperage will decrease.

If the pressure of the generator and the resistance of the circuit both change, then the amperage is equal to the pressure at the time, divided by the resistance at the time.

When the generator output is being delivered as a constant current and the pressure or voltage is varying, the generator is termed a **constant current** generator.

When the output is being delivered at a constant voltage or pressure and the current is varying, the generator is termed a **constant voltage** generator.

With the "constant voltage" regulation system, the amount of current generated, as previously stated, depends upon the state of the battery charge and the amount of lamp load in use. With a discharged battery, the voltage delivered to the battery is a minimum, but as the charge of battery proceeds the voltage of the battery will increase, so that the difference in pressure between generator and battery is continually diminishing. For instance, if the battery is fully charged, and is, say, 6 volts, and if the generator voltage is 7 volts, then there is one volt pressure to send current through the battery, and the generator charging current will be small.

Therefore the charging current is variable even at the same speed of rotation, and tapers from maximum (about 12 to 20 amperes) with a discharged battery, to minimum (4 to 6 amperes) with a fully charged battery.

After the generator reaches a speed at which it develops its normal voltage, the voltage does not increase with speed, but remains constant—if a regulation method is used to decrease the strength of the magnetic field.

Voltage regulation permits of a battery being charged at a high-current rate when the battery voltage is low, and at a much lower rate when the battery voltage is high.

With the constant current regulation, the generated current is independent of the voltage of the battery or the amount of lamp load connected, but depends upon the speed at which the machine is driven and on the regulation system.[1]

GENERATOR REGULATION METHODS

To maintain either a "constant voltage" or a "constant current" (amperage) or both, the following methods are available:

1. **Mechanically, by hand:** Where the resistance is cut into the shunt-field circuit, thus decreasing the strength of the magnetic field (not practical).
2. **Electromagnetic method:** Where the resistance is cut into the shunt-field circuit automatically by an electromagnetic device placed externally to the generator. This was formerly extensively used.
3. **Mechanically, by an automatic governor:** Where a mechanical governor is used to regulate the speed of the generator (obsolete).
4. **Inherent method:** Where there are "two windings" (compound windings) on the field poles, or where a "third-brush regulation" is used. Thus with both of these methods the regulation is "inherent," or within the generator and without the use of external devices. The third-brush method is used most.

The Delco and North East are examples of compound-wound generators which also use a third-brush regulation.

The object of all the regulation methods mentioned above is to decrease the current flowing through the shunt-field winding at very high speeds of the generator, in order to reduce the strength of the magnetic field and to maintain a "constant voltage," or "constant current," or both.

Mechanical Hand Method

The hand method (Fig. 4) of cutting resistance into the shunt-field circuit of a straight shunt-wound generator is impractical, because it would necessitate someone moving the lever (H) constantly back and forth. For instance, if the generator speed is high, the resistance (M) should be cut into the field circuit by moving the lever (H) to 2. As the speed decreases, the lever (H) would be moved back to 1, cutting out the resistance.

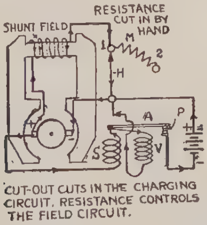
RESISTANCE CUT IN BY HAND
SHUNT FIELD
M
1
2
H
A
P
S
V
CUT-OUT CUTS IN THE CHARGING CIRCUIT. RESISTANCE CONTROLS THE FIELD CIRCUIT.

Fig. 4. Mechanical hand method of regulation (not used as a general practice).

Therefore some means whereby this action can be made to be "automatic" is the method which we shall discuss.

Electromagnetic Regulation Methods

Electromagnetic methods consist of an electromagnetic device (Figs. 5, 6, and 7) similar to a cut-out in appearance. Its purpose is to cut-in resistance into the field circuit at high speeds magnetically thus decreasing the strength of the magnetic field.

Note. Do not confuse the electromagnetic cut-out with the electromagnetic regulator.

The purpose of the cut-out is to open and close the circuit between the generator and the battery and this is explained on page 332. It is placed in the external circuit with practically all generators, regardless of the type of regulation, and is shown in the various illustrations, but is not referred to.

There are three electromagnetic methods. These are:

(1) To regulate the current (amperage) so as to obtain **constant current** or amperage.

(2) To regulate the voltage so as to obtain **constant voltage,** or pressure.

(3) To regulate both voltage and current so as to obtain **constant current and voltage.**

Electromagnetic Voltage Regulation

Voltage regulation of the generator by the electromagnetic method is shown in Fig. 5. The principle of construction is similar to that of an electromagnet with a fine wire voltage winding **(F)** around an iron core (G). This winding is connected **across** the generator charging circuit, and not in series with the generator charging circuit as in Fig. 6; therefore the magnetic force of the core (G) will depend upon the voltage in the fine wire winding (F).

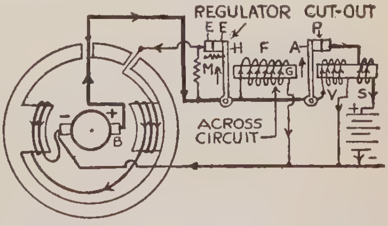

Fig. 5. Electromagnetic voltage-regulation method.

This generator (Fig. 5; also Figs. 6 and 7) is a plain shunt-wound generator. Instead of connecting the ends of both field poles directly to the brushes inside of the generator, the shunt-field circuit is from (+) of the main brush, to the regulator arm **(H)**, to points **(EE)**, through the field windings, to (−) of the main brush. This extension is made in order to be able to insert resistance **(M)** into this shunt field circuit when the generator is running at high speeds, and thus weaken the current flowing in the shunt field circuit and preventing too high an output of the generator. The resistance (M) on the regulator is connected into the field circuit only when points (EE) are open, which is at high speeds of the generator. These points are normally closed, so that the generator field can "build-up," magnetic lines-of-force at low speeds.

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[1] For instance, on the Bijur "third-brush regulated," "constant-current" generator, the cut-out closes at a generator voltage of 6.5, or a generator speed of 500 or 600 r.p.m. With increasing speed, the current increases to maximum value, at speeds of about 1,000 to 1,600 r.p.m; at higher speeds the current gradually decreases owing to the third-brush regulation (explained farther on).

It is not feasible to supply current for lights from a "constant-current" generator without a battery being connected in circuit. For instance, if lamps require 7 amperes and the generator, at speed, delivers 15 amperes, the generator voltage would rise until the additional 8 amperes not required by the lamps will be forced through the lamp circuit and burn them out.

The voltage generated by the generator will determine the opening of the points (EE). The fine wire voltage winding (F) of the regulator is so wound, that with a 6-volt battery, the generator voltage will reach about 7.5 to 8 volts maximum, and points (EE) will remain closed; but on higher speeds and where the generator reaches a higher voltage than the maximum, then the core (G) becomes magnetized sufficiently to draw blade (F) to it, thus opening points (EE), and cutting in resistance (M) into the field circuit. This has the result of weakening the magnetic lines-of-force of the fields.

When the generator speed is less than 8 or 10 miles per hour car speed, the generator voltage drops to less than 6.5 volts, and the core (G) loses its magnetism, and points (EE) close again, thus cutting resistance (M) out of the field circuit. This permits the magnetic lines-of-force to build up again in the fields. This action is repeated over and over as the speed of the engine and generator varies; and thus the blade (F) vibrates back and forth.

With the "constant voltage" regulation, the amount of current generated depends upon the battery voltage (if charged or discharged), and also on the load in the circuit, such as lamps, etc.

Note that the charging circuit from the generator to the battery is not through the regulator winding.

The voltage can be increased or decreased, where the regulator cuts in and cuts out, on many regulators of this type, by increasing the spring tension of blade (H) for an increase of voltage and by decreasing, for a lower voltage.

Electromagnetic Current Regulation

Current regulation of the generator by the electromagnetic principle is shown in Fig. 6. Note that this is a plain shunt-wound generator, as in Fig. 1, and the difference between Fig. 5 and Fig. 6 is that the winding (F) on core (G) is a coarser wire and is in series with the charging circuit instead of across it, and the magnetic force of the core (G) will depend upon the current or amperage passing through this winding.

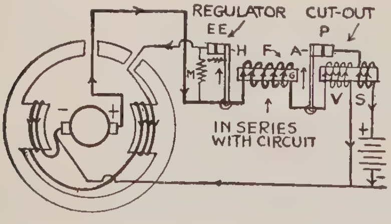

Fig. 6. Electromagnetic current regulation.

The shunt field circuit is from (+) of the main brush of the generator, through regulator blade (H), through points (EE), which are normally closed, to the field winding, through the field windings to (−) main brush.

Note that **the charging from generator to battery** must pass through the regulator winding (F).

When the engine speeds up, the generator builds up voltage (e.m.f.). When the voltage of the generator is sufficient to cause the cut-out points (P) to close, which completes the battery charging circuit, the generator then charges the battery. And as the charging current flows through the regulator winding (F), this will cause core (G) to become magnetized, and when the maximum output of current from the generator (approximately 12 to 15 amperes) is passing through this winding, the blade (H) will be drawn to core (G) against the tension of the spring, thus opening points (EE). This action inserts the resistance (M) in series with the shunt field circuit, thus causing the voltage of the armature to drop and the charging current to decrease, because of the weakening of the shunt field strength, or magnetic lines-of-force.

When this current decrease drops to about 10 amperes, the coil (F) is wound with such a size wire and number of turns that the core (G) loses its magnetizing force and the blade (H) is released and closes the points (EE), thus cutting the resistance (M) out of the field circuit, and permitting the field strength to build up again to its maximum.

The blade (H), in actual practice, vibrates, or opens and closes rapidly, so that the generator will not charge over 12 to 15 amperes (or 15 to 20 on some generators), at high speeds, and thus **the current output is constant,** regardless of the voltage of the battery, whether charged or discharged.

It will be clear, by referring to Fig. 6, that if the battery should be removed, or if the battery terminals are loose, or some other open circuit should exist, there would be no current flowing through the regulator current coil (F), and there would be no regulation of the generator. Thus, at high speeds, it could build up voltage to such an extent that it would damage the generator.

If the battery is removed, open the field circuit by disconnecting the field wire. Usually there is a fuse in the field circuit which can be removed.

To increase the charging rate, the spring tension of blade (H) is increased, and to **decrease the charging rate,** the spring tension is decreased.

Electromagnetic Voltage and Current Regulation

Current and voltage regulation by the electromagnetic principle can be combined as shown in Fig. 7.

This regulator winding (F1) is on the same core as the cut-out winding (F2), with blade (A) on one end of the core as a cut-out blade, and with a regulator blade on the other end of the core.

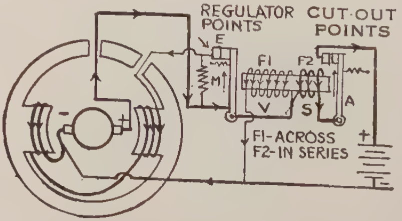

Fig. 7. Electromagnetic voltage and current regulation.

The windings (F1) and (F2) differ, in that (F1) is a fine wire voltage winding and connects across the charging circuit, and the coarse wire current winding (F2) is in series with the charging circuit from the generator to the battery. The charging current does not pass through the voltage winding (F1), but does pass through the current winding (F2). Both windings are in the same direction on the core. The only difference between the regulator and cut-out windings and that of a regular cut-out winding as shown in Fig. 3, page 332, is that in the latter, a regulator blade is provided with points (E) and resistance (M) which can be cut into the field circuit when the points (E) are open.

When the voltage of the generator reaches about 6.5 volts, the current passing through the fine wire winding (F1) is sufficiently magnetized to draw blade (A) of the cut-out against the spring tension, which is so adjusted that the cut-out blade (A) is drawn to the core, and the cut-out points are closed. The charging current then passes through the cut-out winding (F2), through the points, to the (+) terminal of the battery, in the usual manner.

When the voltage or current reaches more than the output should be, the regulator blade (on the left) is drawn to the core against the tension of the spring which is adjusted higher than that of the cut-out blade. This action cuts resistance (M) into the field circuit, as previously explained in connection with Figs. 5 and 6.

It will be noted that **if the cut-out points should not close, or if the battery is disconnected,** current will not flow through the current coil (F2), and the generator will be dependent upon the voltage winding (F1) for regulation. If the voltage winding should become disconnected, then the cut-out points could not close; thus the charging current would not pass to the battery.

If the battery is removed from the circuit, disconnect the shunt-field wire at the regulator, so as to open the field circuit.

An example of a regulation system, similar to the one described is the Ward Leonard "type CC," shown on page 352.

EXAMPLE OF A CONSTANT-VOLTAGE REGULATION (BIJUR CONSTANT-VOLTAGE-REGULATION GENERATOR AS AN EXAMPLE)

The Bijur voltage regulation system is shown in the illustration below (Fig. 8). With this system the amount of current generated depends upon the state of charge of the battery and the amount of lamp load in use. With a discharged battery the voltage is at a minimum, but as the charge of the battery proceeds the voltage of the battery will increase, so that the difference in pressure between generator and battery is continually diminishing. If the battery is fully charged, then the generator charging current will be small. Therefore the charging current is variable even at the same speed of rotation, and tapers from the maximum with a discharged battery to minimum with a fully charged battery.

After the generator reaches a speed at which it develops its normal voltage, the voltage does not materially increase with speed, but remains nearly constant.

Voltage regulation permits of a battery being charged at a high-current rate when the battery voltage is low, and at a much lower rate when the battery voltage is high.

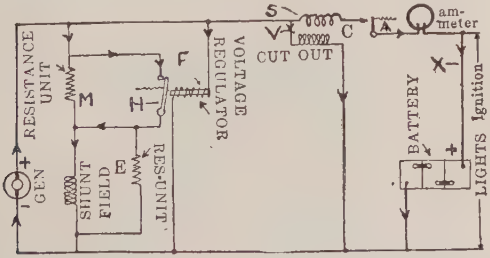

Fig. 8. Bijur electromagnetic voltage regulation system.

Operation of cut-out (C) (Fig. 8): Its purpose is to connect and disconnect the generator to or from the battery when the generator is at rest or at very low speeds. It has a shunt or voltage winding (V), and a series winding (S). The shunt winding (V) is connected across the generator, so as to receive the full voltage of the generator, and when the machine attains a speed at which it develops 6.5 volts, the shunt winding is sufficiently energized to close the cut-out armature (A). The series winding (S) is connected in the main circuit, and current flows through it, and its pull reinforces the pull due to the shunt winding and firmly holds the cut-out armature (A) closed. When the speed of the generator is decreased to a speed where it generates voltage lower than the battery, then a momentary discharge from the battery through the series winding demagnetizes the core of coil (C) and the cut-out is opened.

The voltage-regulating unit (F) (Fig. 8) has a single winding connected across the generator in a manner similar to that of the cut-out voltage winding. It is opened and closed according to the amount of pressure developed by the generator. Below 7.75 volts the resistance (M) is cut out of the field circuit, the path being around it through (H), giving the generator a chance to build up. Above 7.75 volts, the coil (F) pulls (H) to it, which throws resistance (M) into the field circuit, which automatically reduces the generation. While running, this regulator armature vibrates rapidly, cutting the resistance into and out of the field circuit by means of vibrator (H). Thus the pressure never goes above 7.75, or the lamps would burn out.

The other resistance unit (E), which is connected in parallel with the shunt-field winding, is to absorb the field energy when the regulator contacts are open and to reduce sparking at contacts.

Ammeter: In this particular system the meter is connected between the generator and battery, which indicates the generator output only, and does not show a discharge when the generator is at rest. On some cars the meter is connected at branch (X), and with the generator in operation the meter will indicate the output less the current consumed by lights and other devices.

Adjustments: A hole is provided on the regulator box for adjusting the voltage regulator, and another for the cut-out. Turning the adjusting nut to the right on the cut-out raises the cut-in voltage. Turning the adjusting nut on the voltage regulator to the right raises the generator voltage.

Before adjusting cut-out, disconnect one of the battery terminals and place the headlight switch on. Voltmeter leads should be clipped to the generator brushes, and the engine should be run slow, gradually increasing speed. Adjustment should then be made so that the cut-out will close at 6.5 volts. The voltage will then immediately drop on closing, which indicates that it has closed.

In setting the voltage regulator, connect generator to battery, having specific gravity of 1,250 and with light switch off. Voltage should be measured across the brushes as above. Run the engine at such a speed that the generator will turn 1,000 to 1,400 r.p.m. and with the tension of spring regulated until 7.75 to 7.8 volts are generated. Always set adjusting nut tight after adjusting.

The generator can be used without the battery, if lights are on, otherwise the resistance unit is liable to burn out.

Wiring: A single or double wire system can be used with this generator.

Care: (1) every two weeks 2 or 3 drops of thin mineral oil should be put in the oilers; (2) every two weeks **reverse regulator disconnect plug** by pushing it in to unlock, then turn and reverse its connections, which changes the direction of the flow of current through the points of the regulator, thus preventing pitting of points or depolarization, as explained on page 203; (3) inspect brushes every 1,000 miles, to see that they make good contact and move freely up and down.

EXAMPLE OF AN ELECTROMAGNETIC CONSTANT-CURRENT REGULATION SYSTEM (REMY "RELAY-REGULATOR" TYPE)

The Remy generator used with this regulator (Fig. 9) is usually a four-pole generator; however a two-pole type generator is used as an example, which makes no particular difference, because it can be used with either a two or four-pole generator.

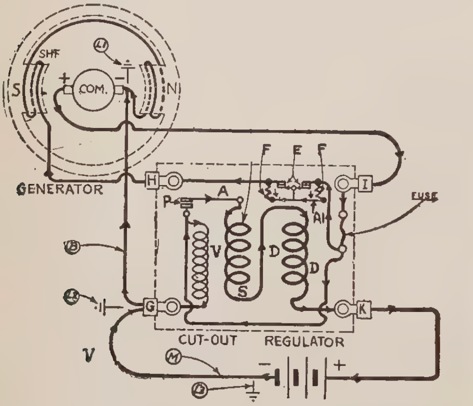

Fig. 9. Remy "relay-regulator"; a current-regulation method. The relay is the same as a cut-out. The cut-out and regulator are mounted on one base, as shown in Fig. 10. See also, Index under "Wiring diagram of Oakland '32'."

The generator is a plain shunt-wound machine and does not have the third-brush regulator, but a "resistance regulation" which is cut into the shunt-field circuit at high speeds by an electro-magnet.

Remy terms a "cut-out" a "relay." Therefore when we speak of a "relay," it is the same device that has been termed a "cut-out" in preceding instructions.

Shunt field circuit: From the (+) main brush of the generator to terminal (I) of the "relay-regulator," through the fuse, through points (E) of regulator, to terminal (H), through the shunt field windings, to the (−) main brush.

Cut-out or voltage circuit: From the (+) brush, to terminal (I), through the fuse, to cut-out voltage winding (V), to terminal (G), to the (−) main brush.

Note. On a grounded or one-wire system, ground connections are made at points (L1), (L2), and (L3) and wires (B) and (M) are not used.

Battery charging circuit: We will assume that the generator has reached a speed where voltage winding (V) has drawn blade (A) to its core, and points (P) are closed. Then the battery charging circuit would be from the (+) main brush, to (I), through the fuse, through points (P), through cut-out blade (A), through cut-out series or current winding (S), through regulator winding (D), to terminal (K), to (+) of battery, to terminal (G), to the main (−) brush.

Note. **If a grounded system,** it would be from (L3) to (L1).

Regulation at high speeds: At high speeds, the current passing through regulator winding (D), which is in series with the charging circuit, would exert a magnetic pull through its core (not shown in the illustration) which would draw the regulator blade, or the armature (A1), to its core, thus opening points (E), which causes resistance (F) to be cut into the shunt-field circuit, thus reducing its lines-of-force, and consequently its current output. The **shunt-field circuit** would then be from the (+) brush, to (I), to the fuse, through resistance (F) because points (E) are open, to (H), to the (−) main brush.

Since the regulator winding (D) is of heavy wire, the amperage or current controls the magnetic strength instead of the voltage, as explained under Fig. 6, page 348. Thus it would be termed "constant-current regulation," by means of an "electro-magnetic" action.

Note. Resistance coils (F) are shunted across each set of regulator points. It is essential that the two sets of regulator points be adjusted so as to be separated by the same current through the regulator coil, and that both sets vibrate together.

Remy Relay-Regulator Adjustments

An internal view of the circuit of the regulator and cut-out (relay), of the Remy system just described, is shown in Fig. 9.

An external view is shown in Fig. 10. Note that the cut-out and regulator are separate windings, but each is mounted on one base, which is usually mounted on the generator.

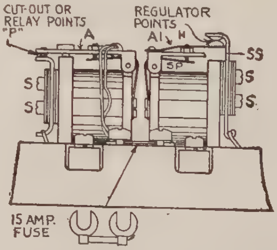

Fig. 10. Cut-out (relay) and regulator used with Remy "relay-regulated" generators.

This cut-out and regulator (Fig. 10) is the combination used with the Remy relay-regulated generator (Fig. 9).

First, however, in order to explain **the adjustment of the cut-out** (relay), we will use an illustration of the Remy cut-out alone (Fig. 11), which represents the same principle as the cut-out shown in Fig. 10 (above).

This cut-out (Fig. 11) is the cut-out used on Remy generators where the regulation is by means of a third-brush (explained farther on), and a regulator of the electromagnetic type (Fig. 10, right) is not used, but, as stated, the cut-out principle of both is similar.

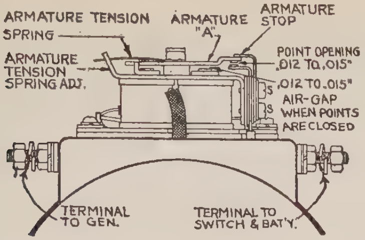
ARMATURE TENSION SPRING
ARMATURE "A"
ARMATURE STOP
POINT OPENING .012 TO .015"
ARMATURE TENSION SPRING ADJ.
.012 TO .015" AIR-GAP WHEN POINTS ARE CLOSED
S
S
TERMINAL TO GEN.
TERMINAL TO SWITCH & BAT'Y.

Fig. 11. Remy cut-out as used with Remy "third-brush regulated" generators. Used as an example to explain the principle of adjustment of the cut-out in Fig. 10, which is similar.

The Remy Cut-Out

The cut-out (termed a "relay") is simply an automatic switch for connecting and disconnecting the generator and the storage battery, as explained on page 332. If the battery were left connected to the generator when the latter runs very slowly or stops, a reverse current would flow from the storage battery back through the generator windings and would soon discharge the storage battery. To prevent this a reverse-current cut-out is provided to act like a check valve, permitting the charging current to flow into the battery when the generator is driven rapidly, but opening the circuit whenever the generator slows down or stops.

The cut-out has two windings, a "shunt" or voltage (V, Fig. 9), consisting of many turns of fine wire, and a "series" winding (S), consisting of comparatively few turns of heavy wire. On the model shown (Fig. 11), the windings are placed on separate iron cores, but in some other models both windings are on the same core.

Whenever a current flows in either winding the core becomes a magnet, the strength of which depends on the amount of current flowing. The shunt or voltage coil is connected directly across the generator terminals in the same manner that a voltmeter would be connected. Hence the current in this coil will depend on the voltage at the generator terminals. The series coil is connected (through the contact points) between the generator and storage battery in the same way that an ammeter would be connected. The internal connections of the cut-out and regulator are shown in Fig. 9.

Cut-Out Adjustments

For correct adjustment of the cut-out (Figs. 10 and 11), it will be necessary to have an ammeter connected between the cut-out and the battery, so that the direction and amount of current flowing can be determined.

The ammeter on the car can be used, but it should be checked to make sure that the hand stands at zero when the engine is at rest and that no lights or other electrical equipment is in use. If it does not indicate correct zero, be sure to allow for the error when making adjustments.

The "air-gap" (Fig. 11), or distance between the end of the core and the armature (A) will affect the operation of the cut-out. Consequently this should be the first point to be considered when the cut-out is to be adjusted.

When the contact points are closed, the air-gap distance between the end of the core and the armature should be .012" to .015". This distance can be changed by moving the stationary contact point up or down. A thickness gauge may be used to check this adjustment. When making this adjustment be sure that the contact points meet each other squarely.

Note. A Remy Service Manual sells for $3. It gives all tests, adjustments and diagrams of generators, etc. See also advertisement on Wiring Diagram Book in the back of this book.

When the contact points are separated, the distance between them should be .012" to .015" on the 263 and 264 models, and .017" to .020" on the other models. On the 263 and 264 models this can be adjusted by bending the armature stop up or down (see Fig. 11). On the other models the stop pin which passes through the armature should fix this adjustment. If it does not, it can be raised or lowered slightly.

"Cut-In" Adjustment of Cut-Out

After having completed these adjustments start the engine and let it idle very slowly; then gradually speed it up until the relay contacts close. This is called the "cut-in," and can usually be determined by watching the ammeter. When the contacts close, the hand should move slightly to indicate a charging current of two or three amperes.

If, when the cut-out "cuts in," the current is greater than three amperes, the armature spring tension should be decreased. This is accomplished as follows: on the 263 and 264 models, by bending the brass strip through which the spring passes; on the M, O, 165, 3923, and similar models, by bending the spring under the armature; on the 60, 66, 261, and 262 models, by backing out the adjusting screw in the center of the armature.

If, when the relay "cuts in," the ammeter indicates a discharge current, the spring tension on the armature should be increased by reversing the processes described above.

Note. The relay cut-in can also be adjusted by connecting a voltmeter across the generator terminals and varying the armature spring tension until the cut-in occurs at the voltage given below:

Models O, 60-A-B, 61-A, 62-A, 64-A, 65-A, 165-D, 261-A-B, 3923	6.4 to 6.6 volts
Models 263-A-C-D-F, 264-A-B-C	7.0 to 7.4 volts
Models M, 66-A, 262-A	12.4 to 12.6 volts
Models 263-B-E	13.5 to 14.0 volts

"Cut-Out" Adjustment of the Cut-Out

Having adjusted the relay to "cut in" properly, speed up the engine until the generator delivers its maximum output, and then gradually reduce the engine speed until the cut-out contact points separate or "cut out." The ammeter hand may swing past zero to the discharge side of the scale for a moment before it cuts out. The discharge current should not be greater than two amperes, nor should the ammeter hand remain on the discharge side for more than a few seconds.

If the discharge current from the battery, back through the cut-out winding, series winding, exceeds two amperes, or if the ammeter hand shows a tendency to remain on the "discharge" side of the scale, the cut-out armature (A, Fig. 11) spring tension should be increased.

If the cut-out "cuts out" while the ammeter still indicates "charge," the armature spring tension should be decreased.

Should the cut-out armature (A) vibrate when the points close it is well to stop the engine and close the contacts by hand for an instant, and then make sure that they open again. This will allow the battery current to flow through the generator windings and magnetize the generator poles with the correct polarity. If the generator polarity is incorrect, the cut-out contacts may be burned.

Vibration of the cut-out armature (**A**) may also be due to "cutting in" when the generator voltage is below that of the battery. This can be corrected by increasing the armature (**A**) spring tension as explained above.

After completing the adjustment of the cut-out, check its operation several times to make sure that it cuts-in and cuts-out properly.

Regulator Adjustments

The action of the regulator, as well as the cut-out just described, is given on pages 350, 351.

After reading the explanation of the action of the regulator, given on page 350, it will readily be seen that an increase in the spring tension on the regulator armature (A1, Fig. 10) would increase the charging rate of the generator, as the current through the regulator winding (D) (Fig. 9), page 350, would have to reach a higher value before the magnetic pull on the armature (A1, Fig. 10) would overcome the increased spring tension.

Before starting to adjust the armature spring tension of the regulator, raise or lower the stationary contact supports (SS, Fig. 10) until the armature stands in the position shown in Fig. 10. The end of the armature should be slightly above the end of the core. Now press down lightly with the finger on the center of the armature and watch the contacts, to determine whether both pairs separate at the same instant (there are two sets of points on the regulator as shown in Fig. 9, page 350). If they do not, adjust one of the stationary contact supports up or down until both pairs separate at once. There are two supports (SS); one for each set of points.

Adjust the spring tension by turning the small screw in the center of the armature in or out until the correct charging rate is obtained (see table below). In some cases it may be necessary to bend the armature tension spring slightly before the correct adjustment can be obtained.

The maximum generator output depends on the model of the regulator as shown by the following table:

Models 60-A, 261-A, 261-B	.13.5 Amperes
Model 60-B	.10.0 Amperes
Models 66-A, 262-A (12-volt)	. 6.5 Amperes

Note. Data books on the regulation, speed, air-gap, cut-in and cut-out speeds of generators, other tests, speeds, etc., for all makes of generators, regulators, and cut-outs can be obtained of A. L. Dyke, St. Louis, Mo. Write for circular.

Care of Remy Cut-Out and Regulator

The cover (Fig. 10) should be removed for inspection at least once every two months. If the contact points are rough, pitted, or dirty, a strip of 00 sandpaper (which has been used) should be drawn through between the contact points (Fig. 12) several times, reversing sides each operation, so as to remove any rough surfaces or foreign material which might have accumulated. Be sure and clean the contact points by drawing a sheet of white paper through the points to remove any material such as sand or dirt.

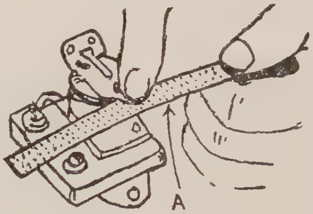

Fig. 12. Strip of sandpaper (A) being drawn between points of cut-out or regulator.

Contact Points

The points should have a smooth, clean surface and make good contact. One of the points is mounted on the end of a screw which can be turned in or out to adjust the air-gap. This gap should be adjusted as previously explained. Three different metals are used for these points: silver, platinum, and tungsten. When silver points are used, a reversing switch (termed a "pole-changing switch"; see Index) should always be used, the reason for this being that the silver passes from one contact to the other with the current, and it is necessary to reverse the direction of current flow occasionally so that the silver will not all build up on one point, leaving none on the other. Tungsten is now used most, and the pole-changing switch is seldom used.

EXAMPLE OF AN ELECTRO-MAGNETIC CONSTANT CURRENT AND VOLTAGE REGULATION SYSTEM (WARD-LEONARD, TYPE "CC")

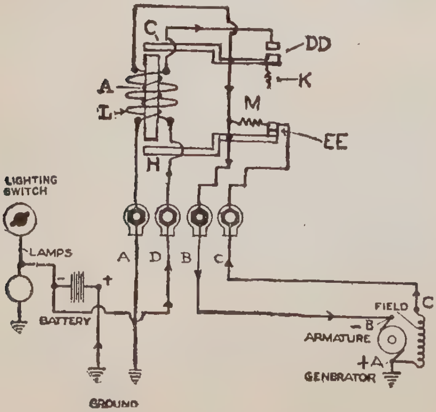

Fig. 13. Internal circuits of the Ward-Leonard type "CC" cut-out and regulator.

An example of a regulator by which **the voltage and current are regulated** is shown in Fig. 13 of the Ward-Leonard, type "CC" cut-out and regulator.

When the generator reaches sufficient speed to generate sufficient voltage to overcome the voltage of the battery, which is usually about 6.5 volts, the current flowing through voltage winding (**A**) magnetizes the core and draws cut-out blade (**C**), thus closing cut-out points (**DD**).

The charging circuit is then from the generator (+) grounded brush, to the (+) grounded terminal of the battery, through the battery, through current winding (**L**), through points (**DD**), to the (−) brush of the generator.

The field circuit is from the (+) brush of the generator, through the field winding, through regulator points (**EE**), through blade or arm (**H**), to the (−) brush of the generator.

This regulation method is similar in principle to that shown in Fig. 7, page 348.

When the charging rate reaches 10 amperes or more (according to tension of spring), the core pull is such that the regulator arm (**H**) is drawn to the core, and thus the points (**EE**) are separated. This action cuts the resistance (**M**) into the field circuit which weakens it, thus the voltage and current are reduced.

When the current decreases slightly below 10 amperes, the core does not have sufficient magnetism to hold the blade (**H**) against its spring tension; it is released, and points (**E**) close, thus cutting out the resistance (**M**).

This blade vibrates as the speed of generator increases and decreases, and thus the output of voltage and current is kept constant.

MECHANICAL REGULATION METHODS; EARLY MODEL AUTOLITE, GRAY & DAVIS AND DELCO

Mechanical Regulation Method (Early Model Autolite)

Mechanical methods for regulating the output on some of the early types of generators were employed. For instance, on an early type of Autolite generator (model "C-60," Fig. 14) permanent magnets were used to produce the lines-of-force for the wires on the drum-type armature to cut.

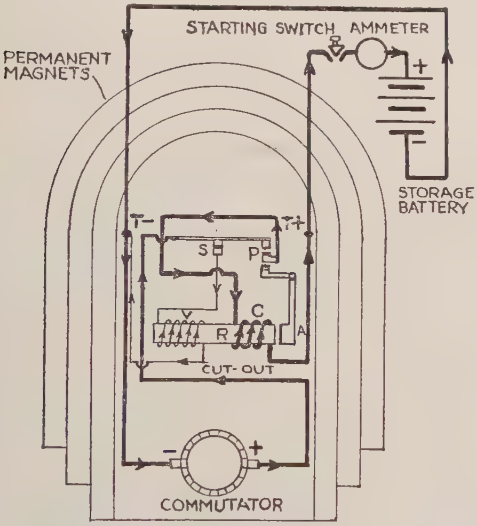

Fig. 14. Early model Autolite mechanical regulation method.

A cut-out, for connecting the generator to the battery when the generator reached about 800 r.p.m. was placed under the magnets above the armature. (Very near all generators have used and now use cut-outs, no matter what regulation method is employed.)[1]

Note that there are two windings, a fine wire voltage winding (**V**) through which current flows when the generator is started, from the (+) brush, to points (**S**), through (**V**) winding, to the (−) generator brush. At 800 r.p.m. of the generator armature, sufficient voltage would be generated for this cut-out voltage winding (**V**) to produce sufficient magnetizing force around core (**R**) to draw arm (**A**) to it, which action closes points (**P**) and opens points (**S**).

The charging circuit is then from the (+) brush, through points (**P**), through the coarse wire current winding (**C**), to the generator (+) terminal, to the switch, to the ammeter, to the battery (+) terminal, through the battery, out battery (−) terminal, to the (−) terminal of generator.

The regulation of output at high speeds could not be controlled by varying the magnetic field, because the strength of the field was permanent. Yet at high speeds the rule is that the greater the rate of speed at which the lines are cut, the greater the e.m.f. generated causing the current to flow. Therefore, in order not to produce too high an output, a **mechanical governor** was employed, which at high speeds disconnected the armature shaft with the drive system. Thus the regulation was a mechanical method of regulating the speed of the generator which reduced the rate of speed of cutting the fixed number of lines-of-force.

This method would be classed as **a mechanically regulated generator** of the "constant-speed constant-current" type.

Mechanical Regulation Method (Early Model Gray & Davis)

One of the first generators designed for automobile work was a Gray & Davis, as shown in Figs. 15 to 15B. This generator used electro-magnetic fields instead of permanent magnets.

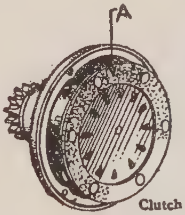

Fig. 15

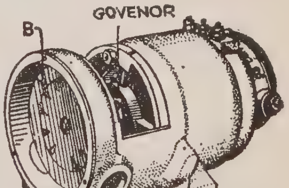

Fig. 15A

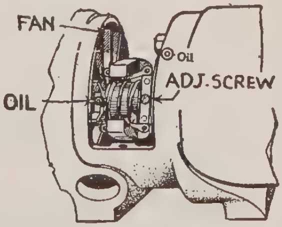

Fig. 15B. Governor of generator.

The mechanical regulation of maximum output was effected by a centrifugal governor, which kept the speed of the machine constant. For that reason this generator may be placed in the class of mechanically regulated machines of "constant-speed constant-current." Variations in speed are taken care of by the automatic "friction" type of clutch.

The friction clutch (**A** and **B**) will slip more or less according to the speed of the engine, and the amount of such slippage is controlled by a governor.

As soon as the speed of the armature increases beyond the rated number of revolutions, the governor will act on the friction clutch. In other words, the two clutch halves (**A** and **B**) will be pulled apart and slip in such a manner that the armature will rotate not faster than the predetermined speed.

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[1] On some of the Delco generators the cut-out is not used. This is explained under the Delco instruction farther on.

A cut-out for connecting and disconnecting the battery and the generator (not illustrated) was used with this system. This generator was an early model and is now obsolete; but it is shown in order to explain one of the mechanical methods for regulating the output of a generator.

Adjustment for a higher or lower charging rate of the output of the generator was made by altering the pressure of the governor clutch spring.

Mechanical Regulation Method; Early Model Delco

On one type of Delco electric system, used on the Hudson "6-40," a **"variable resistance"** was introduced into the field windings mechanically by action of a governor. This is explained under the Delco instruction, as is also the Delco early model "Mercury type voltage regulator," as well as later models where a "third-brush regulation" is used.

INHERENT REGULATION METHODS

Inherent regulation refers to regulation methods inherent of, or **inside of, the generator.** Inherent methods of regulation in most all instances maintain a "constant current" or amperage, the constant-current method being used most.

Inherent, "constant-current" regulation methods would include:

1. **Compound-wound generators** (two windings on the field poles).
2. **Third-brush regulation.**

Compound-Wound Generators

There is a "shunt" winding and a "series" winding on the field poles of a compound-wound generator. The direction in which they are wound relative to each other will produce different actions, as follows:

1. **Cumulative action:** Where the two windings are **wound in the same direction** on the field core, so that one winding assists the other in the magnetizing action of the field poles, it is termed "cumulative" action, and the generator is termed a "cumulative compound" machine.
2. **Differential action:** Where the two windings are **wound in opposite directions** on the field core so that they oppose, or have a "bucking effect," due to the series winding being wound in a reverse direction to that of the shunt winding, it is termed a "differential" action, and the generator is said to be a "differential compound" machine, often termed a "reverse-series" generator.

Simplified Explanation of Cumulative and Differential Action of Windings

Before taking up this subject, glance at Figs. 10 and 10A, and note the **direction of the current** flowing through the wire wrapped around an iron core. Note that the direction in which the wire is wound,

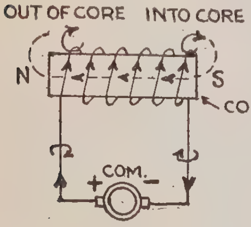

Fig. 10

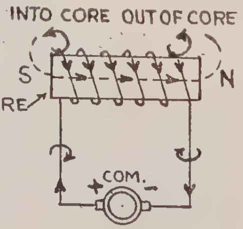

Fig. 10A

Fig. 10. Wound left-hand.
Fig. 10A. Wound right-hand.

and the direction of the current will determine the polarity, or which end of the core will be N and which end S (additional explanations of polarity of electro-magnets are given on page 183). The same principle applies to the iron core, or field poles of a generator, on which is wrapped the field windings.

Suppose, however, that we have two windings on the core, as in Fig. 10B, and that both windings (S and SHF) are wound in such a manner that the current flows through the windings in the same direction around the core. The two windings would then assist each other in establishing a strong polarity of the N pole at one end and of the S pole at the other end. Thus a "cumulative" action is produced.

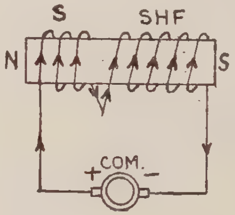

Fig. 10B

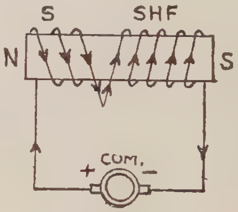

Fig. 10C

Fig. 10B. Cumulative action.
Fig. 10C. Differential action.

Suppose, again, that we have two windings on the core, as in Fig. 10C: one winding (S) with, say, three turns, wrapped in one direction, and another winding (SHF), say, of five turns, wrapped in another direction.

The winding (SHF) (Fig. 10C), having the greatest number of ampere turns, would establish the polarity of the core, making the left end, in this example, the N pole and the right end, the S pole, as in Fig. 10.

The winding (S, Fig. 10C) would **"buck" or oppose the core being thus magnetized,** because the direction in which the current flows through its winding would tend to establish the polarity at opposite ends of the core, as in Fig. 10A. Thus the strength of the magnetic lines-of-force around the core would be weakened, because the current strength which is magnetizing the core is only the difference in the winding (S, Fig. 10C) with three turns, and the winding (SHF) with five turns. Thus this difference holds the polarity of the core, and explains why the principle is termed **"differential action."**

Let us apply this elementary bit of information to the generator of the compound-wound type.

Compound-Wound Generators with "Cumulative" Action

A compound-wound generator with a "shunt" winding and another winding of coarser wire, called a "series" winding is shown in Fig. 11. The shunt winding is connected to the brushes—the usual shunt connected method. The series winding is in series with the generator brushes and the charging circuit. This connection is termed a "short shunt."

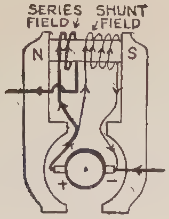

Fig. 11. Compound-wound generator "cumulative" in action; "short shunt" connection.

The series winding, and the shunt-winding both being in the same direction around the field core, the action would be termed "cumulative," as both windings assist each other in building up a strong magnetic field at the N and S poles. The generator would then be termed a "cumulative compound-wound machine" with a "short-shunt" connection. Owing to the fact that both windings assist each other, some sort of regulation at high speeds would be necessary.

The Gray & Davis concern used this principle on an early type of generator, models "C," "C1," "G," and "G1" (see Fig. 11A).

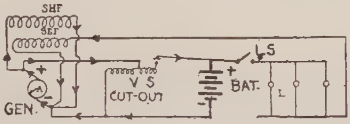

Fig. 11A. **Shunt field circuit:** From (+) brush through shunt field windings (SHF) to (−) brush.

Charging circuit: From (+) brush to cut-out, through cut-out current winding (S) to (+) of battery, to (−) brush of generator.

Lighting circuit: From (+) brush, through cut-out, to lighting switch (LS), through lamps, through series winding (SEF) to (−) brush.

This generator, through its "cumulative" action, would build up just the same as a plain shunt machine. Therefore the mechanical centrifugal governor principle was used to regulate the speed of the generator armature and thus keep the generator at a constant speed, and it was thus termed a **"constant speed"** and **"constant current"** type of generator.

Connections of this system are shown in Fig. 11A. When lamp switch (**LS**) is open, the shunt field winding (**SHF**) is acting alone, and sufficient pressure is generated in the armature winding to overcome the pressure of the battery and produce a charging current.

When the lamp switch (**LS**) is closed, the current to lamps (**L**) passes through the series field (**SEF**) in the same direction as in the shunt field (**SHF**), thus increasing the strength of the magnetic field in which the armature is rotating, and increasing the electromotive force, or pressure generated.

Thus it is possible for the generator to carry the lamp load and to continue to charge the battery at the same rate at which it was charging the battery before the lamps were turned on.

A compound-wound machine with a shunt and series winding is shown in Fig. 12. It is wound so that the current path is in the same direction in both windings, and it would thus be termed **"cumulative compound-wound,"** but it differs from Fig. 11, in that it is "long shunt" connected instead of "short shunt" connected.

Follow the field circuit in Fig. 11, from the (+) brush, and note that the shunt winding connects direct with the brushes and is thus termed a **"short shunt."**

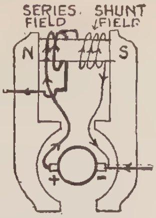

Fig. 12. Compound-wound generator "cumulative" in action; "long shunt" connection. See also Fig. 10B.

Follow the field circuit in Fig. 12 from the (+) brush of the generator and note that the current must first pass through the series winding before it reaches the shunt winding. This is termed a **"long shunt."**

Both are "cumulative" wound and are seldom used, for the reason that the field builds up at high speeds, the same as in a plain shunt generator, and some form of regulation is required.

Compound-Wound Generator with "Differential Action"

A compound-wound machine with a shunt and series winding is shown in Fig. 13. The series winding is wound so that the path of the current through it is in an opposite direction to that in the shunt winding. In other words, the series winding is "reversed"; hence the term often used, **"reversed series"** winding.

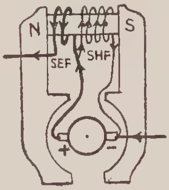

Fig. 13. Compound-wound generator "differential" in action; "short shunt" connection (also termed a "reverse-series" winding).

Connection of the "shunt" and "series" windings with the brushes would be termed a "short shunt," as the shunt winding is connected direct to the brushes.

When the magnetizing action of the current-flow through the series and shunt field windings of a generator is in opposite directions, the action is said to be "differential." Thus we have in Fig. 13 a **"differential compound-wound" generator,** with "short shunt" connection, also termed a **"reverse series"** field winding regulation. This principle is a typical example of "inherent" regulation.

The **shunt winding** (**SHF**), (Fig. 13) is connected with the brushes and establishes the N and S polarity of field pole. Only the field current passes through it. As the generator armature speed increases, the magnetic strength of the field pole increases and would continue to do so if the reversed series winding (**SEF**) did not come into action.

All of the current from generator to battery, lights, etc., must pass through the **reversed series winding** (**SEF**). Note that in Fig. 13 it is wound in an opposite direction to the (**SHF**) winding; therefore as the increasing current passes through the (**SEF**) winding, it tends to **buck or oppose** the (SHF) winding, or, in other words, the effect is to endeavor to reverse the polarity, thus weakening the magnetic field strength, and consequently weakening the output.

COMPOUND-WOUND GENERATORS WITH "DIFFERENTIAL" ACTION—AN EXAMPLE

An example of **a differential-compound wound generator with a "reversed-series"** regulation is shown in Fig. 14. This shows the models "G," "GA," and "GF" Autolite, used on the Overland 82, 86-6, and other cars from 1915 to 1918.

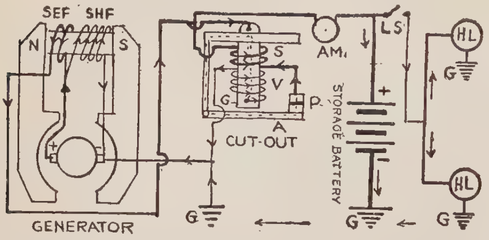

Fig. 14. A compound-wound generator "differential" in action (also termed "reverse-series"); "short shunt" connection.

The generator is a two-pole machine with the two windings on a field core at the top arch of the generator.

The shunt-field circuit is from the (+) main brush through shunt winding (SHF) to the (−) main brush. This establishes the polarity of field poles as N and S.

Cut-out voltage winding circuit: At slow speeds the starting generator current builds up voltage in the cut-out fine winding (V). This circuit is from the (+) brush through series field windings (SEF), to ground (G) on the cut-out frame, through winding (V) to ground (G), to grounded (−) generator brush (G). When the voltage reaches about 6.5 volts the winding (V) magnetizes the core, and armature (A) is drawn to it, thus closing points (P).

Note. The ground (G) on the cut-out frame is insulated from the ground of the car; that is, the cut-out frame is used as an insulated conductor.

The charging circuit is then from the generator main (+) brush, through series field (SEF), to ground on the frame of the cut-out, through points (P), through cut-out series winding (S), through the ammeter, to the (+) terminal of the battery, through the battery to the grounded (−) terminal of battery, to the grounded (−) brush of generator (G).

Regulation of output: At 1,150 r.p.m. the generator gives approximately 12 amperes, and its maximum, 16 amperes, is at 2,000 r.p.m. Above 2,000 revolutions, or at 2,200 r.p.m., it drops to 15 amperes, owing to the effect of the reversed series field winding (SEF).

Refer to the illustration and note that the charging current flows through the series winding (SEF) in a reverse direction to the flow of current through the shunt-field winding (SHF); note also that the series winding (SEF) is in "series" with the battery and generator.

As the current flow increases with the speed of the generator, the current through the series winding (SEF) becomes stronger and stronger until it opposes the shunt-field winding to such an extent that it has the effect of demagnetizing the field core, thus reducing the number of lines-of-force and the output.

This is a form of regulation termed a **"reverse-series" winding regulation,** and is a typical type of an "inherent" system without the use of external devices.

It is clear that since the current for battery and lights is carried through the series winding (which winding serves as a "regulator"), if an open circuit should exist, at high speeds, say, at cut-out points or at the battery, the series field which regulates the output would be open and the generator voltage would build up through the shunt winding (SHF) as on a plain shunt generator and burn out the lights, and in most instances burn out the voltage winding of the cut-out.[1]

Thus, if the battery is disconnected, either a heavy wire should be placed across the brushes or the brushes of the generator should be disconnected altogether.

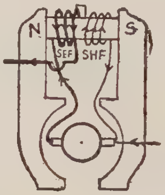

Fig. 15. Compound-wound generator "differential" in action; "long shunt" connection. See also Fig. 10C.

The connections of the compound winding, connected as a "long-shunt" connection are shown in Fig. 15, whereas the short-shunt connection is shown in Fig. 14. It is "differential" in action, as the current flows in opposite directions around the field poles, and thus differs in action from that shown in Fig. 12, which was "cumulative" in action. In other words, current flows in the same direction in both windings.

The principle of the "short" and "long" shunt is similar, except that in the long-shunt connection, the current to the shunt-field must flow first through the series-winding before completing its circuit.

Charging rate adjustments of compound-wound generators with reversed-series winding and shunt winding, differential in action to each other (that is, wound in opposite directions, so as to oppose each other, as in Figs. 13, 14, and 15), are not provided with means for adjustment.

The output can be increased by connecting a resistance wire of low resistance in parallel with the series field. The amount of resistance can be determined only by experiment.

Another method would be to cut out a few turns of the reversed series field coil.

To decrease the output, a few turns could be added to the reversed series coil (SEF).

Compound Winding—"Bucking-Series"

A compound-wound generator with a shunt winding and a "reversed-series-field" winding with a "thermal unit" for cutting into the series-field at high speeds is shown in Fig. 16.[2] This system would be termed an "inherent, constant current" system with a "differential" or "bucking-series" action.

The difference between this system (Fig. 16), and the "differential" system shown in Figs. 13, 14, and 15 is that the series field winding (SEF), also called "regulating winding," does not take all or even a part of the current delivered by the generator until the generator speed reaches a point above a car speed of 15 miles per hour. The current up to this point passes through an iron wire resistance (B), called a "ballast coil," and when cold offers no resistance. Thus the current does not pass through the series winding, because there is less resistance through the resistance coil (B), when cold.

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[1] The voltage winding is also often burned out when the cut-out points stick and the battery discharges for a long period back through the generator.

[2] Formerly the Rushmore (now known as the Bosch) "thermal principle of regulation."

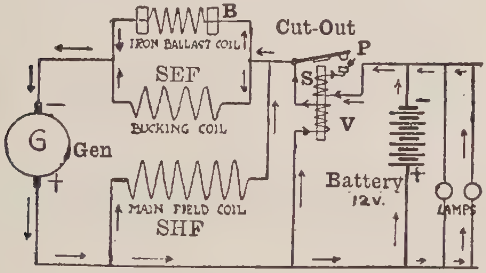


Fig. 16. **Shunt-field circuit:** From (+) brush, through shunt-field winding (SHF), through ballast coil (when cold), to (−) brush of generator (G). When (B) becomes hot, resistance is offered and the path is then through (SEF).

Cut-out voltage winding: From (+) brush, through winding (V), through ballast coil, to (−) brush of generator.

Charging circuit: From (+) brush, through battery (+), to cut-out series winding (S), through points (P), through series bucking coil (or ballast coil, if less than 15 m.p.h.), to (−) brush of generator.

The generator, therefore, acts as a plain uncontrolled shunt-wound machine, and builds up voltage rapidly.

As the speed of the generator increases, the charging current passing through the ballast coil (iron wire B) increases, and thus its temperature is raised. At 15 m.p.h. car speed, the charging current reaches a higher value, and the ballast coil is heated to such an extent that it offers more resistance than does the series winding (SEF). Therefore the current takes the easier path through the series winding, which causes the "differential" effect of opposing the shunt-field winding (SHF), which in turn demagnetizes the field core and reduces the output, as explained under Fig. 14.

This action of **the series field opposing the shunt field is often termed "bucking,"** and the series field (SEF) is often termed a "bucking coil," as it bucks against the shunt-field (SHF) magnetizing effect of the field core.

THIRD-BRUSH REGULATION

The generator using a third brush to regulate the output at high speeds is a shunt-wound generator, and not a compound-wound (unless it is a motor-generator combined, which is explained farther on). The third brush regulates the current out-put of the generator, and is termed a **"constant current"** regulation method.

The third-brush regulation of the out-put of a generator is a typical example of an "inherent" method of regulation. The regulation is accomplished without the use of resistance, or electro-magnets, or any external devices whatsoever, and is the system now in general use.

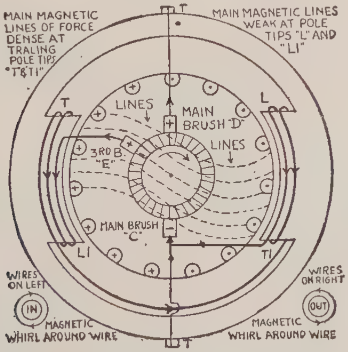

MAIN MAGNETIC LINES OF FORCE DENSE AT TRALING POLE TIPS "T&T1"
T
MAIN MAGNETIC LINES WEAK AT POLE TIPS "L" AND "L1"
T
LINES
MAIN BRUSH "D"
L
LINES
3RD B. "E"
MAIN BRUSH "C"
L1
T1
WIRES ON LEFT
IN
MAGNETIC WHIRL AROUND WIRE
WIRES ON RIGHT
OUT
MAGNETIC WHIRL AROUND WIRE

Fig. 17. Third-brush regulated generator.

A diagram of the internal connections of a third-brush regulated generator is shown in Fig. 17.

Note that instead of both terminals of the shunt-field windings being connected direct to the main brushes, one end of the shunt-field winding is connected to the third brush, and the other end is connected to the (−) main brush. This **third brush** regulates or controls the amount of current passing to the shunt-field windings, and thus tends to keep the current out-put of the generator constant.

The third brush is always connected with one end of the shunt-field windings, either the (+) or the (−), depending upon the direction of rotation of the armature and the side of commutator on which it is placed. In the example given above it is connected with the (+) side; thus the current leads from it into the field windings.

The shunt-field circuit, in Fig. 17, is from the third brush (which is on the (+) side of the armature), through the field windings, to the (−) main brush.

As stated above, the amount of current passing to the field windings is dependent upon the third brush. In a plain shunt-wound generator the field windings are connected direct to the main brushes, but by connecting one end of the field winding to the third brush, we cut out part of the armature coils.

Magnetic Circuit of Generators

Before the principle of the third brush can be understood, it will be necessary to take up the subjects of "magnetic circuits of generators," "brushes," and "armature reaction," which will lead us to the explanation of the third-brush principle.

The same principle applies to the magnetic circuit of a motor.

The main magnetic circuit of a two-pole round-frame generator, with poles 180° apart, is shown in Fig. 18 (page 358). The polarity of the pole is determined by the direction in which the wire is wrapped around it, and the direction in which current flows in the wire, just the same as the polarity of the electro-magnets shown on page 183. The word "polarity" refers to the N or S pole.

The main magnetic circuit, also called the "main magnetic field," or the path of the magnetic lines-of-force is very much the same as on an electro-magnet. In fact, we could term the two field poles "electro-magnets."

Let us assume that wire is wrapped around the field poles and that current is flowing in such a direc-

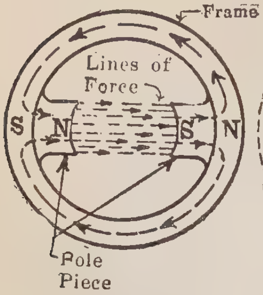


Fig. 18

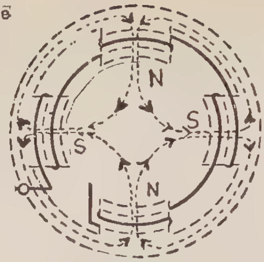


Fig. 19

tion as to give the pole on the left (Fig. 18) a N-pole polarity, and the pole on the right a S-pole polarity.

Therefore the lines-of-force would pass out from the N-pole end of the left electro-magnet (field pole), across the air gap (where the armature revolves), to the S-pole end of the electro-magnet on the right, then out the N-pole end of this magnet on the right, through the frame to the S-pole end of the magnet on the left, back to its N-pole end. Thus the magnetic circuit is completed, above and below and all around.

The magnetic circuit of a four-pole round-frame generator, with field poles 90° apart from the center of each pole, is shown in Fig. 19. Poles opposite each other are of the same polarity, or, in other words, the polarity alternates. This is necessary in order that there be a magnetic circuit.

If the poles opposite each other were of opposite polarity, the lines-of-force could flow only in two directions, as shown in Fig. 21.

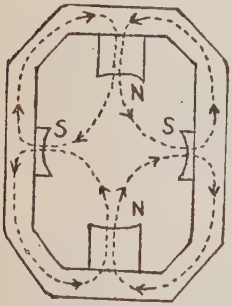


Fig. 20

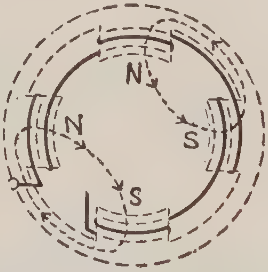


Fig. 21 (wrong).

The main magnetic lines-of-force will not flow across the air-gap from one pole to another, where there are a multiple of poles, because they take the easier path, from one pole to the adjacent pole. They could not flow across air-gap, from one pole to another, because they would have to cross each other and lines-of-force cannot cross or merge into each other.[1] Therefore the plan shown in Figs. 19 and 20 is the usual polarity for "multi-polar" generators.

A four-pole rectangular generator frame with two field poles on which wire is wrapped (the upper and lower poles), and two field poles without wire, is shown in Fig. 20. The field poles on which there is no wire are called "consequent" poles. The magnetic circuit is similar to the four-pole generator (Fig. 19). The magnetic circuit takes the shortest path, as shown.

If the top pole was N and the bottom pole S, then the lines-of-force would only be made to pass from the top to the bottom pole by having the space between poles less than from the pole to the sides of the frame. In other words, the lines take the shortest path.

A two-pole generator has more wire on the field poles than a four-pole generator, the capacity being the same.

It will be noticed that on two-pole generators the magnetic lines-of-force flow straight across and through the armature, and that on four and six-pole generators the lines pass through only a portion of the armature. For this reason, the armature wires are wound accordingly. The two-pole armature is divided into halves, and the four-pole into quarters called "spans." Hence the reason for placing brushes in different positions, as will be explained farther on.

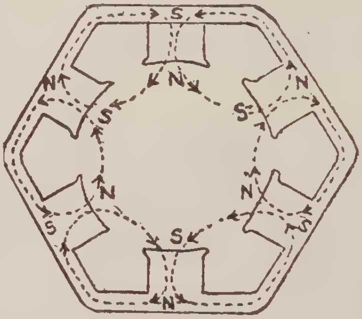


Fig. 22

A six-pole, multi-polar generator frame is shown in Fig. 22. Note that the polarity of the poles alternates, as was the case in Fig. 19.

Note, too, that there are six field poles. If wire was wrapped on these field poles and current passed through the winding, each field pole would be an electro-magnet; one end of the field pole would be N and the other S.

Therefore, if the field pole, say, in the center, at top, was wrapped with wire in such a direction that its inner end, facing the center of the generator was the N pole, its other, or upper end, would be the S pole, just the same as in the case of an electro-magnet.

The next pole would have the wire wrapped around it in such a direction that its inner end would be the S and the upper end of it would be the N pole, and so on, around the entire lot of field poles.

The main magnetic circuit would then be just the same as explained in Fig. 19, page 358, which is: out of the N-pole end, into the adjacent poles at the S-pole end, out of the N pole, or the upper end of the S pole, into the frame, into the S-pole end of the N pole, thus completing the magnetic circuit.

Note. Diagrams showing the N and S pole polarity of generators are rarely marked at the upper end, next to the frame. Where they are marked, which is usually at the inner end, or it may be at the upper end, as a matter of convenience, such marking always refers to the polarity at the inner end of the field pole next to the armature.

---

[1] Lines-of-force do not cross or merge into each other. Although there are millions of them, each line is independent of the other.

Brushes

It is also necessary to explain the location of brushes on a generator commutator, in order to lead up to the principle of the third brush, because the position of the third brush and the distortion of the main magnetic field are two factors governing the operation of the third brush,

Main brushes on a two-pole (bi-polar) generator are placed 180° apart (Fig. 26). One is positive (+), the other negative (−).

Main brushes on a four-pole (multi-polar) generator can use either two or four main brushes.

If two brushes, they would be placed 90° apart (Fig. 26A), and one would be negative and the other positive.

If four brushes (Fig. 26B), two would be positive (+) and two negative (−), the brushes opposite each other being of the same polarity.

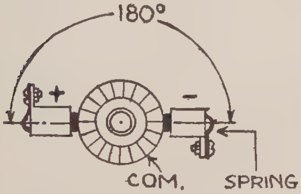


Fig. 26

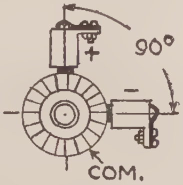


Fig. 26A

Only two brushes on a four-pole generator are necessary, if they are large enough to carry the current, as they are more accessible.

On many of the Remy four-pole generators of the straight shunt-wound type, using an external regulation system (Fig. 17, page 422), there are **three brushes** (Fig. 26E). Two of these are "main brushes" and the third is a "field brush." **This is not a "third brush,"** and it is not absolutely necessary, but is used as a common ground for the armature and field.

The third brush is usually smaller than the main brushes and is usually black, whereas the main brushes are often copper plated.

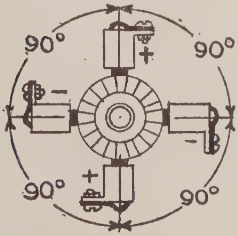


Fig. 26B

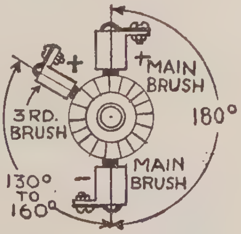


Fig. 26C

On a two-pole, or bi-polar generator, the third brush is placed slightly nearer to either the (+) or (−) main brush, as in Fig. 26C. Thus it will usually be (−) if nearer the (−) brush, or (+) if nearer the (+) brush. The location varies according to the direction of motion of the armature and the direction of current through the field windings.

On a four-pole, or multi-polar generator where there is a third brush, the two main brushes are usually located 90° apart. The position of the third brush will be between 130° and 160° from the main brush of opposite polarity, as shown in Fig. 26D.

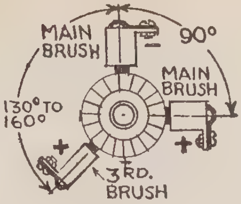


Fig. 26D

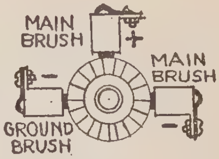


Fig. 26E

Brush construction: The brushes used on generators are usually carbon brushes. The reason carbon is used is because they have the advantage of giving better commutation than copper brushes, as they offer a higher resistance in the path of the short-circuited coil (C, Fig. 26H) than copper brushes do, and thus keep down sparking to a certain extent. They are quite often copper plated, so that the current will be conducted to the main circuit without this resistance effect, but the part resting on the commutator segments is plain carbon, and thus offers resistance to the coil (C) of the armature, which it short-circuits across when over two segments.

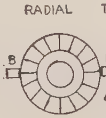


Fig. 26F.

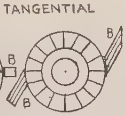


Fig. 26G.

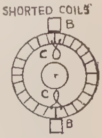


Fig. 26H.

Brushes on motors were formerly made of gauze, but are now made of composition, something like graphite and carbon.

A radial brush is where the brushes butt directly against the commutator, as in Fig. 26F. They are usually of carbon and this is the principle of construction for brushes used on automobile generators and motors.

Tangential brushes are usually made of copper, and are placed as shown in Fig. 26G. They are seldom used. Starting motor brushes are now made of a composition similar to carbon, but softer, and are placed in a radial position (Fig. 26F).

Brushes must be seated (rounded out) to fit the curvature of the commutator. See Index under "Seating brushes."

Setting Brushes

An armature with wires around the core is shown in Fig. 27. The commutator is not shown, but the brushes are shown as if connected with the wires.

The lines-of-force are flowing from N to S, as indicated by the straight arrows. We will term this the "main magnetic field." Therefore, the armature revolving as it does, it would cut the lines up on the left, and current would flow in, and as the wires cut down on the right, current flows out.

If these lines-of-force always passed in a straight line as shown, a "neutral" line could be drawn directly down through two commutator bars at a position where the current in the wires on the two sides are opposed to each other. In other words, one side is (+) and the other (−). The "neutral line" therefore would be as shown.

Armature Reaction

Owing, however, to what is termed "armature reaction," this line is always farther advanced in the direction of rotation, for the reason mentioned on the next page.

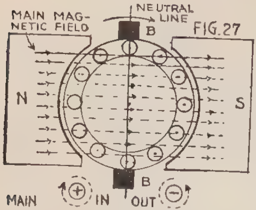


FIG. 27

MAGNECTIC LINES FLOWING STRAIGHT ACROSS

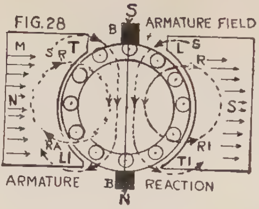
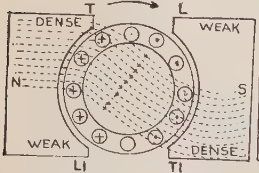


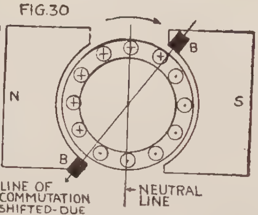
FIG. 28

FIG. 29



DUE TO ARMATURE REACTION THE MAIN MAGNECTIC LINES ARE THROWN OUT OF LINE

FIG. 30



LINE OF COMMUTATION SHIFTED-DUE TO ARMATURE REACTION

When the armature revolves, current flows through its winding, and it immediately does what an electro-magnet would do; its core would become magnetized. That is, it would produce an electro-magnetic effect of its own, independent of the "main magnetic circuit," with a N and S pole polarity, as shown in Fig. 28, resulting from the lines-of-force produced around the wires by the current flowing in the wires. As will be noted in Fig. 28, these lines are directly across the main magnetic field, as shown in Fig. 27.

It will be noted, by referring to Fig. 28, that the "main magnetic field" (straight arrows), in passing from the N to the S pole, would flow in the same direction at the "trailing pole tip" (T), as the lines-of-force produced around the armature (curved lines), and thus would offer no opposition, and the main magnetic lines-of-force would be dense, as at (T) (Fig. 29).

On the other side, however, at the top (Fig. 28), at the "leading pole tip" (L), the lines-of-force around the armature wires are flowing in the opposite direction to the "main magnetic field" and would oppose it. Therefore the lines would drop, and at this pole tip (L), the magnetic field is weak (Fig. 29).

At the bottom (L1) (Fig. 28), opposition is offered, and thus this "leading pole tip" would be weak (see Fig. 29), whereas at the "trailing pole tip" (T1), the "main magnetic field" and "armature field" would be in the same direction, and thus (T1) would be dense, as in Fig. 29.

Refer now to Fig. 29, and note that **the magnetic lines have been distorted out of a regular straight line,** so as to weaken the "leading pole tips" (L) and (L1) and to strengthen the "trailing pole tips" (T) and (T1) because of the "armature reaction," or lines-of-force set up in the armature, as in Fig. 28.

The position of neutral plane will not therefore now be as in Fig. 27, but would be somewhere in the position shown in Fig. 30, in the direction of rotation of the armature. And the angle would increase as the current from the armature increased.

Therefore the necessity of **shifting brushes forward or backward** to locate the **"line of commutation"** in order to reduce sparking at the brushes will be evident. This **"neutral line"** must be found when setting brushes, otherwise the voltage may not come up to normal.

On some of the Westinghouse generators the brushes are set on this neutral line (Fig. 30). The brush rigging holding the main brushes is permanent, but they can be shifted, if necessary, by loosening and moving the commutator end housing.

The Remy generator brushes are moved one-half or two-thirds the width of the segment in the direction of rotation from the neutral line. The Delco and Bijur main brushes are set permanently.

To Find Neutral Position

To find the neutral position on the commutator it is necessary to "motor" the generator, that is, to connect a battery of the same voltage as the generator to the main brushes, and then shift the brushes one way or the other until the armature will not turn in either direction. This is "neutral point," or where the wires on one side are positive and the other side negative, and the neutral line is between.

This position can also be found by connecting a voltmeter between the brushes and moving the rocker-ring until the point of highest voltage is reached. The voltage will decrease as the brushes are moved away from the neutral plane.

Note. The current on this test is sent through the armature. Therefore always disconnect one side of the field from the circuit. If in a third-brush generator, this can be done by raising the third brush, as the third brush connects with one end of the field. As an example relative to finding "neutral" position, the Ford generator will be used.

To locate neutral position of brushes on a Ford generator: When brushes seat properly, the main brushes should be set on the neutral point. Raise the third brush and disconnect the field circuit. Connect the battery wire to the generator terminal. If the armature revolves, the brushes are not set on the neutral point. Turn the ring against the direction of rotation until the armature ceases to turn or until it revolves in the opposite direction. If it turns in the opposite direction, bring the ring back until the armature will not revolve in either direction, even when started by turning the shaft by hand. The brushes are now set on neutral point. Tighten the screws which hold the ring to head; lower the third brush and try it for running. If it turns over properly, drawing less than six—preferably less than four—amperes, the generator should be assembled to the engine, and proper connections should be made through the cut-out to the battery.

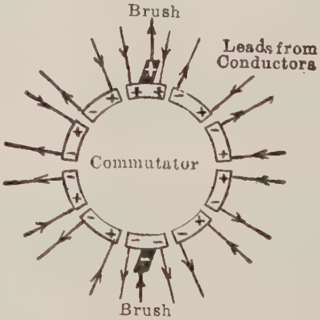


Fig. 30A. Showing the reason for placing the brushes in a neutral position.

Why a brush must be set on or near to neutral: Without going into the subject of armature winding, which would require considerable explanation, of value only to an armature winder, a simplified explanation is given as follows:

In the case of either a lap or wave-wound armature, by referring to Fig. 30A, it will be noted that two conductors are connected to each commutator bar. On most of these commutator bars, the current is flowing into the bar from one of the conductors, and out of this same bar to the other conductors.

Note that there is only one commutator bar to which current is flowing from both conductors;

consequently the (+) brush should be in contact with this commutator bar. In the same way there is only one commutator bar from which current is flowing to both conductors; consequently the (−) brush should be in contact with this commutator bar.

Brushes on motors are shifted in the opposite direction to that of generators owing to the fact that the armature reaction is in the opposite direction.

Figs. 31 and 32 illustrate methods of keeping the **brushes pressed firmly to the commutator** by spring tension. Note the spring.

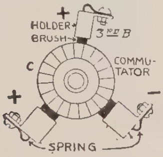


Fig. 31.

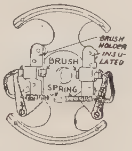


Fig. 32.

Fig. 31 represents **two main brushes and a third brush** as on the Ford "FA," 4-pole generator.

Fig. 32 shows the **brush holder, the brushes, and the end plate** of a two-pole generator, as shown in Fig. 33.

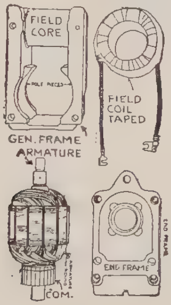


Fig. 33.

Fig. 33 illustrates the parts of a two-pole generator with a single-field winding. The field coil is shown to the right at top, and the armature and end plate are at the bottom of the illustration. The **round frame** with two and four poles is **used most.**

The Principle of Operation of the Third Brush

Now that we have learned how the magnetic circuit is distorted and how the pole-tips are weakened, the principle of the third brush will be easier to understand.

Refer to Fig. 34. Suppose the voltage from the main brush (C) to the main brush (D) is 6½ volts, the voltage would be about 5 volts from the main brush (C) to the third brush (E). Thus 5 volts would be applied to the shunt-field winding, which is sufficient pressure to cause approximately 1¼ amperes to flow to the shunt-field windings. At low speeds, where the generator armature sends little or no current into the battery, the "main magnetic field" is almost straight across from N to S poles, as in Fig. 27, page 360.

As the generator speed rises, the current going to the battery increases. This current of course flows through the armature, from the main (+) brush (D), to the battery, to the main (−) brush (C).

This current flowing through the armature winding sets up what is termed "armature reaction," as explained on page 360 (Fig. 28), with the result that the "main magnetic field," which at low speeds moved straight across from N to S pole (as in Fig. 27, page 360), is now distorted or twisted out of its original position, very much like two streams of water coming together, and as shown in Fig. 34. Thus, as explained on page 360, at the trailing pole tips (T) and (T1), the lines-of-force are dense and strong, and at the leading pole tips (L) and (L1), they are weak.

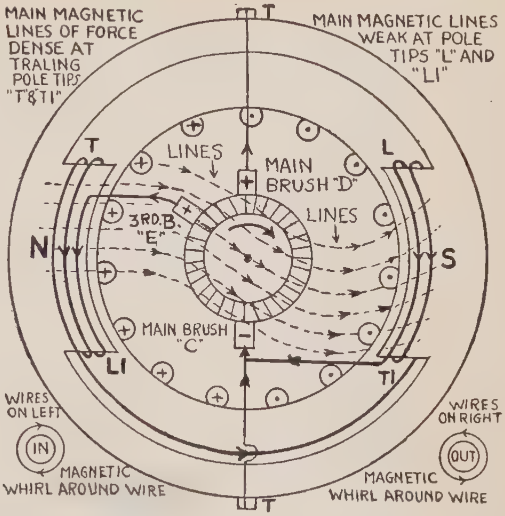

MAIN MAGNETIC LINES OF FORCE DENSE AT TRALING POLE TIPS "T"&"T1"
T
MAIN MAGNETIC LINES WEAK AT POLE TIPS "L" AND "L1"
T
LINES
MAIN BRUSH "D"
L
3RD.B. "E"
LINES
N
S
MAIN BRUSH "C"
L1
T1
WIRES ON LEFT
IN
MAGNETIC WHIRL AROUND WIRE
WIRES ON RIGHT
OUT
MAGNETIC WHIRL AROUND WIRE
T

Fig. 34. Explaining the principle, or action of the third brush.

Therefore the armature coils, in passing from brush (E) to (D), is passing through the weakest magnetic field, and consequently a very low voltage is generated.

The greater part of the voltage is generated when passing from brushes (C) to (E), as this part of the magnetic field is strongest.

Thus, as the speed increases the distortion is greater, weakening the leading pole tips where the third brush takes its current for the field windings. As the magnetic lines-of-force are weakened, the current to the field weakens, and the voltage of the machine becomes less than would be the case with the full-field strength, thus holding the generated current down to the maximum for which the brush is set. Clearly, then, the shunt-field current decreases as the speed increases.

Adjusting Output of Third-Brush Regulated Generators

The maximum output of a third-brush regulated generator can be increased by moving the third brush on the commutator away from the main brush, which is connected to the field-windings. **To decrease,** move it in the opposite direction.

Since the field is connected between these two brushes, it can readily be seen that increasing the distance between them will insert a greater number of armature conductors between them, thus increasing the voltage applied to the field windings, which in turn will increase the field strength, consequently increasing the generator output.

Most third-brush generators have **an adjustable brush arm** which can be adjusted in either direction.

It is important that all brushes be fully seated, especially the third brush.

The third-brush regulated generator is now used more than any other method of regulation.

The third-brush regulated generator is a "constant-current" regulated type of generator, because of the fact that the charging current flowing through the armature winding produces the field distortion necessary for regulation. Therefore, **the charging circuit must not be opened** by removal of the battery or open circuits, otherwise the generator would build up voltage to a high value.

When disconnecting the battery, the main generator terminal should be grounded or the shunt-field fuse removed.

Most third-brush regulated generators have **field fuses** connected with the shunt-field winding.

If lamps are operated from a constant-current generator, the lamps will be burned out when the battery is disconnected unless the lamps are so connected that they consume the entire output of the generator.

EXAMPLE OF A THIRD-BRUSH REGULATED GENERATOR (REMY)

A Remy four-pole, third-brush regulated generator is shown in Fig. 35.

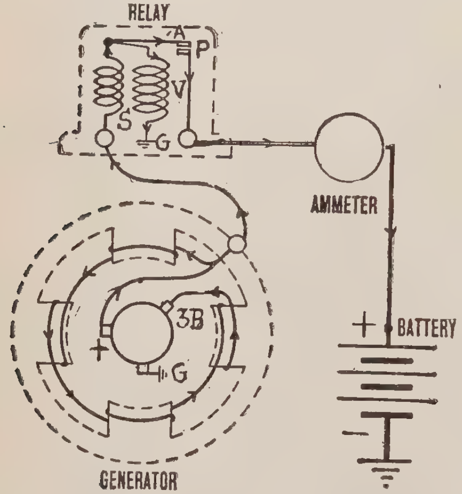


Fig. 35. A Remy four-pole, third-brush regulated generator.

Shunt-field circuit: From the (+) main brush, through the field windings, to the third brush, which in this instance is connected on the (−) side. This completes the field circuit. The regulation of this field circuit at high speeds is by means of the third brush, as explained on page 361.

The cut-out voltage winding circuit is the next circuit to trace. This circuit starts at the (+) main brush, to cut-out[1] series coil (S), to voltage winding (V), to ground, to the grounded (−) main brush of the generator. Thus the cut-out voltage winding is completed.

Battery-charging circuit: When the speed of the generator reaches a voltage higher than that of the battery, the voltage is such that the voltage winding (V) exerts sufficient magnetizing effect to draw the cut-out armature blade (A) to the core, thus closing points (P). The charging circuit is then from the (+) brush, through series coil (S), through blade (A), through points (P), to the ammeter, to (+) of the battery, through the battery, to (−) ground of the battery, to the (−) grounded main brush.

The battery discharge circuit is about 2 amperes back through the cut-out series coil (S) to cause the points (P) to open when the generator speed drops to a low speed (see action in Fig. 5, page 333).

Third-Brush Regulated Generator with a Thermostat Control (Remy)

It will be noticed in Fig. 36 that a **thermostat** is provided in addition to the third brush, the purpose of which is explained farther on.

Shunt-field circuit: From the (+) main brush through the thermostat blades (which offers no resistance when cold), through the thermostat closed points (X), through the field windings (two-pole generator), to the third brush. (Note that the third brush is on the (−) side in this instance.) Thus a third brush regulates the output of the generator.

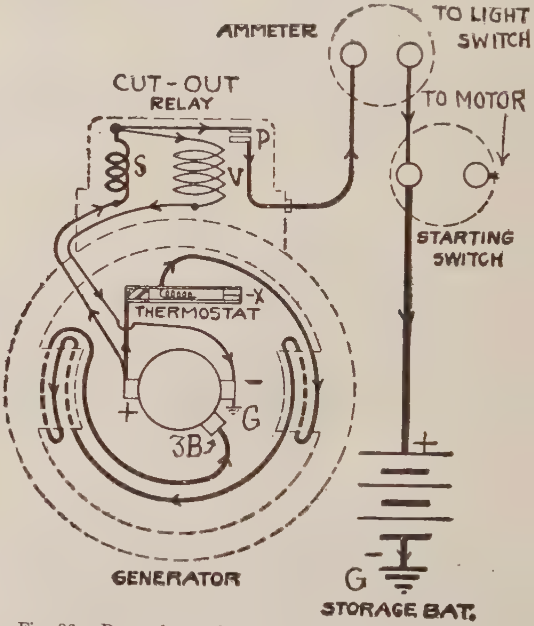


Fig. 36. Remy four-pole, third-brush regulated generator using a thermostat control.

The thermostat, more clearly shown in Fig. 37, **is in series with the field circuit** (Fig. 36). Its purpose is to permit setting the third brush to a much higher charging rate. Thus when first starting with a cold generator, the charging rate will be higher than if there was no thermostat. Thus a heavy charge goes to the battery.

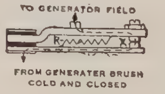


Fig. 37

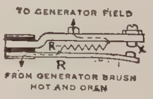


Fig. 38

Fig. 37. Thermostat points (X) closed. Resistance (R) not in the circuit.

Fig. 38. Thermostat points (X) open. Resistance (R) is now in the field circuit.

When the generator is cold, the thermostat springs hold the contact points closed, and no resistance is offered to the flow of current from the armature through the field windings, which, as stated, is higher than if the thermostat was not used.

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[1] Thus the cut-out consists of two cores, one for the voltage winding and one for the cut-out series winding.

Owing to the heavy current flowing through the thermostat blades, the temperature rises quickly to a degree of approximately 175° F., at which time the blades warp and the points separate, thus inserting the resistance (see Fig. 38) into the field circuit. With this resistance in the field circuit, the charging rate is then about what the average third-brush regulated generator would be set for, or the regular charging rate, though the strength of the field circuit is normal.

Thus **the thermostat is not classed as a regulator** for cutting down the output at high speeds, but is merely used so that a heavier charging current will go to the battery when first starting or when the generator is cold, thus, termed a **"thermostat control."**

On some of the Remy systems, for instance in the 1919 Stearns, a multiple of four of the thermostat blades were used, connected in parallel, and set for different temperature openings.

The blades of thermostat are made of a strip of spring brass welded to a strip of nickel steel, a combination which warps when heated, because of the greater expansion of brass.

The thermostat is generally used with only the third-brush regulated type of generator.

The third-brush constant-current regulation is the principle used on this generator at high speeds, the principle of which is explained on page 361.

The cut-out voltage or shunt circuit: Current flows from the (+) brush through the current or series winding (S) of the cut-out, through voltage winding (V), to the (−) main brush.

Charging circuit: When the voltage of the generator is higher than that of the battery, the magnetic strength of the voltage winding around its core will be sufficient to draw the cut-out armature blade, thus closing points (P); the charging circuit is then from the (+) brush, through series winding (S) of the cut-out, through the blade, through points (P), to the ammeter, to the (+) terminal of the battery, to the (−) terminal of the battery, to ground, to ground of the (−) main brush.

Remy Generator Adjustments

Third-brush adjustment. To raise the output of a generator on which the third-brush regulation is used, it is necessary to move the third brush near the main brush, which is not connected to the field windings, or farther away from the "leading" main brush, which is connected to the field windings. Since the field is connected between this latter main brush and the third brush, it can readily be seen that increasing the distance between these brushes will increase the voltage impressed upon the field, which will also increase the field strength, and will in turn increase the generator output. On the other hand moving the brush farther away from the trailing main brush or nearer the leading main brush will decrease the field strength and decrease the output.

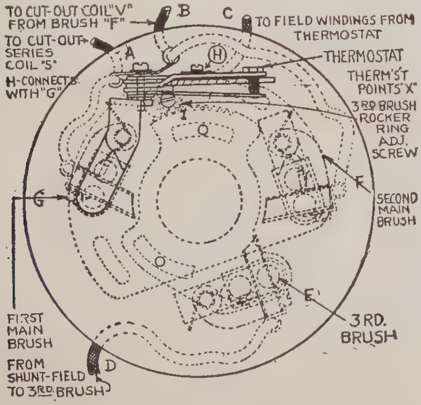
TO CUT-OUT COIL "V" FROM BRUSH "F"
B
C
TO FIELD WINDINGS FROM THERMOSTAT
TO CUT-OUT SERIES COIL "S"
A
H
THERMOSTAT
H-CONNECTS WITH "G"
THERM'ST POINTS "X"
3RD BRUSH ROCKER RING ADJ. SCREW
SECOND MAIN BRUSH
G
E
FIRST MAIN BRUSH
3 RD. BRUSH
FROM SHUNT-FIELD TO 3RD BRUSH
D

Fig. 39. Remy third-brush adjustment, showing the location of parts. The third brush can be adjusted by the third-brush rocker-ring adjusting screw through the part marked (1). E is the third brush; D, connection to field winding; G, first main brush on the brush holder to which the thermostat assembly (H) is attached; C is the field lead showing the return from the field winding; A is the lead to the cut-out and battery. See also Fig. 36.

Setting brushes on generators: All generator brushes should be set in the position of least sparking when carrying full load, which position will be located a short distance ahead (in the direction of rotation) from the neutral plane. (See page 360 explaining the "neutral plane.") The brushes are in the neutral plane when at the position where the current is reversing in the winding, and, therefore, at the position where the highest voltage is obtained between brushes of opposite polarity.

This position can be located by connecting a voltmeter between the brushes and moving the rocker-ring until the point of highest voltage is reached. The voltage will decrease as the brushes are moved away from the neutral plane.

The cut-out used with the Remy generator (Figs. 35 and 36) is explained on pages 351 and 350.

Third-brush adjustment (fixed type): Fig. 40 illustrates the method of regulating the output of a stationary third-brush type generator, such as models "O" and "OB." Filing away a portion of the third brush so as to reduce the seat will tend to throw the brush nearer or farther away from the trailing main brush.

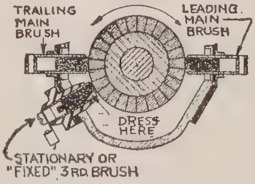

Fig. 40. Third-brush "fixed type." Seldom used.

To increase the output, file the third brush as shown in Fig. 40, which places the brush ahead, or towards the trailing brush, which is the same as moving it in the direction of rotation.

To decrease the output, file the top side, so as to place the brush away from the trailing main brush.

File only a small portion of the brush at a time, making tests by installing it and running the generator until desired maximum output is obtained.

If the armature revolves in the opposite direction to that in Fig. 40, employ the same principle.

The third brushes in Remy generators (Figs. 35 and 36) are **adjustable.**

The cut-out, as used with the Remy third-brush regulated generator, and the method of adjusting them, is shown on page 351.

Remy generators with a plain shunt-winding and with an "electromagnetic principle of regulation" have no adjustment, except that the brushes should be adjusted and seated for good commutation.

The relay-regulator, however, is adjustable. This is explained on page 350, and thus the plain shunt-wound generators which are used with this "electromagnetic" regulation method can be adjusted in the manner explained on page 352.

BIJUR THIRD-BRUSH REGULATED GENERATORS

Two examples of the Bijur generators are shown: one with the cut-out external of the generator, and the other with the cut-out internal of the generator.

Example of a Third-Brush Regulated Generator (Bijur) with an "External" Cut-Out

The Bijur third-brush regulated generator[1] is of the constant-current type. Models L-220, P-230, K-230, and U-250 are shown in Fig. 41.

Note that the cut-out is external of the generator, being placed on the top of the generator. There are four field-poles, consequently there are four shunt-field windings (SHF).

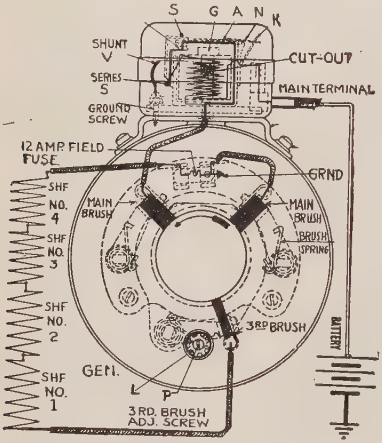

Fig. 41. Bijur third-brush regulated generator with cut-out external.

Shunt-field circuit: From the third brush, through field windings (SHF), through the fuse, to the (−) main brush (top right).

Cut-out voltage circuit: From the (+) main brush (top left), through cut-out voltage winding (V), to the ground screw, to ground of the (−) main brush at the fuse.

Charging circuit: From the (+) main brush (top left), to closed points (S), through the series cut-out winding (S), to the main cut-out terminal, to (+) of the battery, through the battery, out the (−) battery terminal, to ground, to ground (GRND) of the (−) main brush at fuse.

Example of a Third-Brush Regulated Generator (Bijur) with an "Internal" Cut-Out

The Bijur third-brush regulated generator of the constant-current type, model L-61, used on 1919 cars, is shown in Fig. 42.

Note that the cut-out is placed inside of the generator. There are four field poles and field windings.

Shunt-field circuit: From the third brush, through the four field windings, through the fuse, to ground, to ground (G) of the (−) main brush (B1), thus completing the shunt-field circuit.

Cut-out voltage circuit: From the (+) main brush (B2), through the fine wire voltage winding (V), to ground (G), to ground (G) of the (−) main brush (B1).

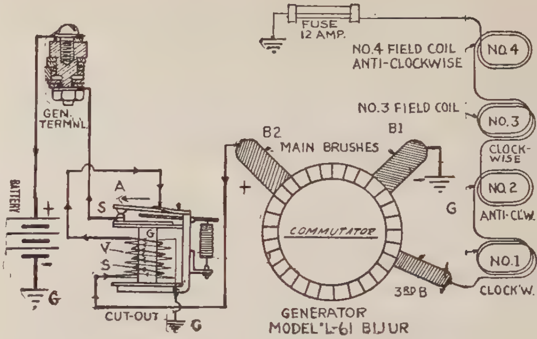

Fig. 42. Bijur third-brush regulated generator with cut-out internal of the generator.

Charging circuit: From the (+) main brush (B2), to the cut-out series coil (S), to blade (A), through cut-out closed points (S), to the generator terminal, to (+) of the battery, to the battery (−) ground (G), to ground (G) of the (−) main brush.

Remarks on the Bijur Third-Brush Regulated Constant-Current Generator (Figs. 41, 42)

The wiring: A single wire, grounded-return system is shown in Figs. 41 and 42. With the constant-current third-brush regulation, the generated current is independent of the voltage of the battery or the amount of lamp load connected, but depends upon the speed at which the machine is driven and the position of the regulating third brush with respect to the two main brushes. The cut-out (V) closes when the generator reaches 6.5 volts, or a generator speed of 500 or 600 r.p.m. With increasing speed the current increases to maximum value, at speeds about 1,000 to 1,600 r.p.m.; at higher speeds the current gradually decreases.

Adjustment: Moving the brush (by loosening the nuts) in the direction of rotation of the armature increases the generator output; in the opposite direction, it decreases. At 1,400 to 1,600 r.p.m. of the generator (20 to 25 miles, car speed) the amperage should be not less than 12 nor more than 15. Approximately a shift of the third brush 1/16″ will change the output 2 to 3 amperes. If adjusted on the car, remove generator cables and tape ends, then replace, after adjusting, and run the generator and test. Two or three trials may be necessary. Best results are obtained after running the car when the generator is hot and connected to the battery with 1,250 specific gravity (s.g.).

Fuse: A 6 to 12-ampere fuse is placed in the field to protect the coils from burning out.

It is not feasible to supply current for lights from a constant current generator without a battery being connected in circuit. For instance, if lamps require 7 amperes and the generator at speed delivers 15 amperes, the generator voltage would rise until the additional 8 amperes not required by the lamps will be forced through the lamp circuit and burn them out.

Circuit of Bijur Cut-Out and Generator (Fig. 41)

The path of the circuit from the generator through the cut-out is through the "shunt-winding" on the cut-out. When core (G) is sufficiently magnetized by the increased speed of the generator and current through this voltage shunt-winding (V), then the cut-out points close at (S). The charging current will then pass from the generator through the cut-out armature (A), through closed points (S), through cut-out "series coil" (S), to the main terminal on the cut-out to the battery, through the ground connection of the battery to ground connection in the generator through fields and brushes.

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[1] See page 349 for description of the Bijur "voltage-regulated" generator where a plain shunt-wound generator without a third brush is used.

Cut-Out Adjustment (Fig. 41)

The generator should be connected up with a fully charged battery when testing.

Testing cut-out on generator (Fig. 41): The correct voltage at which the cut-out should close is 7.5 to 8 volts. It is not necessary to consider the speed. This can be tested by placing the leads of a voltmeter across the two main brushes of the generator and by noting the voltage at the instant that the generator automatically connects itself to the load, or to the battery connected.

The voltage at which the contacts (S) **close** is dependent upon the tension exerted by the spring (N), attached to the cut-out armature (A). Bending the bridge (K) up or down decreases or increases the tension, thus decreasing or increasing the voltage at which it closes.

Adjusting Generator (Fig. 41)

Adjusting current output: When driven at a speed of 1,400 to 1,800 r.p.m., the generator should show not less than 12 nor more than 15 amperes when cold, or 9 to 12 amperes when hot, and its output should be adjusted accordingly. Place a "test" ammeter[1] between the generator terminal and the cable leading to it. It is not necessary to remove the generator from the car for adjusting. If the current delivered by the generator is less than 12 or more than 15 amperes, then adjust.

The regulating third brush can be adjusted by loosening the nut (L), and then turning the shaft (P) with a screwdriver. The third brush can then be moved. Lock the nut (L) securely after adjusting.

Moving the third brush in a direction opposite to the rotation of the generator armature decreases the current output; and moving it in the same direction as that of the armature rotation increases the output.

Adjusting the third brush should be made when the generator is hot and connected to the battery through the cut-out. The battery should be fully charged and have a specific gravity of 1.250 or more. Be sure that the battery connections are tight.

When a generator is adjusted on the bench, the cut-out, battery, etc., should be connected as if on the car. Owing to a line drop in the car wiring, which is to allow for normal operating conditions when current must pass through the longer length of the car wiring, the output should be set for 12 amperes at a voltage of 8.2, measured across the two main brushes when the generator is driven at speeds of from 1,400 to 1,800 r.p.m.

Adjusting Bijur Cut-Out and Generator (Fig. 42)

Testing cut-out: The cut-out on model L-61 third-brush generator is inside of the generator. A voltmeter should be placed across the two main brushes (Fig. 42).

The cut-out armature (A) should close at points (S) when the generator voltage reaches 6.5 to 7 volts; if the voltage is above or below this, the cut-out can be adjusted by inserting a small fiber-handle socket-wrench in the adjusting hole. Turn the cut-out tension spring adjusting nut until points (S) of the cut-out close at the correct time. This adjustment is on the outside of the generator, as the cut-out in this instance is on the inside of the generator.

To adjust the current output of model L-61 generator (Fig. 42), which is a third-brush regulated constant-current type generator, with cut-out placed inside the generator, place the test ammeter between the generator terminal with the cable removed. Connect the generator with a fully charged battery (1.250 specific gravity), or more, then drive the generator at 1,400 to 1,600 r.p.m.; it should show not less than 12 nor more than 15 amperes when cold, or 9 to 12 amperes when hot, and should be adjusted accordingly.

If the current delivered is less than 12 amperes, increase the output by moving the third brush in the direction of rotation of the armature until the required amperage shows on the meter. If more than 15 amperes, then move the third brush in the opposite direction until the proper amperage shows.

It is not necessary to remove the generator from the car for adjusting the third brush. It can be moved by inserting a special-toothed adjusting wrench in the adjustment hole, and engaging the ratchet. The entire regulating brush assembly can then be shifted in the direction required. To get the best results, set when the generator is hot, and be sure that a fully charged battery (1.250 specific gravity or more) is used.

When adjusted on the bench, the generator should be connected to a fully charged battery, and in order to allow for the line drop in the car wiring, the output should be adjusted for 14 amperes at a voltage of 7.4 measured across the two main brushes, when driven at a speed of 1,400 to 1,600 r.p.m.

This type of generator does not employ an external regulator and would be termed a "constant current" or "inherent" regulated generator; a cut-out, however, is used.

A point worth mentioning here is the importance of having a battery in the circuit at all times and having good connections at all points.

REMARKS ON THE POLARITY OF A SHUNT-WOUND GENERATOR RELATIVE TO CONNECTION TO BATTERY

Connection of battery to generator: The proper method of connecting a generator to a battery is to connect the (+) terminal of the generator to the (+) terminal of the battery. If the generator (+) brush is grounded, then the battery (+) terminal should be grounded. If the generator (−) brush is grounded, then the (−) terminal of the battery should be grounded.

If a shunt-wound generator is wrongly connected to the battery, that is, the (−) terminal of the generator to the (+) terminal of the battery, the vibrator points on the cut-out will open and close or vibrate at first until the polarity of the core changes. It will then close and charge in the proper direction, or with the polarity of the battery, if the generator is running at sufficient speed. The polarity of the generator fields will change to the polarity of the battery, because if the battery is charged, it will send sufficient current through the fields to overcome the field current from the generator. The disadvantage will be that the ammeter will read in the wrong direction.

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[1] If a dash ammeter on the car is used to make this check, it is probably connected so that the ignition circuit of 1 to 3 amperes will be taken through the ammeter. Therefore the current reading will then range from 6 to 9 amperes. The best plan is to use a separate test instrument.

The following explanation will probably make the statement clearer. When the cut-out contact points are drawn closed, with the generator and battery connected in the reverse polarity, for normal operation, the battery voltage and generator voltage are of such a polarity that they are connected in series with a short circuit across the sum of these two voltages. This causes a short-circuiting current to flow from the battery through the generator and generator fields, and through the series winding to the cut-out, in such a direction as to open the cut-out contacts and to reverse the polarity of the fields and generator. As soon as the cut-out contacts have opened, the current just described permits the generator to build up in the correct polarity. The contacts are then closed, and the generator is then properly connected to the battery.

If the battery is discharged, the battery cannot overcome the polarity of the generator fields, and the cut-out points will close, but the battery will be charged in the wrong direction. Some of the old-style cut-outs with permanent magnet cores will not change polarity, and the battery must be connected properly. It is best to connect the (+) terminal of the generator with the (+) terminal of battery.

DISCONNECTING BATTERY FROM GENERATOR

The question what to do when disconnecting the battery from the electric system of a car depends upon the kind of system involved. There are many different systems, and what would be satisfactory on one may be injurious on another.

It is not possible to operate lamps from a "constant current" generator when the battery is disconnected, unless the lamps so connected consume the entire current output of the generator; otherwise the lamps would burn out.

The answers appended to the following questions are those furnished by the Remy, Delco, Bijur, Westinghouse, and Ward-Leonard Electric Companies:

Question 1: What method should be adopted if a battery is disconnected from an electric system using a shunt-wound generator with "third-brush regulation"?

Answer (Remy): The generator should be short-circuited with a piece of heavy copper wire.

Answer (Delco): Probably the most effective and the surest method would be to lift all the brushes on the generator. This will eliminate any possibility of damaging the generator windings, and will hold good in all cases, regardless of the generator connections or methods of regulation.

Answer (Bijur): When a Bijur third-brush regulated generator is operated without battery, the field fuse should first be removed. If this is not done, the fuse will blow as soon as the field current builds up. This automatically opens the field circuit, but a new fuse must be put in place before the generator will again charge the battery.

Answer (Westinghouse): Remove the field fuse. If the generator is not equipped with a field fuse, then remove the field or third brush, which is smaller than the armature brushes.

Answer (Ward-Leonard): If either the cut-out or battery is disconnected, the field fuse should be removed, or the generator short-circuited by grounding the insulated terminal. If these generators are run on open circuit, the voltage will build up to probably five or six times its normal value, which in a short time would result in a burned-out field.

Question 2: What method should be adopted if a plain shunt-wound generator is equipped with an external electromagnetic "voltage regulator"?

Answer (Remy): A generator equipped with a voltage regulation can be operated without a storage battery in the circuit, since the regulation is independent of the charging current.

Answer (Bijur): When a Bijur generator is fitted with an external voltage regulator and is to be operated without a battery, the regulator should be removed. This opens the field circuit. The generators in question are plain shunt-wound generators.

Answer (Westinghouse): Machines of this type are usually equipped with a field and armature terminal on the exterior of the generator. In this case, it is necessary to disconnect the field lead and tape it up. This opens the field circuit and the machine can be operated without danger of burning up.

Answer (Ward-Leonard): The answer to No. 1 can be applied to this question also, with the exception of the regulator. As a rule, when a vibrating type of regulator is disconnected, it automatically opens the shunt-field circuit, and gives the necessary protection to the generator.

Question 3: What method should be adopted if a plain shunt-wound generator is equipped with an external electromagnetic "current regulator"?

Answer (Remy): A generator having its output controlled by a vibrating-current regulator should have its field circuit open whenever it is operated with the battery disconnected. Removing the fuse on our relay regulators will protect the generator.

Answer (Bijur): The same action is advised in the case of generators having external vibrating current regulators. The external construction of these is the same as that of generators fitted with voltage regulation.

Answer (Westinghouse): In this case, it would be advisable to remove one brush if the machine is equipped with two brushes, and if equipped with four brushes remove the two brushes opposite each other. This method is always safe.

Question 4: What method should be adopted if the generator is a compound-wound, constant-current machine?

Answer (Remy): The only generators which we manufactured with compound windings are our models "M" and "J." On this type of machine the shunt circuit should be opened when the generator is operated with the battery disconnected. This is accomplished either by removing the fuse, or by disconnecting the lead which is connected to the brush holder.

Answer (Westinghouse): This should be taken care of in the same manner as described in the answer to question No. 3. We suggest that you advise your readers that, regardless of what type of generator a car is equipped with, when in doubt as to what to do, they should remove the brushes in order to protect the generator when the battery is removed. Of course, this is not always convenient, but it is a sure method.

Answer (Ward-Leonard): The "bucking field," or "shunt-series wound" generator, should be handled in the same manner as the third-brush regulated generator referred to in No. 1.

Question 5: If the battery is disconnected how could ignition be obtained?

Answer (Ward-Leonard): The simplest way to obtain ignition under the three conditions mentioned, would be to connect four or five dry cells in place of the storage battery, leaving the generator disconnected. The current for the side and tail lights can be obtained temporarily in this same manner, or, if necessary, by putting two or three sets of dry cells in parallel.

INSTRUCTION No. 34

MOTOR-GENERATORS: North-East (with Ignition System); Simms-Huff; U.S.L.

MOTOR-GENERATORS

Motor-generators are of two general types:

First: Those with one set of field poles on which there are two, or compound windings: a "shunt winding" and a "series winding."

It is not necessary that the "series winding" be placed on all four poles. In fact, on many four-pole motor-generators, all four poles have "shunt windings" on them which fact determines the polarity of the poles, because there are more turns of wire in the shunt winding, and only two of the poles have "series" windings.

One **armature with one winding** and **one commutator,** with compound windings on the four field poles is the principle of the North East four-pole motor-generator as used on the Dodge. The Simms-Huff, formerly used on the Maxwell, was a six-pole motor-generator with one winding on the armature and one commutator. There are shunt windings on all six field poles, but series windings on only three poles.

The two field windings oppose each other when operating as a generator; thus the result is a "differential" action, as explained on page 354.

A **third-brush regulation** is used on the North East system, and also on some of the Simms-Huff; on early model Simms-Huff six-pole motor-generators, the regulation was by means of an electro-magnetic resistance method.

The two field windings assist each other when used as a starting motor, and thus the result is a "cumulative" action.

Second: the Delco motor-generator is similar in principle, except that many of these motor-generators have **two windings on the armature** (see "Buick armature windings," page 343) with **two commutators.** (See also Index for Delco generator instructions.)

A motor-generator of an early type, where there were two sets of field poles and two armatures, but mounted together in one unit, is shown in Fig. 1.

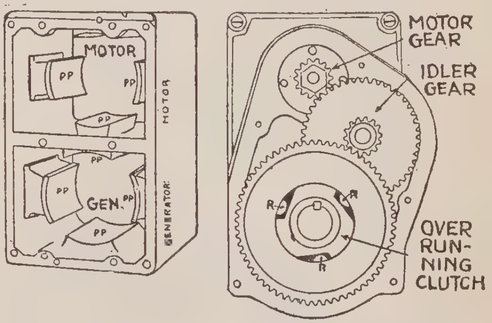

Fig. 1. An **early type of motor-generator** consisting of a generator below and a motor above, using two separate armatures and two separate fields, and termed a "double decker," since the motor armature is superimposed over the generator armature.

The two armatures are connected together with a system of gearing and an over-running clutch (**R**) (similar to clutch explained on page 324). The motor armature and the gearing are in operation only when the starting switch is pressed.

The generator armature is the only moving part under running conditions, as the over-running clutch of the roller type is provided to disengage the motor armature and reduction gears, which remain idle and inoperative when the engine is started and running under its own power. The generator armature revolves in the lower field. The motor and generator are entirely separate—armature is of the drum type. A regulator and automatic cut-out of the usual type are provided.

A modern type of motor-generator is where only one armature and one set of field poles are used for both the motor and generator, such as the North East and Delco.

As an example of the construction of a modern motor-generator and of its principle and its relation to the other parts of the electric system, the North East model "G" motor-generator will be discussed.

THE NORTH EAST ELECTRIC SYSTEM AS USED ON THE DODGE. A TYPICAL EXAMPLE OF A MOTOR-GENERATOR (TWELVE-VOLT SYSTEM)

In order to explain just how the same windings serve for both a motor and a generator, simplified illustrations are shown in Figs. 2 and 3 (page 368), which represent the North East model "G" system as used on the Dodge Bros. car.

Both actions do not take place at the same time. That is to say, if used as a motor, the generator action is not in operation; if used as a generator, the motor action is not in operation. Both windings on the field poles, however, are used for both the generator and motor action.

Note that there are four poles, each with a "shunt-field" winding and a "series-field" winding. Note also the cut-out which is used with the generator action. The generator is a third-brush regulated generator. The starting switch is used with the motor action.

Parts of the North East Electric System on the Dodge[1]

The principal parts of this system are enumerated as follows: (1) motor-generator (12 volt); (2) battery, 6 cells (12 volt); (3) ignition system (12 volt); (4) wiring system (single-wire grounded return).

The motor-generator (model "G") is a "single-unit" machine and operates either as a starting motor or as a generator, depending upon whether the current is supplied to it from the battery, in which case it acts as a **starting motor,** or whether it is driven by the engine, at which time it **generates current** and charges the battery.

The same field windings, armature, commutator, and brushes serve both for starting and for generat-

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[1] By courtesy and permission of the North East Electric Co., Rochester, N.Y.

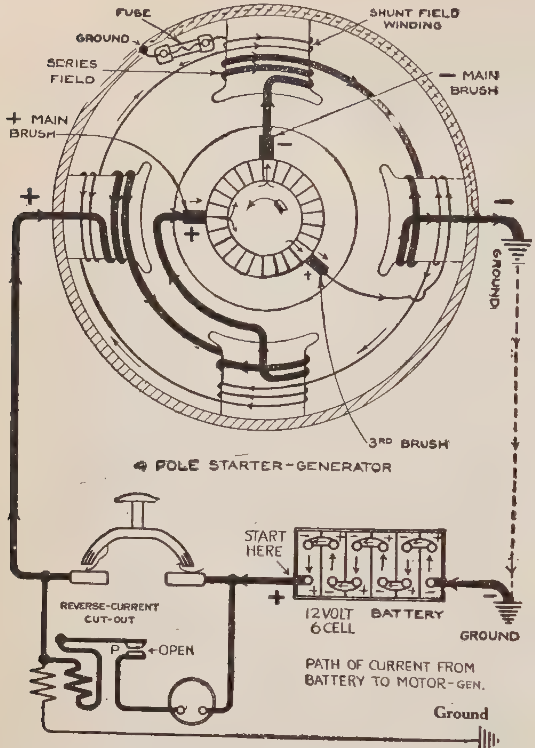


Fig. 2. Path of current from battery when used as a starting motor to crank the engine. Note that the current flow around the field poles of both the series and shunt-field windings is in the same direction, and thus is "cumulative" in action, which strengthens the polarity of the field poles.

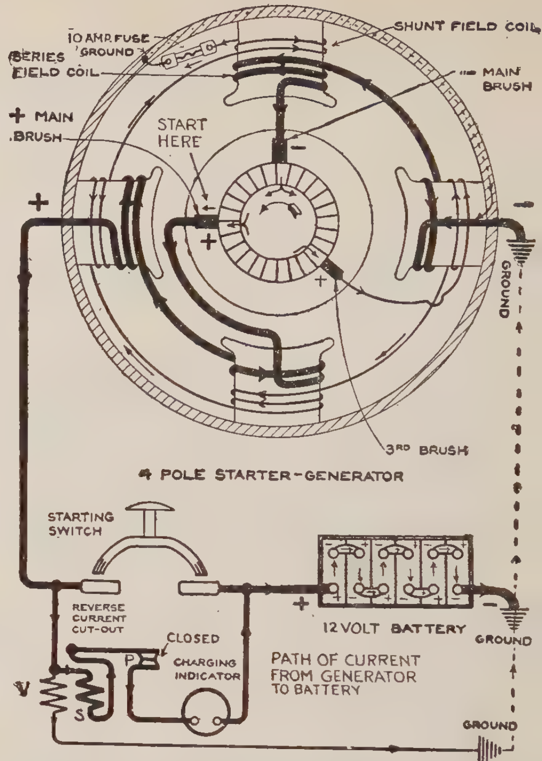


Fig. 3. Path of current from generator, when generator is charging battery. Note that the current flow around the field poles of both the series and shunt-field windings is in the opposite direction. Thus it is "differential" in action, which tends to weaken the field strength at high speeds (explained in the text).

ing purposes. In its general construction it differs very little from the ordinary compound-wound generator, except for the third-brush regulating feature and certain mechanical details.

Fig. 4. The motor-generator is driven by a silent chain from the crank shaft of the engine.

The motor-generator is mounted on the front left side of the engine and is driven from the crank shaft by means of a silent chain (Fig. 4). The driving ratio is three revolutions of the armature to one of the engine crank shaft.

Starting Motor Action

When running as a starting motor (see Figs. 2 and 5), the electric current from the battery flows from (+) of the battery to the switch terminals (1 and 2) on the cut-out. The starting switch connects these two terminals, thus closing the circuit around the cut-out, direct from the battery to the motor-generator, through the (+) terminal of the motor-generator, through half of the series field winding to the (+) main brush, through the armature coils out of the (−) main brush, through the other half of the series field winding, to the grounded terminal (−), back to the grounded terminal of battery (−).

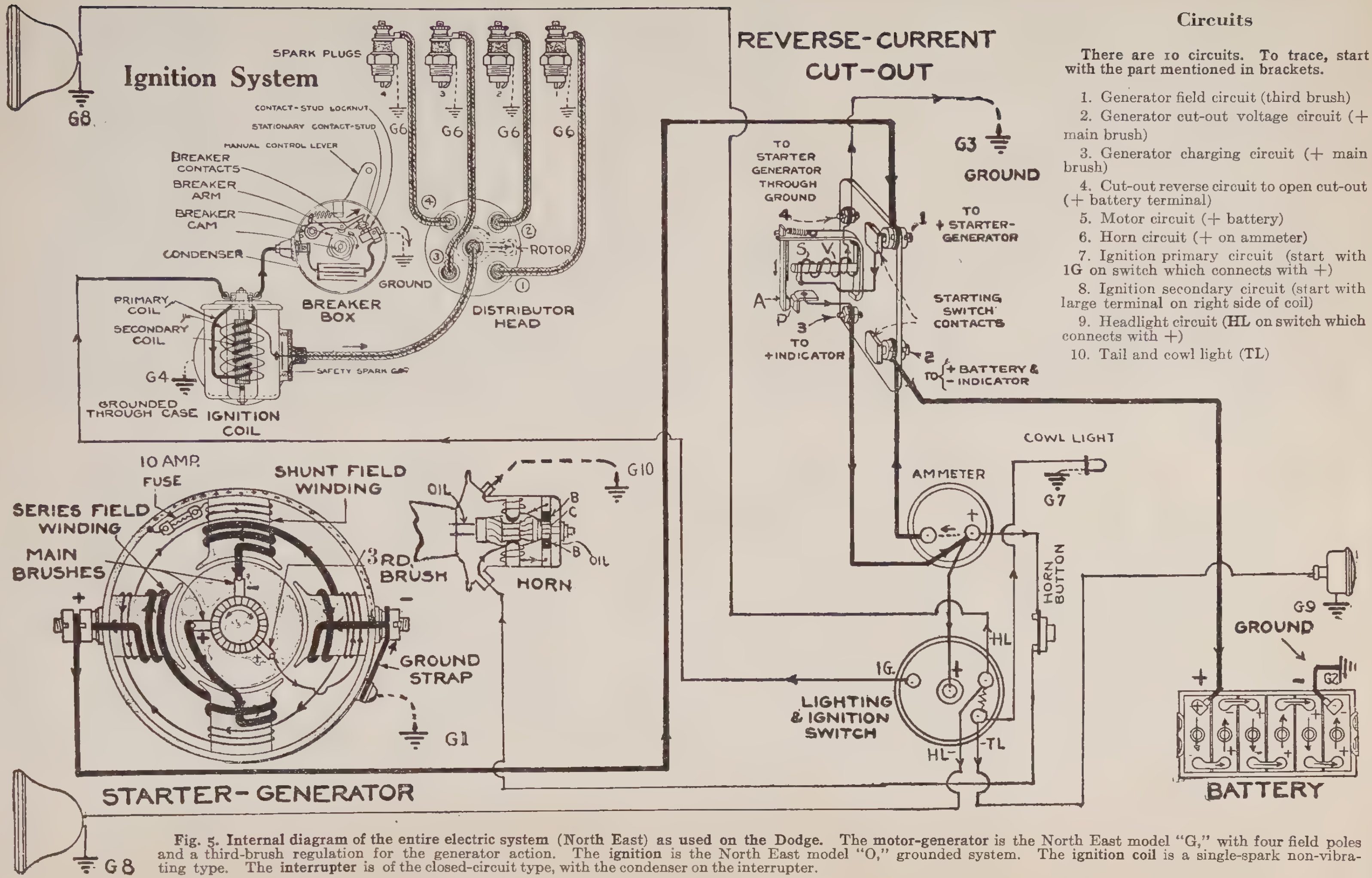
The current from the (+) terminal also flows through the armature out the third brush around the field poles to the fuse, thence from the grounded end of the fuse through the motor-generator frame, through the (−) grounded terminal, to the (−) grounded battery terminal (G2).

It will be noted (in Fig. 2) that the current flow around the "series-winding" and the "shunt-winding" is in the **same** direction, therefore the two windings assist each other in producing a strong magnetic field. The "series coil" provides the bulk of the magnetic field under starting conditions, and the "shunt-field coils" serve simply to assist in raising the magnetic field to its maximum strength. In other words, the greater part of the current flows through the "series-windings" when used as a motor.

Where the two windings assist each other by being wound so that the current flows through the two windings in the same direction, it is called a "cumulative-compound field winding."

Generator Action

When driven as a generator, the operation is practically that of a constant-current generator (see Figs. 3 and 5). The magnetic field resulting



Circuits

There are 10 circuits. To trace, start with the part mentioned in brackets.

1. Generator field circuit (third brush)
2. Generator cut-out voltage circuit (+ main brush)
3. Generator charging circuit (+ main brush)
4. Cut-out reverse circuit to open cut-out (+ battery terminal)
5. Motor circuit (+ battery)
6. Horn circuit (+ on ammeter)
7. Ignition primary circuit (start with 1G on switch which connects with +)
8. Ignition secondary circuit (start with large terminal on right side of coil)
9. Headlight circuit (HL on switch which connects with +)
10. Tail and cowl light (TL)

Fig. 5. **Internal diagram of the entire electric system (North East) as used on the Dodge.** The **motor-generator** is the North East model "G," with four field poles and a third-brush regulation for the generator action. The **ignition** is the North East model "O," grounded system. The **ignition coil** is a single-spark non-vibrating type. The **interrupter** is of the closed-circuit type, with the condenser on the interrupter.

from the current flowing around the windings on the field poles is produced by the current generated in the armature coils flowing through the "shunt-field" windings. The generated current from the armature also flows through the "series-field" windings, but in an **opposite** or reverse direction from that in which it flows through the "shunt-field windings." Thus the "series-winding" **opposes** the "shunt-field winding" instead of assisting it in building up the magnetic field, and this winding is termed a compound winding with a "differential" action, or a so-called "bucking" effect.

This bucking effect of the "series field" aids the "third brush" in preventing the output of the machine from rising above a definite output. The third brush could do this unassisted, but it is necessary that the series winding should be on the generator for starting purposes; its effect is utilized in conjunction with the third brush, which is desirable.

The path of the current (Fig. 5) through the shunt-field winding is as follows: When the generator is started, the current from the armature flows from the third brush (+), through the shunt-field windings in the direction shown by the arrow marks, through the fuse, through the frame of the motor-generator, through two of the series field coils, through (−) main brush back to the armature. This causes the magnetic field to start building up.

The cut-out voltage winding circuit is from the (+) main brush, through the series windings around two poles (note that it is in the direction opposite to the flow of current through the shunt field) out the (+) main brush to connection (1) on cut-out, through the cut-out shunt or voltage winding (V), to terminal (4), to ground (G3), to ground strap on the generator (G1), through two series field coils, to the (−) main brush, through to the armature (+) main brush, thus completing the cut-out voltage winding circuit.

This circuit through the fine wire voltage winding (V) on the core of the cut-out is to magnetize the core so that it will pull the cut-out armature (A) to the core and close the cut-out points (P), in order that the generator charging current can pass to the battery.

It is not desirable to have the points (P) close until the generator has built up sufficient voltage to overcome the voltage of the battery, otherwise the rush of current from the battery through the field windings would oppose its action of building up in the right direction.

Charging circuit:[1] At about 1,000 r.p.m. of the generator (which corresponds to 9 to 10 miles per hour car speed) the generator has built up to 14.5 volts at which voltage the cut-out shunt, or voltage winding (V) has sufficient voltage through its winding to magnetize the core so that it will have magnetic strength to pull the cut-out armature (A) down against the tension of the spring and thus close the cut-out points (P). The voltage of the battery being 12 volts and of the generator 14.5, the generator therefore has a slightly greater voltage than the battery. Thus the battery is charged by the generator, and the path of the charging circuit is then from the (+) main brush of the generator, to terminal (1) of the cut-out, through series winding (S) on the cut-out, through the frame of the cut-out armature blade (A), through points (P), to cut-out terminal (3), through the ammeter to cut-out terminal (2), to the battery (+) terminal, through the battery, to the (−) grounded battery terminal (G2), to the (−) ground strap on the generator, through two series coils, to the (−) main brush. Note that the current flow in the series-field windings is in the opposite direction to the flow of current in the shunt-field windings.

From 1,000 r.p.m. of the generator, to 1,700 or 1,800 r.p.m. (15 or 16 miles per hour car speed) the charging rate rises rapidly (see page 374). The maximum charging rate of 7 amperes is reached at from 1,700 to 1,800 r.p.m., and remains unchanged with further increase of speed up to approximately 2,100 r.p.m., at which point it begins to decrease. The decline in output continues from this point on, becoming more and more gradual as the upper limit of the speed range of the engine is reached. At 5,500 r.p.m. (50 m.p.h.) the charging rate usually drops as low as 4 amperes; and at still higher speeds it declines even more.

When the speed of the generator drops to less than 1,000 r.p.m., then the voltage will also drop, and the cut-out points (P) will open and thus prevent the battery from sending a reverse current back through the motor-generator.

It is necessary, however, to have the battery **discharge back through the cut-out series winding** in order that the points open. This is explained as follows: When the voltage coil (V) has gained sufficient strength to pull the cut-out armature (A) down, the current flows through the series winding (S) around the same core, and as it flows in the same direction as the cut-out shunt winding (V), each combines to hold the points tightly together. Although soft iron is supposed to lose its magnetism when current is stopped from flowing around the winding, it is slow in demagnetizing and has a tendency to retain some of its magnetism even though the current flow should stop altogether. In this instance however, the current flow has not stopped altogether, and although only a small amount of current is flowing through the cut-out shunt fine wire winding (V) when the generator is below 1,000 r.p.m., it has a tendency to hold on until the last. The action of opening and closing of points (P) must be quick, and in order to cause it to open quickly at the correct time, the battery discharges back through this series cut-out winding (S) in a reverse direction, which reverses the polarity of the core and demagnetizes it. Instantly the cut-out armature (A) is released and the points (P) are opened, because the strength of the battery current is greater than the current then flowing from the generator through the fine wire winding (V) of the cut-out in an opposite direction. (This is the principle of all reverse-current cut-outs.)

This discharge back from the battery, however, must not be over 1 ampere in this example, and the cut-out is set originally by adjusting the spring tension. If it should permit a greater discharge, this spring tension can be adjusted to correspond to a given degree of magnetic pull of the cut-out core, and the cut-out armature (A) can be made to open or close at any desired voltage within reasonable limits.

Thus the reverse current cut-out keeps the charging circuit closed between the generator and battery only when the generator is capable of charging the battery, and under all other conditions it automatically opens the circuit to prevent the battery from discharging back through the motor-generator.

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[1] The current for headlights, horn, and ignition flows through the ammeter only when the generator is not charging, that is, when the current flows direct from the battery. At all other times it does not flow through the ammeter. The return path for all the circuit is by way of ground to the battery.

North East Ignition System (Model "O") as Used on the Dodge Car[1]

An internal diagram of the North East model "O" ignition system, as used on the Dodge, is shown in Fig. 5. The primary circuit is from the battery when the generator is running slow or not running at all, or from the generator when it is running at sufficient speed to generate a voltage higher than the battery. Note that the generator is at 12 volts, and so also is the battery; therefore the ignition is a 12-volt grounded system.

The primary ignition circuit is from the (+) side of the ignition and lighting switch (IG), to the primary terminal on top of the coil, through the primary winding, to the movable contact arm on the interrupter, or breaker-box, through the points, out through the stationary contact to ground, thence to ground of battery (G2), or generator (G1), thus completing the primary circuit.

The secondary ignition circuit is from secondary terminal on the side of the coil, to the center terminal of the distributor, to the spark plugs through the revolving "rotor," through the spark-plug electrode, through the gap to the engine, through ground of the engine, to ground of the coil, to the grounded secondary terminal.

Note that a safety gap is shunted across the secondary circuit, so that if a spark-plug terminal comes loose, the spark will jump from the secondary terminal at the side of the coil to ground; thus it is shunted. This gap is slightly wider than the spark-plug gap, and thus the secondary circuit will always go to the spark plugs without jumping, unless the spark-plug gap is wider than the safety gap. The spark-plug gap should be set to .030".

The North East model "O" ignition unit (Fig. 6) consists of a shaft with a coupling yoke for driving the distributor and interrupter. The coupling yoke is connected with the pump shaft. The distributor shaft is driven at one-half the speed of the crank shaft; that is, while the crank shaft completes two revolutions the distributor shaft completes one revolution.

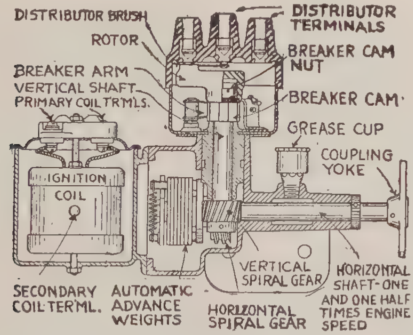

Fig. 6. North East model "O" ignition unit on the Dodge.

The distributor is advanced by an "automatic" arrangement, and by a "manual" control connected with the spark lever on the steering wheel.

The ignition coil is attached to the unit at the left, and **the condenser** is in the interrupter or contact-breaker housing. The interrupter is a "closed-circuit" type. By referring to the illustration, the names of the several parts will be found.

Adjusting the North East (Dodge) Contact Breaker

Always turn off the ignition switch when adjusting or testing any part of the ignition.

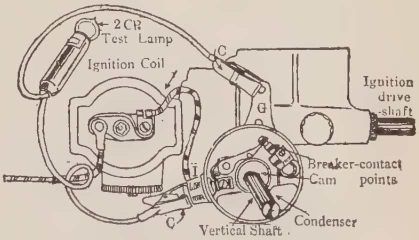

Fig. 7. Adjusting the contact-breaker points.

To adjust breaker-contact points: (1) Turn the vertical distributor shaft (Fig. 7) until one of the lobes of the breaker cam comes against the fiber block or breaker-arm so that it pushes the breaker-arm back to the limit of its normal movement. Be sure that the contact points are separated the full distance. (2) Back off the contact-breaker stud lock-nut sufficiently to release the contact stud. (3) After loosening, use a thickness gauge between the points and adjust to .020" when the points are fully separated. (4) Tighten the lock-nuts, and after the stud has been locked in the new position, check the gap once more to make sure that no alteration occurred during the locking process.

If contact points are pitted use an oil stone, as explained on page 225.

If contact points are renewed, replace both the stationary contact stud and the breaker-arm assembly. After assembling, hold a piece of white paper behind the contact points to serve as a light background and sight between them and see if they meet evenly over their entire surface. If not, bend or twist the breaker arm slightly until they are brought into correct relationship.

Timing the Ignition

If the coupling yoke (Fig. 6) attached to the shaft driving the ignition mechanism is disconnected from the pump-shaft yoke which drives it, note the position of the distributor rotor and the two halves of the coupling, and mark it carefully. If this is not done at time of removal, it will be necessary to time the ignition assembly as follows:

1. **Turn off** the ignition switch.

2. **Attach the ignition driving-shaft coupling** to the pump-shaft coupling.

3. **Crank the engine** until the position of No. 1 cylinder has reached dead center of its compression stroke and has passed 8 engine degrees beyond it.

A good way to tell this is to watch the exhaust valve on No. 4 cylinder. This valve should be just on the point of closing when No. 1 piston is approximately 8 engine degrees beyond the dead center of its compression stroke. See pages 70, 307 for methods of finding the compression stroke. The best plan is to remove the cylinder head to expose the pistons.

4. **Shift the breaker-box** to full retard position.

5. **Remove the distributor-head** or cap, and the distributor rotor arm.

6. With a broad-bladed screwdriver, **back off the breaker-cam nut** one or two turns, so that the cam can be turned free of its shaft on which it is set.

7. **Place the rotor-arm temporarily on the distributor-shaft** and turn it in a clockwise direction

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[1] By courtesy and permission of the North East Co., Rochester, N.Y.

until the rotor is in position where it would normally make contact with No. 1 distributor terminal. The breaker-contacts should then be fully separated.

8. **Turn the cam back carefully a short distance,** until the cam lobe permits the points to come together again; then turn it back to the correct position. This action will allow for any slack in the gears. Lock the cam lock-nut.

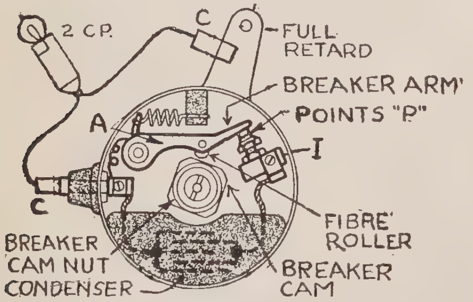

Fig. 8. To tell when the contact-breaker points open, use a 2 c.p. lamp bulb, as shown.

9. **Place a 14 to 16-volt 2-candle power test lamp across the contact-breaker circuit** (Fig. 8), by placing one clamp (C) of the test light to the binding post and the other clamp to the frame of the breaker-box, as this is a grounded system. The wires from the coil, etc., are not disconnected; the ignition switch, however, is off during this time. The purpose of the light is to enable one to tell the instant the contact points separate, because the opening of the points occurs so rapidly that it is difficult otherwise to tell, and this insures correct adjustment.

10. **Turn on the ignition switch.** Replace the distributor rotor again and verify the cam setting which has been made, by rocking the distributor shaft backward and forward as far as the slack in the gears permits. The lamp will light the moment the contacts begin to separate, and will go out the moment they come together. Note that the lamp is in series with the circuit when the contact points are opened.

Note. This is a good timing test for other ignition systems. If, however, there are two binding posts or terminals on the contact-breaker, then the test-light clamps (C) would be attached to each.

It is very important that the timing be exact, because the speed of the engine crank shaft is twice as great as the vertical distributor shaft, and inaccuracy in setting will produce a doubly magnified effect upon the operation of the engine.

The spark-plug air-gap on the Dodge is 1/32", or about the thickness of a smooth dime.

Lubrication of Ignition Mechanism

The automatic advance mechanism (Fig. 6) is lubricated by grease in this compartment. The original grease should last for several seasons. If renewed, it should have not over 3 cubic inches and grease to correspond with No. 4 Keystone grease.

The horizontal shaft is supplied with grease from the automatic compartment and also from the grease cup shown in Fig. 6. This grease cup should receive attention every few thousand miles.

Cut-Out Adjustments: N. E. Model 8100 Used on the Dodge

The air gap space at the carbon blocks of the cut-out (P), when separated (Fig. 5; see also Figs. 9 and 9A), must be .030"; the air-gap between the small copper button or the under side of the cut-out armature and the upper end of the iron core about which coils are wound, should be approximately .020".

The contact blocks (656, Fig. 9A) should be in perfect vertical alignment and the carbon blocks should be parallel. If they are not, bend with long-nosed pliers.

Inspect adjustment of the cut-out contact points by holding them up to the light, being careful to make sure that it is correct.

After aligning properly, then measure the air-gap. If it is not enough, bend the stop away from the armature slightly. If there is too much air gap, bend down.

Cut-out closes: The starter-generator should be showing 14.5 volts on test when connected with the battery through the cut-out.

The cut-out armature (A, Fig. 5, or 2168, Fig. 9A), should close at this voltage.[1] If it does not, alter the spring tension (2184, Fig. 9A).

The spring tension can be lessened by spreading apart one or two of the spring turns, or by bending down the portion of the armature spring plate that extends back beyond the iron body of the armature.

The spring tension can be increased by forcing together the separated turns, or by bending up the armature blade. Flat-nose pliers are handy for these adjustments.

Cut-out opens: As soon as the cut-out has been set to close the charging circuit when the voltage is 14.5, then check the adjustment by reducing the starter-generator speed to 500 or 600 r.p.m., and then raise it again gradually until the cut-out closes. In making this test, note the voltage carefully as registered on the voltmeter at the instant when the cut-out closes, and if found other than 14.5 volts when it closes, adjust to that voltage.

After adjusting for the closing point as just described, then adjust for the opening point as follows: Speed the generator up to 1,500 or 1,600 r.p.m.; then reduce speed gradually until the cut-out contacts open. Watch the ammeter[2] at the moment when the cut-out breaks the charging circuit, and note closely the amount of discharge current that is required to cause the cut-out to open. This discharge back through the cut-out reverse-current coil from the battery should not exceed 1 ampere. If more than 1 ampere, investigate the cause. This discharge is the reverse current flowing from the battery back to the generator in an opposite direction. It thus demagnetizes the iron core.

Too high a discharge current is due to: too great air-gap at the cut-out armature core at (A) (Fig. 5), or cut-out series coil (S) (Fig. 5) is short-circuited.

North East Cut-Out Winding Tests

To test for a cut-out ground: Hold one test lead (110 or 220-volt lamp and leads) on cover 8107 (Figs. 9 and 9A) and touch binding post No. 3, and then No 4. If the lamp lights, there is a ground. (The internal diagram of this cut is shown in Fig. 5.)

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[1] A voltmeter is connected across the circuit leading to the cut-out, say, at the (+) terminal of the generator, or at terminal 1 of the cut-out and ground.

[2] The ammeter is shown in circuit in Fig. 5. Check it with a test ammeter to see if it indicates correctly. If not, connect in the "test ammeter" instead.

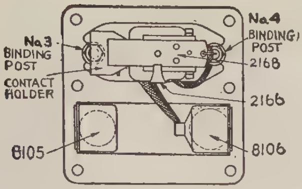

Fig. 9. Top view of cut-out.

To test for an open circuit in the shunt winding (coil **V**, Fig. 5) of the cut-out: Place one test lead on terminal No. 4 and the other on No. 1 (Figs. 9 and 9**A**). If the circuit is complete through the shunt coil, the lamp will light dimly and the cut-out armature will be drawn against the core; if an open circuit exists, the lamps will fail to light, and the cut-out armature will not respond.

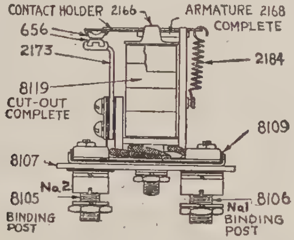

Fig. 9**A**. Side view of cut-out.

To test for an open circuit in the cut-out (see also **S**, Fig. 5) **series coil:** Place one test lead on No. 1 binding post and the other on No. 3, and close the contacts (656) by hand. If the normal circuits are complete, the test lamp will light the moment the contacts are closed.

To test for a short circuit between the cut-out shunt (V) and the series (S) coil: Place one test lead on No. 1 binding post, and the other on No. 4. If the circuits are normal, the test lamp will burn dimly; but if a short circuit exists between the coils, the lamp will burn with full brilliancy.

To test for a short circuit between the cut-out contact points on the contact bracket and cut-out frame: Place one test lead on No. 1 binding post and the other against No. 3 binding post, but do not close the cut-out contacts. If a short circuit exists, the lamps will light, even though the cut-out contacts are not closed.

To "Run In" Brushes on North East Motor-Generator

Use only North East brushes, as they are specially made and are necessary. Never transpose the third brush for a main brush.

The main brushes composed of copper graphite mixture and heavy, are copper-colored and partly copper-plated. The third brush, made of graphite only, is lighter, and is black and uncoated.

Brushes should be run-in if new ones are fitted or if old ones are resurfaced.

To "run-in" brushes: Connect the starter-generator with a battery of the proper rated voltage (a 12-volt battery is to be used with a 12-volt machine), and allow the machine to run free at a high speed for twenty or thirty minutes. The requisite high speed can be obtained by temporarily converting the machine into a plain series motor. This can be done readily by removing the fuse so as to open the shunt-field circuit. In the case of the type 3554 starter-generator, which has no fuse, the shunt-field circuit can be opened by disconnecting the pigtail from the third brush.

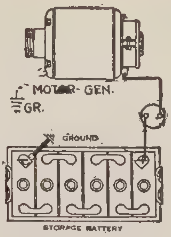

Fig. 10. Motor-generator run as a motor to "run-in" the brushes.

This applies to other makes also, except that in case of a 6-volt system a 6-volt battery should be used.

The "running in" process must be continued until the entire surface of all three brushes has become sufficiently concave to fit the commutator. Fine (No. 00) sandpaper, never emery paper, may be used, if desired, to hasten the process; but if this is done, care must be exercised to avoid rounding the edges of the brushes, or otherwise modifying their working surfaces. As soon as the brushes have become completely fitted to the commutator, the charging rate should be measured carefully, and if it is found to be at variance with the standard rate given in the table on page 375, it should be readjusted to the correct value in accordance with the directions given in the preceding section. The output variations, due to changes in the battery c.e.m.f., must always be borne in mind when the charging rate is to be measured or adjusted.

The commutator should be examined whenever new brushes have been found to be necessary, because its possibly roughened condition may have been responsible for the brush difficulty. If the commutator should be found to be in a roughened or burned state, it should be carefully resurfaced, and, if necessary, undercut. See Index under "Commutators, undercutting of."

Removing and Replacing Chain

1. Remove housing enclosing the starter-generator pinion.

2. Turn engine over until master link is exposed.

3. Break the master link and attach both ends of the new chain to the old chain.

4. Crank the engine over until the new chain is in place, when the old one may be removed and the master link of the new chain may be closed.

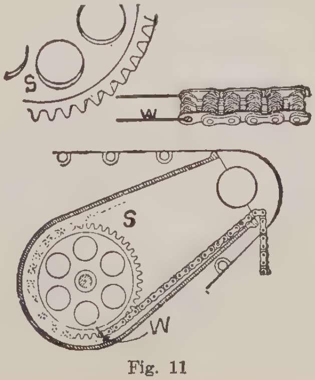

Fig. 11

Another method: (1) Pass a short piece of wire through the end of the chain and bend it into the form of a staple.

(2) start the chain on the lower side of the sprocket (S) (Fig. 11). Hook the wire (W) through the sprocket to keep the chain in mesh and turn the engine with the starting crank unit until the end of the chain appears at the top of the sprocket. Remove the wire from the sprocket, hold the end of the chain and continue to turn the engine until the chain is in position for applying the master link.

Chain-driven starting motors and generators should have the chain kept lubricated and adjusted, but the chain should never be adjusted too tightly.

Chain Adjustment

To obtain the proper adjustment for quiet running of the chain, proceed as follows:

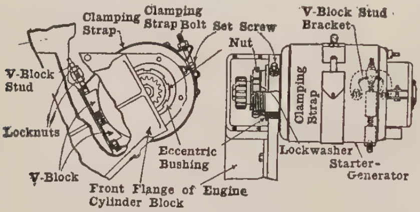

Fig. 12

Loosen the set screw and lock nut on the edge of the front flange of the cylinder block, and back off the starter binding nut, just enough to remove the pressure from the adjusting ring. Loosen the "V" blocks and strap to allow the starter-generator to move. This will allow the eccentric adjusting ring to be turned until the required play in the chain is obtained. There should be about one-half inch up-and-down movement in the chain. After the proper adjustment has been made, be sure that the set screw, lock nut, and binding nut are screwed up tightly. See that the chain tension has not been disturbed while performing this last operation.

Carefully adjust "V" blocks up snug between the engine and the starter-generator, and then tighten the holding strap. After the inspection cover has been replaced, the chain should run without perceptible noise. It is lubricated by its dipping into the oil in the bottom of the front gear compartment, thus needing no further attention after it has been properly adjusted.

Removing Armature

1. Remove the four nuts on the sprocket-end of the generator and pull the drive-end housing off with the armature.

2. Undo the pinion sprocket nut and lockwasher and pull the pinion off.

3. The armature can now be removed.

4. Remove the four screws holding the retaining plate after which the ball bearing, crimped spacer, and cork packing washer can be driven out. The front armature bearing is lubricated automatically from the chain.

Adjusting Charging Rate of North East Model "G" Motor-Generator

Adjusting the charging rate: Run the starter-generator at a speed to deliver its maximum output, which is 1,775 and 1,825 r.p.m.

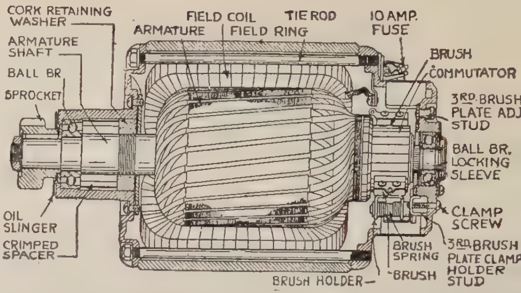

Fig. 13. Sectional view and name of parts of North East model "G" motor-generator.

The charging rate should never be set lower than 4 amperes, nor higher than 10 amperes. The adjustment is made by shifting the third brush (Fig. 15) with respect to the main brush and its maximum capacity is 12 amperes. Moving the third brush in a clockwise direction (Fig. 15 shows the commutator end-view) will **reduce** the charging rate. A counter-clockwise movement will **increase**[1] the rate. A speed of 1,800 r.p.m. of the generator on a Dodge represents about 600 r.p.m. of the engine. The average setting is for about 8 or 8½ amperes.

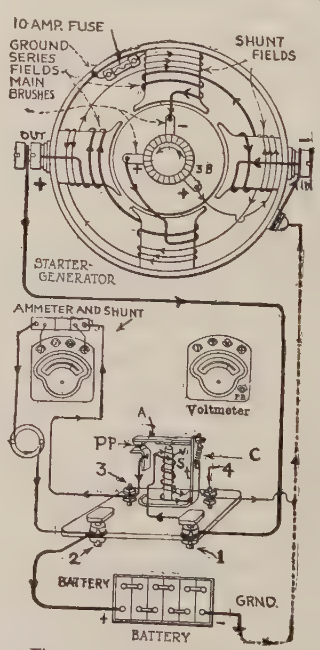

Fig. 14. Method of testing.

A test made on the car can be carried out as shown in Fig. 14 Use an ammeter reading to 30 amperes, and connect as shown, or attach between the starter-generator (+) binding post and the lead normally attached to it. If this is done, short-circuit the instrument while starting the engine, as a heavy starting current would burn it out.

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[1] This may appear to conflict with the statement, formerly made, that to increase the charging rate, the third brush should be moved away from the main brush which is connected to the shunt field-windings. However, in the case of this 4-pole machine, another (−) main brush could be placed opposite to the one shown, that is, on the bottom of the commutator, and connected to the shunt field-windings (grounded). Therefore, by moving the third brush counter-clockwise in this instance, we should increase the charging rate because we would then be moving it away from its closest main brush. Refer to Fig. 15 and note that the commutator is turning in a counter-clockwise direction, and the third brush is shifted with the direction of rotation of the commutator to increase the output.

Connect a voltmeter (reading to 20 volts) across the starter-generator binding posts.

Compare the current and voltage readings obtained at a constant speed of 1,800 r.p.m. in accordance with the table below.

There are **certain slight variations in the output due to changes in the battery counter-electromotive force** (c.e.m.f.), which must be taken into consideration whenever the charging rate is being investigated. The variations have been tabulated below for battery voltage variations from 12 to 16 volts, the speed of the generator having been considered constant at 1,800 r.p.m. throughout.

An illustration as to how the charging rate is influenced by changes in the battery c.e.m.f. is as follows: Let us assume that a 6-cell, 12-volt battery, which has become entirely exhausted, is placed on charge by connecting it in the usual manner to a model "G" starter-generator driven at a constant speed of 1,800 r.p.m. At the beginning, while the battery is in a discharged condition, it will have a relatively low c.e.m.f., which, in this instance, we will assume to be 12 volts. The charging rate of a normal starter-generator supplying current at this voltage will accordingly be 5.5 amperes.

Variations in Charging Rate Due to Changes in Battery C. E. M. F.

Charging Rate	Battery C. E. M. F. *(Starter-generator Terminal E. M. F.)	Starter-generator
AMPERES	VOLTS	R. P. M.
5.5	12	1800
6	13	1800
Normal 6.5	14	1800
Setting 7	15	1800
7.5	16	1800

*The battery c.e.m.f. (counter-electro-motive force) and the starter-generator terminal e.m.f. (electro-motive-force) are virtually equivalent under normal operating conditions, and may accordingly be considered as identical in ordinary tests. The voltage readings should always be taken across the positive (+) and the negative (−) generator binding posts.

If, however, the battery is allowed to remain on charge 7 or 8 hours, its c.e.m.f. will rise gradually until a final high value of 15 or 16 volts is reached.

This rise in the battery c.e.m.f. will naturally result in a corresponding increase in the generator charging rate. Assuming that the battery c.e.m.f. has now risen to its highest value, 16 volts, the charging rate, as indicated by the table, will have become 7.5 amperes. At intermediate points, between charged and discharged conditions, similar variations in the charging rate will occur, in accordance with the value of the particular battery c.e.m.f. which exists at the points considered.

From this it is obvious that both voltage and speed readings, as well as current readings, must be taken whenever the charging rate of a model "G" starter-generator under test is to be compared with the established standard. Current readings alone cannot be depended upon as an accurate indication of the charging rate, because of this modifying effect of the battery c.e.m.f.

Do not increase the charging rate above a maximum of 10 amperes at a battery c.e.m.f. of 15 volts.

Do not reduce the rate below a maximum of 4 amperes at a battery c.e.m.f. of 15 volts.

To Increase or Decrease Charging Rate on Model "G" North East Motor-Generator

To increase the charging rate: Turn the adjusting pinion stud (8035, Fig. 15) slowly in a clockwise[1] direction until the ammeter indicates that the desired value of the charging rate has been obtained.

If it is ever impossible to raise the charging rate to the desired value in this way, the special measures listed below are recommended.

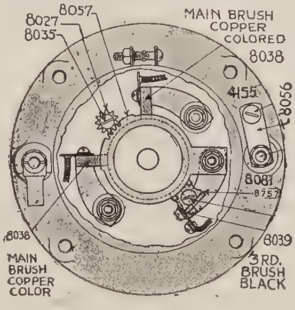

Fig. 15. End view of the N.E. motor generator, showing the commutator end. The commutator revolves counter-clockwise.

1. Increase the range of adjustment by filing an extra notch in the third brush-holder plate, taking care not to increase the range to such an extent that the third and main brush-holders are allowed to come in contact with each other.

2. Where the extra notch is impracticable or inadequate, the original third brush-holder (No. 8060-A) should be replaced by the later style brush-holder (No. 9599).

3. Should (1) and (2) ever prove inadequate, it is advisable to remove the armature and replace it by another. If the new armature gives the desired results, it may be assumed that some irregularity is in the original armature and it should be sent to the nearest North East branch for adjustment.

Do not increase the rate above a maximum value of 10 amperes at a battery c.e.m.f. of 15 volts.

To reduce the charging rate: Turn the adjusting pinion stud (8035) slowly in a counter-clockwise direction until the charging rate has been cut down as far as desired.

Do not reduce the rate below a maximum of 4 amperes at a battery c.e.m.f. of 15 volts.

Always bear in mind, when adjusting the charging rate, that the output variation due to changing battery c.e.m.f. forms an important factor in the accurate setting of the rate. By overlooking this point an error may be introduced into the setting, which can easily be serious enough to bring about the development of future battery trouble.

As soon as the proper brush position has been found, lock the third brush-plate by tightening the clamp screw. Then note once more the ammeter and voltmeter readings, to make certain that the adjustment has not been disturbed by the locking operation.

Before considering the work finished, run the starter-generator for fifteen or twenty minutes at varying speeds to make sure that the new setting for the third brush is permanent and accurate. Also make a general examination of the machine to see that no other parts have been disturbed while the charging rate adjustment was being made.

In every instance where the charging rate has been altered from its normal value for the purpose of meeting special service requirements, a close watch should be kept on the condition of the battery, and any tendency toward undercharge or overcharge should be corrected at once by further readjustment of the charging rate. Moreover, if cars with specially adjusted starter-generators are transferred back again into normal service at any time, the charging rate should be changed accordingly to the regular setting. If this readjustment is not made, possible injury may be caused to the battery.

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[1] The starter-generator is here considered as viewed from the commutator-end. Turning the pinion in a clockwise direction will cause the third brush-plate to move in a counter-clockwise direction, and, vice versa, turning the pinion in a counter-clockwise direction will cause the plate to move in a clockwise direction.

North East Instructions for Disconnecting Battery from Model "G" Motor-Generator

If the battery is disconnected without proper precaution, or if there is an open circuit in the charging circuit of the generator and battery, and the generator is driven at a speed which will permit the generator voltage to rise, it will reach an abnormal value which will injure the commutator and the brushes, and even the field coils, if allowed to continue for any considerable period of time.

To serve as a protection in such an emergency, a "fuse," designed to "blow" as soon as the generated voltage reaches an injurious value, is included in the shunt-field circuit and is mounted on the outside of the commutator end housing. With a "blown" or removed fuse the motor-generator is incapable of producing electricity, because of the shunt-field circuit being open. Thus the motor-generator can be run without injury.

If the battery should be disconnected and the motor-generator is to be operated, remove the fuse. If the machine is of the type not equipped with a fuse, then connect the positive binding post to the negative binding post, by means of a piece of clean copper wire, not smaller than No. 18 B. & S. gauge.

As soon as the battery is replaced, be sure and install the fuse again, and the short-circuiting wire must be removed. As long as the fuse is left out, the generator cannot charge the battery, and if the short-circuiting wire is left in place, the generator will be completely short-circuited.

If the charging circuit is broken elsewhere than at the battery, the motor-generator will be subjected to the same detrimental conditions as described. Thus an open circuit in the charging indicator, or at the terminals of the motor-generator, or in the car wiring, will under ordinary circumstances cause serious trouble. Likewise, if the reverse-current cut-out is prevented from functioning properly by an open circuit in its voltage shunt coil, or in the ground, or in the ground wire from that coil to the car frame, the effect will be equivalent to a break in the charging circuit proper.

The same results, moreover, in the case of the type 3554 machine only, can be produced by an open circuit at the ground strap. In all other model "G" motor-generators, however, an open circuit at this point will cause no actual damage, but will simply prevent the machine from generating, because of the fact that the shunt-field circuit will be open as well as the charging circuit.

The ground strap, which forms not only a section of the charging circuit, but also of the starting circuit, must always be kept in good electrical contact with the motor-generator frame.

In case it is necessary to operate the equipment with the charging indicator (current type) removed from the circuit, the wires normally attached to its two binding posts should all be connected together until the indicator is again placed in circuit.

Shunt Field Fuse

The fuse (Fig. 5), located on the outside of the commutator-end housing of the starter-generator, is inserted in the shunt-field circuit, and is designed to blow if the battery circuit is opened, thus protecting the system by rendering the starter-generat inoperative.

Therefore, if the machine fails to charge the ba tery at any time, inspect the fuse first of all; anc in case it is found blown, replace it with a new one If the new fuse in turn blows as soon as the machin is started up, make a careful search for the cause c the trouble before running the generator again.

Adjustments and Tests of North East Model "G" Starter-Generator

To test for a ground: Remove the ground-stra screw and bend the ground strap away from th housing and remove the fuse (see Fig. 5; also Fig 16). Then, using the ordinary 110-volt test lead (see Index for "Test leads" or "Test light"), hol one lead against the starter-generator field ring anc touch either the positive (+) or the negative (– binding posts with the other. If a ground is present the test lamp will light.

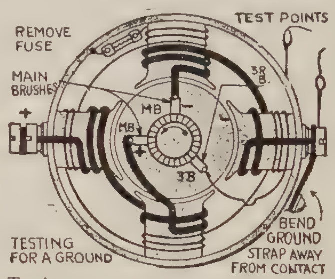


Fig. 16. Testing motor-generator windings for grounds and open circuits, test points, and light.

To localize a ground in the armature: Insert slips of paper between all three brushes (**MB**, **3B**) and the commutator to insulate the commutator and the armature from the rest of the machine. Hold one test lead against the armature shaft and touch the commutator with the other. If there is a ground, the test lamp will light.

To localize a ground in the brushes or field coils: With the brushes insulated from the commutator and the fuse removed, hold one test lead against the positive (+) binding post and touch the field ring with the other. If the test lamp does not light, the two-series field coils between the positive (+) binding post and the positive main brush (**MB**+) may be considered free from grounds.

Next, hold one test lead against the negative (–) binding post and touch the field ring with the other. If the test lamp does not light, it may be assumed that the two-series field coils in the negative half of the machine (top and right-field poles, Fig. 16) are free from grounds.

Finally, hold one test lead against the third brush (3B) and touch the field ring with the other. If the test lamp does not light, the shunt-field coils may also be considered free from grounds.

To test for an open circuit in the armature, the brushes or the series field coils: Disconnect the ground strap and remove the fuse. Hold one test lead against the positive (+) binding post, the other against the negative (–) binding post. The test lamp will light only if the circuit is complete.

To test for an open circuit in the shunt field coils: Leave the ground strap disconnected, but replace the fuse, and insulate the third brush (3B) from the commutator. Hold one test lead against one of the fuse clips and touch the third brush (3B) with the other. An open circuit in the shunt-field coils will be indicated if the test lamps fail to light.

To make sure that the open circuit is not in the fuse rather than in the coils, remove the fuse and test it by holding one test lead against each end.

To test for a short circuit, between the shunt and series field coils: Insulate the third brush (3B) from the commutator, remove the fuse, and test between the third brush (3B) and either binding post. A short circuit between these coils will cause the test lamp to light.

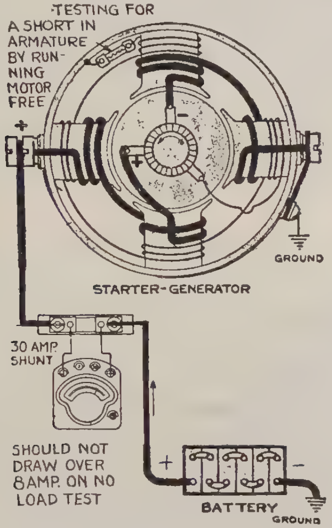

TESTING FOR A SHORT IN ARMATURE BY RUNNING MOTOR FREE
+
GROUND
STARTER-GENERATOR
30 AMP. SHUNT
SHOULD NOT DRAW OVER 8AMP. ON NO LOAD TEST
+
−
BATTERY
GROUND

Fig. 17. Testing N.E. motor-generator armature for short circuits.

To test for a short circuit in the armature: Connect an ammeter (20 or 30-ampere range) in the starting circuit (Fig. 17), and allow the machine to run free as a motor with no load. Note carefully the amount of current required to drive the machine as a motor. A normal 12-volt starter-generator will not draw over 8 amperes from a 12-volt battery when tested in this way. As a matter of fact the current drawn by the average machine when tested in this way is generally about 5 amperes. An ammeter reading of more than 8 amperes should be considered as evidence of a short-circuited armature, provided the machine is free from mechanical difficulties.

Note. The ammeter shown connected is the Weston model 280, used in connection with a 30-ampere shunt, explained under "Ammeters" (see Index).

Directions for Assembling the Sprocket-End Housing-Models "G," North East Motor-Generators

The construction of the housing, No. 8003, used on all model "G" machines is shown in Fig. 18. This shows how the oil is kept from the interior of the generator.

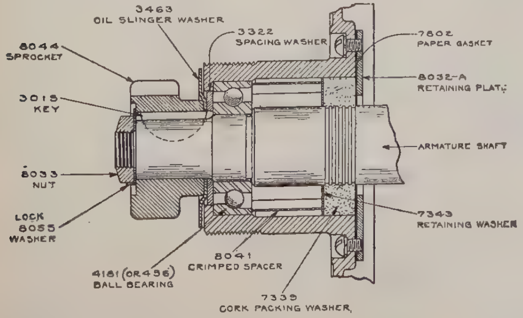


Fig. 18. Showing how oil is kept from the interior of the N.E. motor-generator.

It is ordinarily assembled as follows:

1. Insert the ball bearing (4181 separable type, or 456 annular type) in the housing.

2. Put in the crimped spacer (8041) and its retaining washer (7343).

3. Press the cork packing-washer (7339) into position, and lubricate its inner surface, where it will come into contact with the armature shaft, with a small amount of graphite grease. Whenever a cork washer has been damaged by removing it from the housing or is found to have become worn so that it no longer fits the shaft tightly, it must always be replaced by a new one. A cork packing-washer that is not in practically perfect condition cannot be relied upon to prevent the entrance of oil into the interior of the machine, and should, therefore, never be used.

Early Model North East Motor-Generators and Electric Systems Used on the Dodge

The North East system described on pages 367, 369 is the standard model "G" used on the Dodge since the fall of 1916, with slight internal modifications. For ignition, the Dodge has used the high-tension magneto and also the Delco ignition system, and since March, 1918, the North East model "O" system has been used, as shown in Fig. 5, page 369.

On the 1915 and early 1916 cars, the model "D" electric system (Figs. 19 and 21) were used. With this system a cut-out and regulator were contained in the starter-generator unit (this can be determined when there are four terminals on the starter-generator; see Fig. 23).

The model "G" system (page 369), differs from all previous models in that it has a third-brush regulation instead of an electromagnetic type regulator, shown in Fig. 23, which formed a part of all preceding North East models. The cut-out, however, is retained, but it is now enclosed in the housing with starting switch (pages 368, 369), instead of in the generator itself. There is, therefore, only one connection to the starter-generator and one grounded terminal.

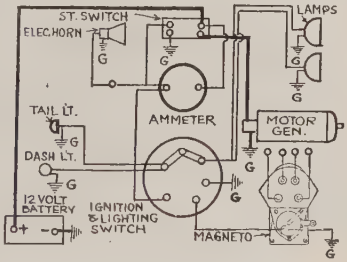


Fig. 19. Single-wire system using an Eisemann magneto for ignition.

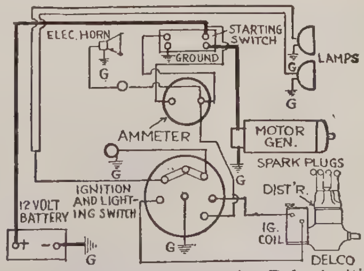


Fig. 20. Single-wire system using Delco ignition.

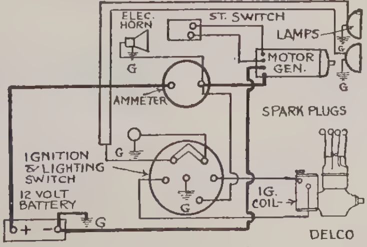


Fig. 21. Two-wire system for starting motor, rest of circuit grounded. Note the four-terminal motor-generator. Delco ignition.—*Continued on page 379.*

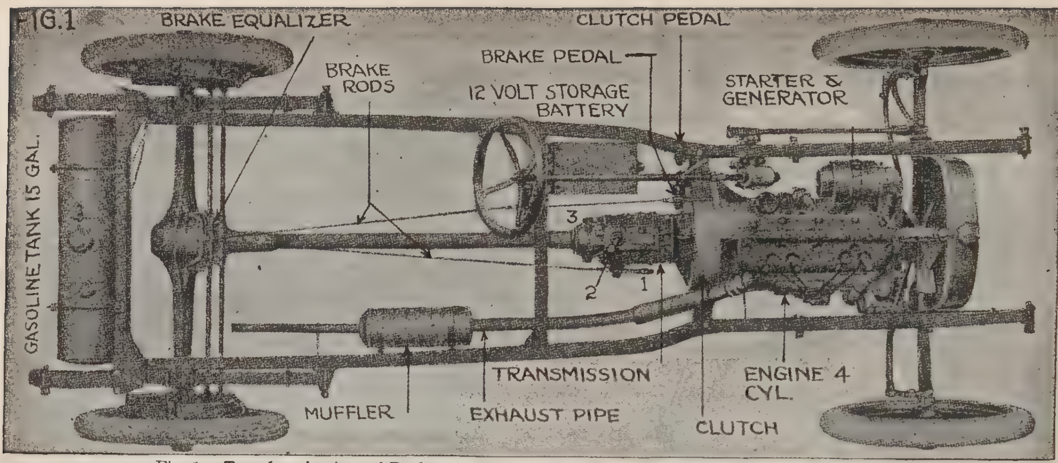


Fig. 1. Top chassis view of Dodge car, showing location of battery and motor-generator.

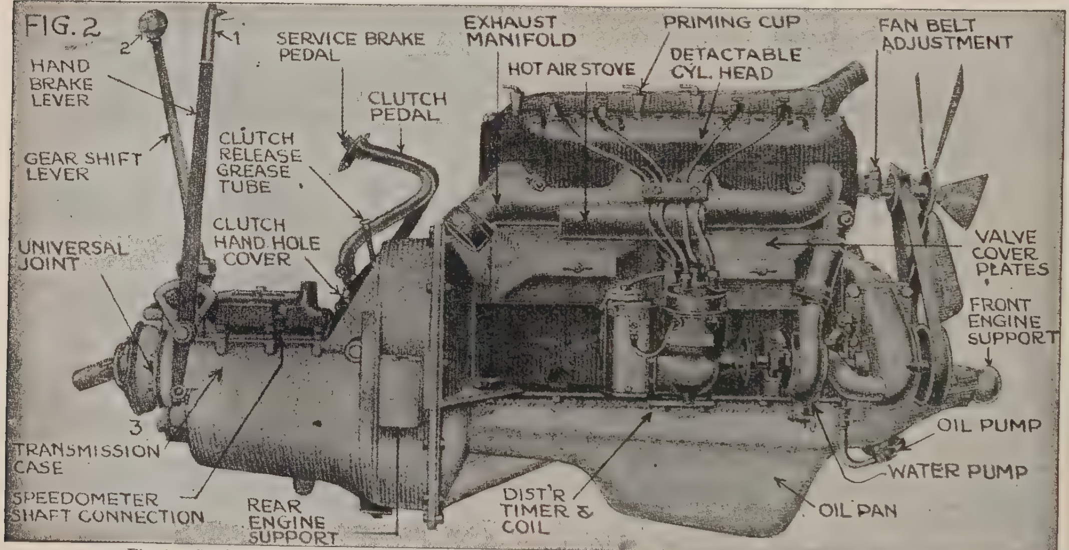


Fig. 2. Right-hand side view of the engine, showing ignition unit on the valve side of the engine.

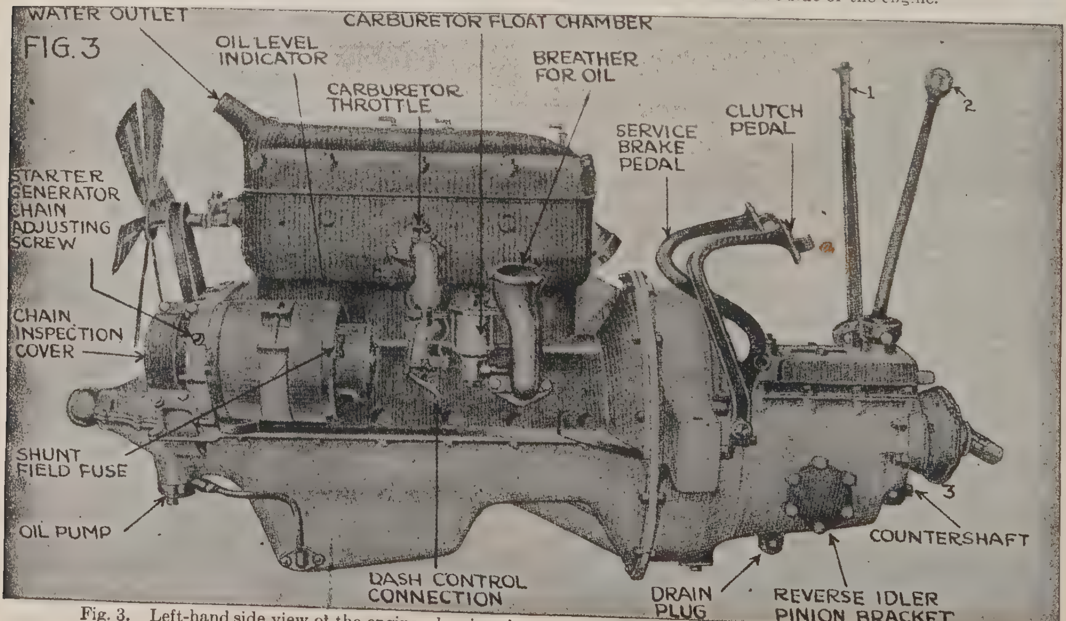


Fig. 3. Left-hand side view of the engine, showing the **motor-generator** on the carburetor side of the engine.

—*Continued from page 377.*

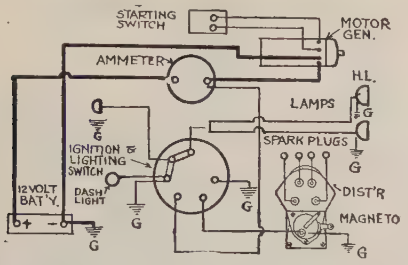


Fig. 22. Early 1916 Dodge-North East electric system with magneto ignition. Note the four terminals on the motor-generator.

This system differs from the one in Fig. 19, in that two wires are used from the motor-generator to the battery instead of a single wire. The internal connections of the model "D" four-pole North East motor-generator are shown in Fig. 23.

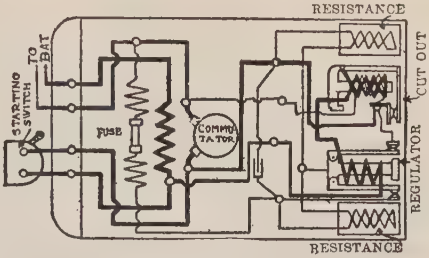


Fig. 23. The four-terminal North East model "D" motor-generator, used on the 1915 and early 1916 Dodge. The diagram shows the internal circuit of the motor-generator. A regulator of the electro-magnetic type with resistance which was cut into the shunt-field circuit at high speeds was used for regulating the output of the generator instead of a third brush. The regulator and cut-out are inside of the motor-generator.

SIMMS-HUFF SIX-POLE MOTOR-GENERATORS

Simms-Huff Type "HM" Motor-Generator

The Simms-Huff motor-generators are of the six-pole type. They are all designed essentially on the same principle, but differ in construction, as will be explained.

An example of a six-pole motor-generator compound-wound, with an electromagnetic shunt-field regulation, is shown in Fig. 1 as used on the 1918 Maxwell with a 12-volt battery, generator, and motor.

Field poles: There are six field poles with "shunt" winding on all. Three of the field poles have "series" windings, connected in "series-parallel."

Motor Circuit

Motor circuit (see arrow points on the outside of the wires): From (+) of the battery, to starting switch (**SC**), through switch to (**A+**) of the motor-generator, which is connected with the (+) ring bar, to the (+) brushes, through the armature, out the (−) brushes to the three series-field coils on poles 5, 1, and 3, to grounds on field poles (G5), (G1), and (G3), to the (−) ground of the battery.

Shunt-field circuit during motor operation is from (**A+**), through wire (**W1**), through the shunt-field fuse, to (**C1**), through regulator blade (**F**), through closed regulator points, to (**R2**), through wire (**W2**), to (**T**), through shunt-field windings 4, 5, 6, 1, 2, 3, to ground (**G1**), to the (−) ground of the battery.

Note that the current flow from the battery during the motor operation is in the same direction around the "shunt" and "series" field windings (see arrow points on the outside of the wires—not on the wires; the arrow points on the wires are the generator path). Thus it would be termed "cumulative action," where they assist each other to build up a strong magnetic field from N to S poles.

Switch-lock circuit: Before the starting switch was closed to operate as a motor, the lock button was pressed, which caused pin (**P**) to raise so that switch rod (**R**) could be moved. The circuit was then from (+) of the battery, through the button, through the electro-magnet or solenoid coil (**C**), to (**X**), through the motor-generator, to (−) ground of the battery. Note that switch circuit (**SC**) is open when this operation takes place, and the purpose of this switch lock is to prevent the starting

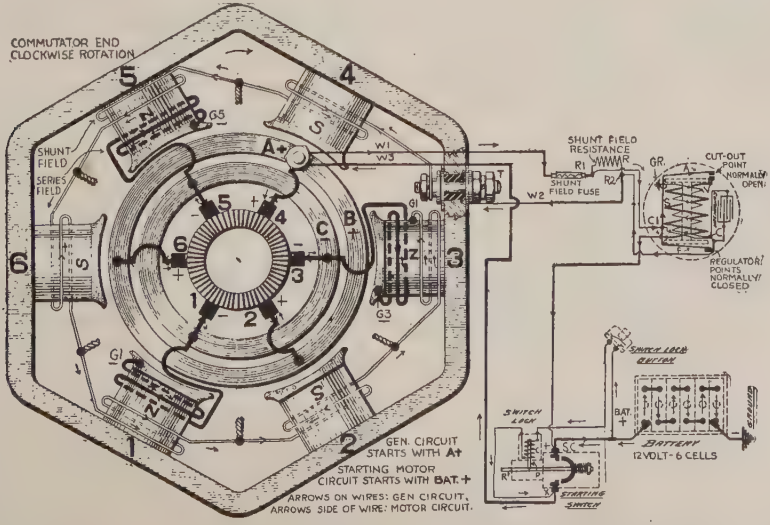


Fig. 1. Simms-Huff type "HM" motor-generator, with six field-poles. A 12-volt system with shunt field-resistance regulation.

switch from being depressed until the pin (P) is raised by the electro-magnet coil (C).

Generator Circuit

The shunt-field circuit is from (A+), to (R1), to (C1), through regulator points, to (R2), to (T), to the other end of the shunt-field winding which is grounded on pole 3 at (G1), through ground of the series coil at (G3), to (−) brush (3), through the armature, to the (A+) ring.

Cut-out voltage circuit: From (A+), to (R1), to (C1), to (C), through voltage winding (V), to ground (GR), to the (−) ground of battery. When the generator voltage is higher than that of the battery, this winding has sufficient voltage to exert sufficient magnetic influence to cause the cut-out core to draw blade (A) and close cut-out points (P).

Charging circuit: From generator (A+), to (R1), to (C1), up side of cut-out, to points (P), through cut-out armature blade (A) (supposed now to be closed), through cut-out current windings (S), to (SC) on the starter switch, to (+) of the battery, to (−) ground of the battery, to grounded series field coils (G1, G3, G5), to (−) brushes (1, 3, 5).

Note that the current flow around the "shunt" and "series" field is in opposite directions when used as a generator (see arrow points on the wires). Thus a "differential action" or "bucking" effect, where they oppose each other, is produced. The shunt field governs the polarity of the poles.

Shunt-Field Regulation; Electromagnetic Principle

Regulation is by means of an electromagnetic principle. Note the regulator points at the bottom of the cut-out core. The heavy winding (S) controls the opening of the regulator points, and is therefore a "constant current" regulator. Note that one set of windings serves for a cut-out and regulator.

At high speeds when the voltage and amperage rise rapidly, the maximum amperage is kept from rising above 7.5 amperes by the regulator.

Regulator action at high speeds: When the charging current passes through the series winding (S) of the cut-out and regulator, the regulator points are closed unless the current passing through this coil (S) is more than 7.5 amperes (1,700 r.p.m.). If so, it exerts sufficient magnetic strength to pull regulator blade (F) to the core, thus opening the points.

This action cuts in "resistance" (R) into the shunt-field circuit, and the circuit would be from (A+), to (R1), through resistance (R), to (R2) (because the points of the regulator are now open), to (T), to the shunt-field winding, thus cutting down the lines-of-force or strength of the shunt field, and consequently keeping the current below 8 amperes. During variations of speeds the regulator vibrator vibrates rapidly, opening and closing the shunt-field circuit.

Simms-Huff Model "SMS2" Motor-Generator—a 12-Volt System

Simms-Huff six-pole motor-generator, compound wound, model "SMS2," used on the 1919 Maxwell, using a "third brush for regulation" instead of an external electromagnetic regulator as in Fig. 1, is shown in Fig. 2. This is a straight 12-volt system.

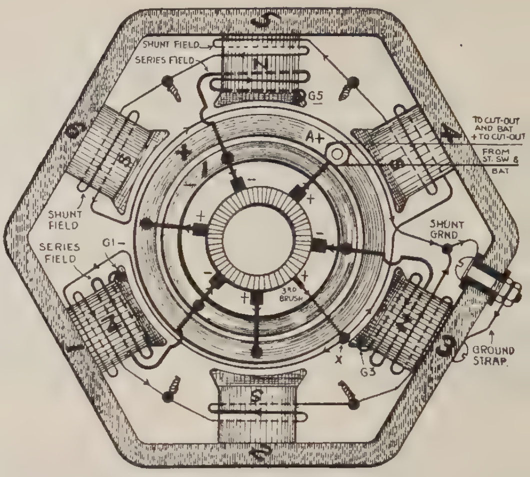


Fig. 2. Simms-Huff six-pole type "SMS2" motor-generator with third-brush regulation (1919 model). A 12-volt system.

The motor principle is similar to that shown in Fig. 1.

The generator principle: The shunt-field circuit starts with the third brush and divides at (X), going (to the left) through field windings 1, 2, and 3, and from (X) (to the right), through field windings 4, 5, and 6, to shunt (GRND), through the frame to the series field grounds (G1), (G5), (G3), to the (−) main brushes.

The charging circuit is from the generator (A+), to the cut-out, to the battery, to the (−) battery ground, to the (−) ground (G1), (G5), (G3), through the "series field coils" to the (−) brush ring, to the (−) brushes.

Simms-Huff Models "HB," "HK" Motor-Generator—12-Volt Starting Motor, 6-Volt Generator

A Simms-Huff six-pole motor-generator, models "HB," "HK," compound wound, used on the 1915, 1916, and 1917 Maxwell is shown in Fig. 3. The generator is 6-volt, and the motor is 12-volt. Regulation is by means of an electromagnetic regulator, similar to that shown in Fig. 1, except that instead of the generator being 12 volts, it is 6 volts and the starting motor is 12 volts.

Motor circuit: From battery (+12), to (12) on switch, to (13), to (13) of battery, connecting (+) of cell 12 to (−) of cell 13, making a 12-volt battery; from (+10), to switch (10), to (11) (when switch is closed), to (A+) of the motor-generator, through (+) brushes, through the armature, to (−) brushes, to (−) brush ring (B), to field coils, to ground of frame, to (−) of battery (19).

Generator field circuit: From (A+), through wire 2, to (2) on the regulator and cut-out, through the cut-out frame, through the regulator points to (3) to terminal (3) on the motor-generator, through the shunt-field windings, to ground, through series coil on pole 3, to (−) brush (4).

Cut-out voltage circuit: From generator (A+), wire 2, to cut-out (2), through the cut-out frame, to voltage winding (V), to ground of the motor-generator, through series fields, to (−) brushes. This winding causes the cut-out points to close when the generator voltage is higher than the battery voltage.

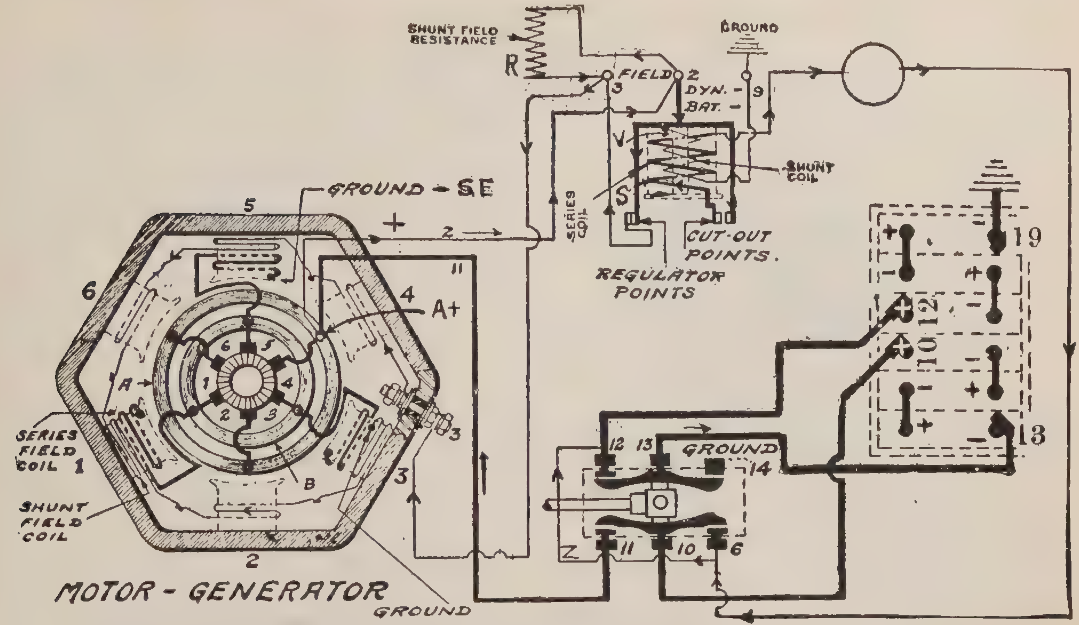


Fig. 3. Simms-Huff models "HB" and "HK" motor-generator. It operates as a 12-volt motor and a 6-volt generator.

Charging circuit: From generator (**A**+), wire 2, to cut-out (2), to the closed points of cut-out, through cut-out winding (S), to ammeter (round circle at right of cut-out), to (6) on starting switch.

After the engine is started, and on releasing the starting pedal, the starting switch plunger comes all the way back and makes connection between (13) and (14), and (10) and (6) on the starting switch.

From (6) on the starting switch the current divides, in order to join (10) and (12) (+) on the battery in multiple as follows:

From (6) through the switch terminal (shown open—should be closed) to (10) on the switch, to (10) on the battery, through the three cells to (13), to (13) on the switch, through contact (14) which is grounded. This grounds (13) (−).

Now follow from (6) through the permanent wire connection (Z) to (12) on the switch, to (12) (+) on the storage battery, through three cells to (19) (−) which is grounded.

We now have batteries 12 (+) and 10 (+) connected together, and batteries 13 (−) and 19 (−) grounded.

Thus (+) current, coming in at (6) on the starting switch, divides and passes through (12) to (+12), out (−19), to (−) ground of series coils, to (−) brushes on the generator. Current also passes from (6) to (+10) to (13), out (−13) to the (−) ground of series field coils, to (−) brushes on the generator.

In other words, the 12-volt battery is connected in multiple as two 6-volt batteries.

In regulation at high speeds, or where more than 15 amperes of current is passing in the charging circuit (which flows through the winding (S) of the cut-out and regulator) the regulator points are drawn to the core, and resistance (**R**) is inserted into the shunt-field circuit.

The shunt-field circuit would then be from (**A**+), wire 2, to cut-out (2), to and through resistance (**R**) (because the regulator points are open), to (3), to (3) terminal of the generator. Thus the magnetic strength of the shunt field is weakened by this resistance (**R**). The regulator blade vibrates at varying speeds, cutting in and out this resistance, thus holding the output normal. The generator delivers 15 amperes at 1,300 r.p.m.

The method of regulation would be termed "constant current," by an "electromagnetic action."

If the generator does not appear to charge at a high enough rate, see if the belt is tight and does not slip, that the regulator is adjusted properly, that the commutator is clean, that the brushes are clean and not sticking, and that all terminals and connections are tight and clean.

To test as a generator, remove all wires. Connect a wire from the field terminal on the side to the main terminal post on the front; then connect another wire from the main terminal post through an ammeter or test lamp to ground. Run the motor-generator at about 1,200 r.p.m. The generator should show a charge of about 12 amperes on the ammeter.

Oil and dirt cause the most trouble, as they will cut down the current output, short-circuit the brush holder, etc. Inspect and clean the motor-generator occasionally.

Electric Systems on Maxwell—1915 to 1921

1915-16-17 Maxwell cars used a Simms-Huff motor-generator combined in one unit. As a starting motor it operated at 12 volts from the 12-volt battery (as in Fig. 3). As a generator, it delivered current at 6 volts to the battery in two halves, or in parallel. A Simms magneto was used for ignition.

The 1918 car used the same system, except that the Atwater-Kent 6-volt ignition was used instead of a magneto. In August, 1918, the system was changed to a straight 12-volt battery and 12-volt ignition (Fig. 1).

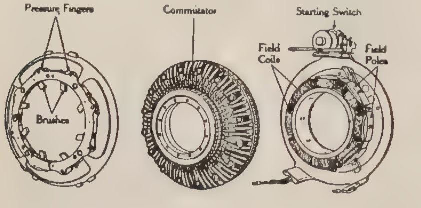
The 1919 cars used the system shown in Fig. 2.

The 1920 cars used an Auto-Lite 6-volt generator, third-brush regulation; 6-volt Atwater-Kent ignition, and a separate starting motor with a Bendix drive and 6-volt battery.

The 1921 and part of the 1920 cars use a Simms-Huff type "G," 4-pole third-brush regulated generator and a separate 6-pole type B starting motor with Atwater-Kent type "CC" closed-circuit ignition.

U.S.L. MOTOR-GENERATOR (EARLY MODEL)—24-VOLT MOTOR AND 12-VOLT GENERATOR

The U.S.L. motor-generator consists of a motor and generator combined. The motor-generator takes the place of the flywheel.



Brush Rig **Armature** **Field and Starting Switch**

Fig. 1. Armature and field-poles.

The field has two windings: a shunt and a series. When the machine operates as a motor the two windings have a "cumulative" action.

When operating as a generator, the two windings oppose each other, resulting in a "differential" action.

The voltage of the motor is 24 volts and of the generator, 12 volts.

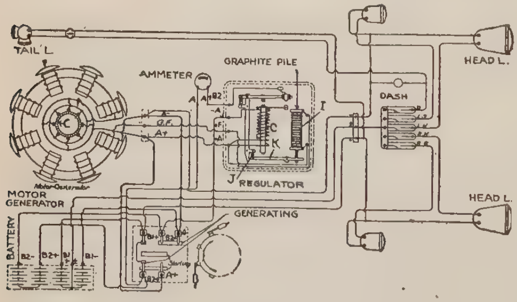


Fig. 2. Wiring circuit of the U.S.L. motor-generator.

Motor action: When the foot pedal is depressed, the battery is connected to the motor which turns over the engine at the rate of 200 to 300 r.p.m. The battery is connected in series by the starting switch when used as a motor; thus 24 volts are used.

Generator action: As soon as the engine picks up to a speed going 8 m.p.h., the motor-generator becomes a shunt-wound generator and starts to charge the battery, restoring the current used at a 3-ampere rate. The generator charges the battery at 12 volts; thus the battery is connected in multiple by the starting switch being released.

Regulation of output: A carbon-graphite pile regulator is used. It is similar in action to an electromagnetic principle of regulation.

Instead of resistance in the form of resistance wire being cut into the field circuit at high speeds, a **carbon pile resistance** is used which offers resistance to the flow of current, thus weakening the strength of the field circuit at high speeds.

The series coil (C) keeps the output constant from 600 to 1,200 r.p.m. Thus it is termed a "constant-current" electromagnetic regulation.

The electromagnetic principle of regulation is shown in Fig. 3. The current for the **voltage winding circuit** of the coil is from (+) brush, through fine wire winding (V), to the series winding on the motor-generator, to the (−) brush.

When sufficient voltage is generated the points (**P**) close. The **charging circuit** is then from the (+) brush, through the regulator series coil (**C**), to points (**P**), to the battery connected in multiple, and thus charges at 12 volts.

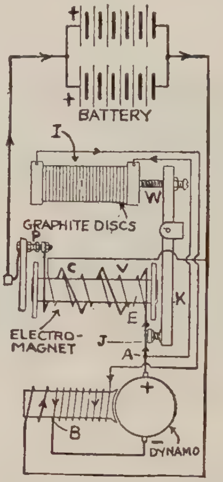


Fig. 3. Explaining the regulation method.

The shunt-field circuit is from the (+) wire above the (+) brush at (**A**), through the graphite pile, to the shunt-field winding of the motor-generator, to (**B**), to the (−) main brush of the generator.

The regulation is maintained by pressure upon the graphite disks (**I**), which are pressed together by lever (**K**), through the pressure of the coil spring (**J**).

The less the pressure, the greater the resistance thrown into the field winding, for if the disks are not close and tight, resistance is offered to the flow of current.

When the generator speed is low, the tension of spring (**J**) is great enough to cause screw (**W**) to press tightly against the graphite disks; thus the resistance is less and the generator shunt field builds up.

When the generator speed is high, the current flowing through coil (**C**) increases the magnetic pull of core (**E**), thus drawing blade (**K**) to it, thus relieving the pressure of screw (**W**). As the disks are not so tightly pressed together, the resistance is greater, thus the field strength is cut down.

On a later U.S.L. system, the carbon pile was eliminated, as also the "series parallel switch."

No regulator is used, as the windings of the generator are so proportioned that the output of the generator cannot exceed the current demand of the storage battery and lamps.

A portion of the multi-polar field of the motor-generator is wound with a series coil for starting purposes. The other portion of the fields is wound with shunt and compensating coils for generating and regulating purposes. The brushes are so connected that the entire number is used for starting, whereas but three are used for generating.

The storage battery is provided in some cases with two and in some cases three terminal posts. When two terminals are provided, a 14-volt lamp must be used. When three posts are provided, 7-volt lamps are used.

The number of cells of the battery are cut down from 12 to 6, giving 12 volts instead of 24.

This system was formerly used on the early models of Jeffery, Sheffield, Simplex, Willys-Knight, S.G.V., and Mercer.

INSTRUCTION No. 35

DELCO ELECTRIC SYSTEMS[1]

In order that the reader may understand the later Delco systems, it will be necessary to begin with the 1914 models. Some of the early model Delco systems will therefore be shown before taking up the later models.

The motor-generator principle was first used by Delco—and is still used, but with a different regulating principle, and with other changes from the early models.

The Delco also make single-unit systems, where the generator and starting motor are separate, as will be explained farther on.

The early 1914 system should be carefully studied in order to understand the later systems.

DELCO 1913-14 MOTOR-GENERATOR; ELECTROMAGNETIC REGULATION; CONSTANT VOLTAGE

The 1914 Delco motor-generator and electric system, as used on the 1914 Cadillac and Hudson 1914, "6-54," Oakland 43, Olds 55, Packard 1-38, 3-48, Cole series 9, model cars is explained as follows: The motor-generator is located alongside of the engine driven by a pump shaft (Fig. 1).

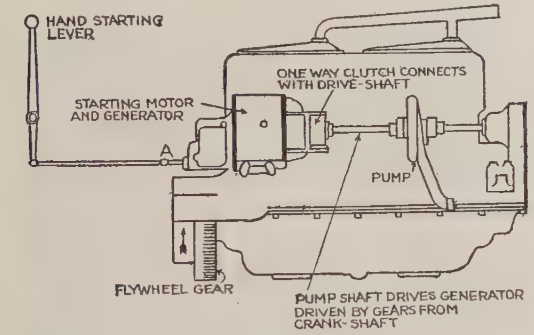

HAND STARTING LEVER
ONE WAY CLUTCH CONNECTS WITH DRIVE-SHAFT
STARTING MOTOR AND GENERATOR
A
PUMP
FLYWHEEL GEAR
PUMP SHAFT DRIVES GENERATOR DRIVEN BY GEARS FROM CRANK-SHAFT

Fig. 1. The mounting of the 1914 Delco motor-generator is similar to that of the later models.

The armature is used for both the starting motor and the generator with two windings; one a "series" winding for the motor (Fig. 2), and a "shunt" winding for the generator (Fig. 3).

When the motor is in operation, the current flows from the battery to the series-field winding through the motor brush (**F**) and commutator.

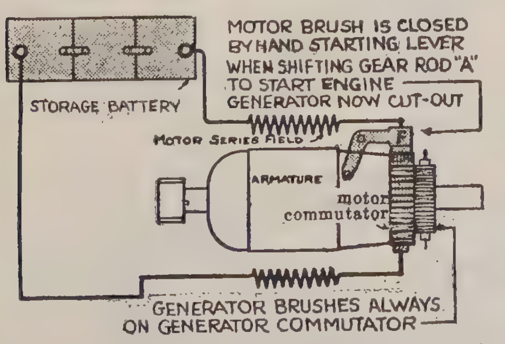

MOTOR BRUSH IS CLOSED BY HAND STARTING LEVER WHEN SHIFTING GEAR ROD "A" TO START ENGINE
GENERATOR NOW CUT-OUT
STORAGE BATTERY
MOTOR SERIES FIELD
F
ARMATURE
motor commutator
GENERATOR BRUSHES ALWAYS ON GENERATOR COMMUTATOR

Fig. 2. The motor brush is now down and the starting motor is working. The generator is cut out.

The starting switch is eliminated, as the action of the motor brushes is lowered to the motor commutator, and thus when starting, the lever meshes the gears with the flywheel and so takes the place of a starting switch.

The starting motor drives the flywheel gear through the gears (**C**), (**D**), and (**B**) (Fig. 4). A roller-type clutch is provided on the front part of the armature shaft, so that the armature is free from the pump shaft which drives the generator.

When the generator is in operation, the motor brush (**F**) is raised (Fig. 3). The generator brushes remain on the commutator at all times. The current then flows through the shunt-field winding.

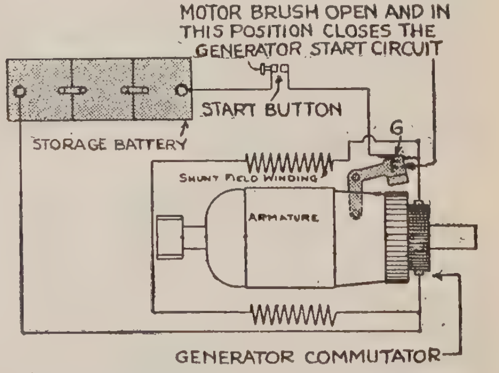


Fig. 3. To start, the "start button" is pressed. This sends current from the battery to the generator (not the motor) armature, through the field winding and the armature revolves slowly. Note that the motor brush is up and makes contact at (G) for the generator.

The armature is driven by connection with the pump shaft by the engine (Fig. 1), after the engine is started and after the starting gears are out of mesh. A one-way clutch connects the pump shaft with the armature shaft to drive the generator. This clutch will permit the pump shaft to drive the generator, but the generator armature, when running as a motor, cannot drive the shaft.

Starting Operation

First: Place the ignition switch on the battery side. Next: depress starting button on the dash (see Fig. 3). This sends current from the storage battery to the generator (not the motor), and in passing through the generator field shunt winding, and the armature winding, the armature slowly revolves. This is termed **"motoring the generator."**

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[1] **The Delco Service Manual** can be secured of A. L. Dyke, St. Louis, Mo., price $3, which contains descriptions of all Delco systems, tests, and diagrams from 1913. Manuals on Remy, Autolite, and other systems can also be furnished.

The purpose of using the generator as a motor is to revolve the armature slowly, so that the gears will mesh with the flywheel gears when the starting lever throws them in mesh. It must be remembered that the brush on the starting motor commutator is not in contact, but, being in the position as shown in Fig. 3, the generator circuit is closed at (G), but not the motor circuit.

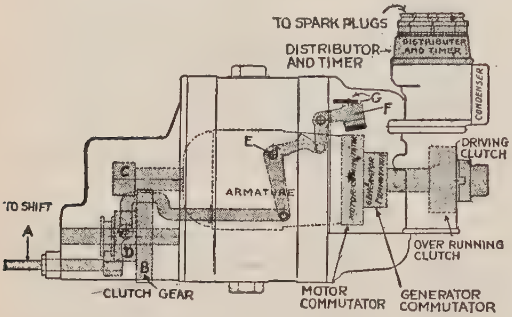

Fig. 4. Phantom view of motor-generator.

After the generator armature is revolving slowly pull back on the starting lever (see Figs. 1 and 4).

This causes rod (A) (Fig. 4) to be pushed forward, causing gear (B) of the starting clutch to mesh with motor pinion (C).

Immediately after gears (B) and (C) are meshed, the gear (D), which is integral with (B), meshes with the gear teeth on the flywheel. At the same time, the extension of the rod (A) to the bell crank (E) allows the motor brush (F) to travel toward the motor commutator, opening the generator circuit and shunt field at (G), and closing the motor circuit.

The generator would then be cut out and the starting motor is causing the engine to revolve, through the flywheel (Fig. 2).

Generating Current

When the starting lever is released, the spring throws the gears out of mesh, and at the same time raises the motor brush (F) from the motor commutator and closes the generator circuit again at (G). The "start" button having been released in the first operation, the generator is now generating current, as the engine is running and driving the armature as a generator through the pump shaft.

The starting motor has served its purpose and is now cut out of operation, as the brush (F) is away from the motor commutator (Fig. 3).

Regulation of the Generator (Shunt-Field; Electromagnetic)

A mercury type of voltage regulator was used, which is an electromagnetic principle of cutting resistance into the shunt-field circuit, explained as follows: The generator, as stated previously, is driven from the pump shaft which is driven by gears in front of the engine from the crank shaft.

After the engine is started, and the hand-starting lever disengages the gears out of the flywheel, and motor brush (F) is lifted off the motor commutator, the motor is cut out and the generator is now in action. It must run when the engine runs, as the pump shaft is connected with the armature through a one-way clutch (Fig. 4), which permits the engine to drive the armature. But the armature, when revolving as a motor, cannot drive the engine except through the gears to the flywheel. This clutch permits the armature to run ahead of the driving shaft during the cranking operation.

The generator now begins to generate current; but until the engine is running at a speed which will turn the generator armature fast enough to generate a pressure of 6 volts, or the required amount to overcome the pressure or voltage of the storage battery, the current will pass from generator commutator 1, to 2, around the fine wire voltage winding (V) of cut-out core (D) (Fig. 5), thence back to the other commutator brush 15. This current will continue to travel in this path until it has sufficient pressure, which is slightly over 6 volts, to magnetize the core (D) so that it will draw the magnet armature of cut-out (C) down, closing cut-out points (P) at which time the circuit is closed to the battery. The battery will then be charged from the generator, or the generator will also supply current for light. (At other times, the storage battery supplies current for lights.)

If the engine is speeded up, the pressure increases and the lights would be burned out. Therefore, the "mercury regulator" is brought into action.

Voltage regulator: As the voltage increases with speed, the intensity of the magnetic pull exerted by the magnet voltage coil (A) upon plunger (C) causes the plunger (C) to move up out of the mercury (see Figs. 5 and 6).

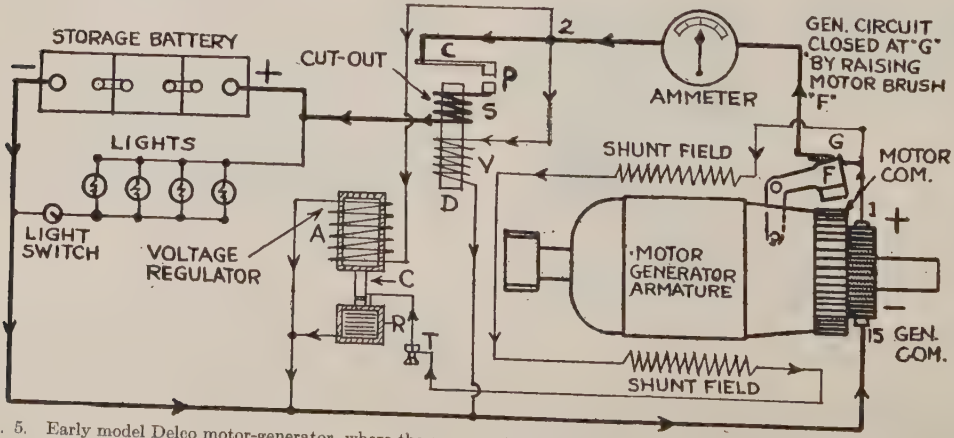

Fig. 5. Early model Delco motor-generator, where the mercury type of voltage regulator was used to regulate the generator output.

The regulator voltage coil (A) circuit is from (+) brush (1) to (2), through (A) to (−) brush(15).

The current to the shunt field of the generator starts at the (+) brush of the generator, through the two field windings, to (T) on the regulator, and must follow a path leading into the outer well of mercury, through the resistance coil (R) wound on the plunger tube, to the needle (D) carried at the center of the plunger, into the center well of mercury and out of the regulator, back to the (−) brush (15).

It will be seen that as the plunger is withdrawn from the mercury, more resistance is thrown into this field circuit, owing to the fact that the current must pass through a greater length of resistance wire. This greater resistance in the field of the generator causes the amount of current flowing to the battery to be gradually reduced as the battery nears a state of complete charge, until finally the plunger is almost completely withdrawn from the mercury, throwing the entire length of resistance coil into the shunt-field circuit, thus causing a condition of practical electric balance between the battery and generator, and obviating any possibility of over-charging the battery. As the speed decreases, the magnetic pull of the core (A) of the regulator voltage coil is weaker and plunger (C) assumes a lower position.

Note that **there are two voltage windings:** one (V), on the cut-out core to close the cut-out points, and one (A), on the regulator to operate the needle which cuts in and out the resistance to the field circuit. Both voltage coils are placed across the generator circuit.

The charging circuit is from the (+) brush (1) of the generator, through generator switch (G), to cut-out (2), through cut-out series winding (S), through points (P), to (+) terminal of the battery, to (−) brush of the generator (15).

FIG. 6

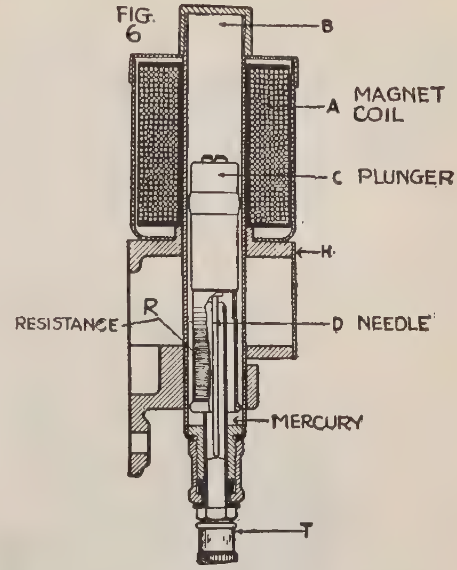

Fig. 6. **The Delco mercury-type voltage regulator** is located alongside of the cut-out, both being in the battery box or on the inside of the dash under the hood.

Purpose: to control the amount of current flowing from the generator to the storage battery.

Description: A magnet coil (A) surrounds the upper half of the mercury tube (B). Within this mercury tube is a plunger (C) comprising an iron tube with a coil of resistance wire (R), wrapped around the lower portion on top of mica insulation. One end of this coil is attached to the lower end of the tube, the other end being connected to a needle (D) carried in the center of the plunger.

The lower portion of the mercury tube is divided by an insulation tube into two concentric wells, the plunger tube being partly immersed in the outer well, and the needle in the inner well. The space in the mercury tube above the body of the mercury is filled with an especially treated oil, which serves to protect the mercury from oxidization, and to lubricate the plunger. A bracket (H) serves to support the parts described.

DELCO MOTOR-GENERATOR: MECHANICAL REGULATION METHOD, BY MEANS OF A GOVERNOR AND VARIABLE RESISTANCE (6-VOLT CONSTANT-VOLTAGE SYSTEM)

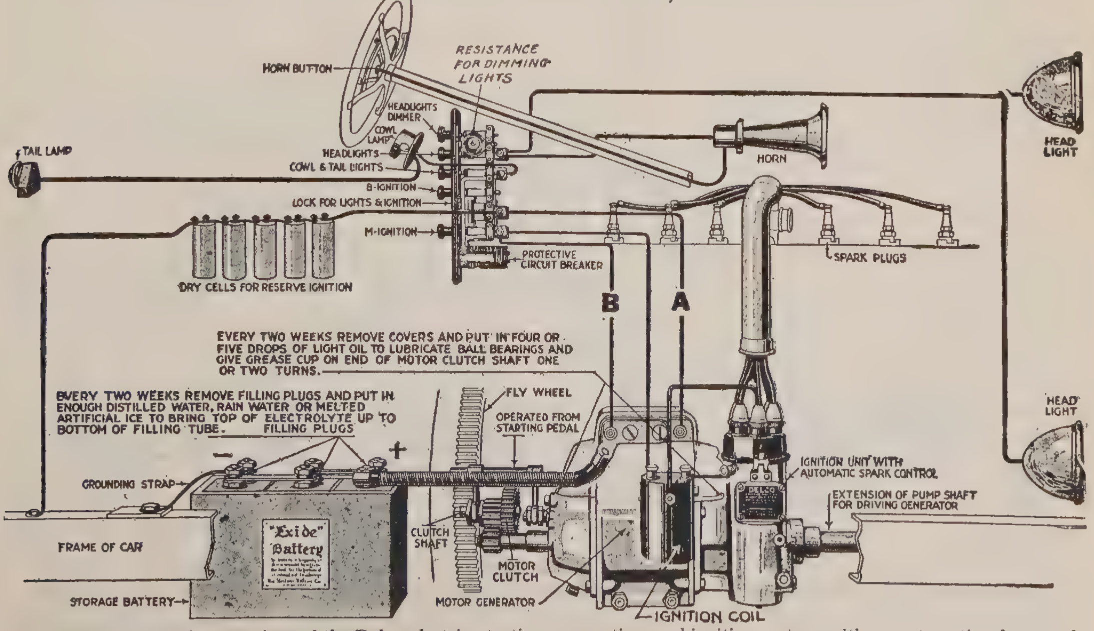
HORN BUTTON
RESISTANCE FOR DIMMING LIGHTS
HEADLIGHTS DIMMER
COWL LAMP
HEADLIGHTS
COWL & TAIL LIGHTS
TAIL LAMP
B-IGNITION
LOCK FOR LIGHTS & IGNITION
M-IGNITION
HORN
HEAD LIGHT
PROTECTIVE CIRCUIT BREAKER
SPARK PLUGS
DRY CELLS FOR RESERVE IGNITION
B
A
EVERY TWO WEEKS REMOVE COVERS AND PUT IN FOUR OR FIVE DROPS OF LIGHT OIL TO LUBRICATE BALL BEARINGS AND GIVE GREASE CUP ON END OF MOTOR CLUTCH SHAFT ONE OR TWO TURNS.
EVERY TWO WEEKS REMOVE FILLING PLUGS AND PUT IN ENOUGH DISTILLED WATER, RAIN WATER OR MELTED ARTIFICIAL ICE TO BRING TOP OF ELECTROLYTE UP TO BOTTOM OF FILLING TUBE.
FILLING PLUGS
FLY WHEEL
OPERATED FROM STARTING PEDAL
HEAD LIGHT
−
+
GROUNDING STRAP
IGNITION UNIT WITH AUTOMATIC SPARK CONTROL
EXTENSION OF PUMP SHAFT FOR DRIVING GENERATOR
FRAME OF CAR
"Exide" Battery
CLUTCH SHAFT
MOTOR CLUTCH
STORAGE BATTERY
MOTOR GENERATOR
IGNITION COIL

Fig. 7. External connections of the Delco electric starting, generating, and ignition system, with an automatic advance of ignition. A single-wire grounded-return wiring system.

On the Hudson "Six-40" (1915–16), Buick models "C–54, C–55, C–36–37" (1915), Cole "6–50," Oakland 49 (1915), Olds 42 (1915), the Delco motor-generator was used, but with a "variable resistance" cut in and out of the shunt-field circuit by means of a mechanical governor instead of the electromagnetic principle, as previously described.

The armature winding: There are two regular "drum"-type windings on the armature, one for the generator and one for the motor. But only one armature is used. There are two commutators on this system, one at each end; one for the generator circuit and one for the motor circuit (see Fig. 8).

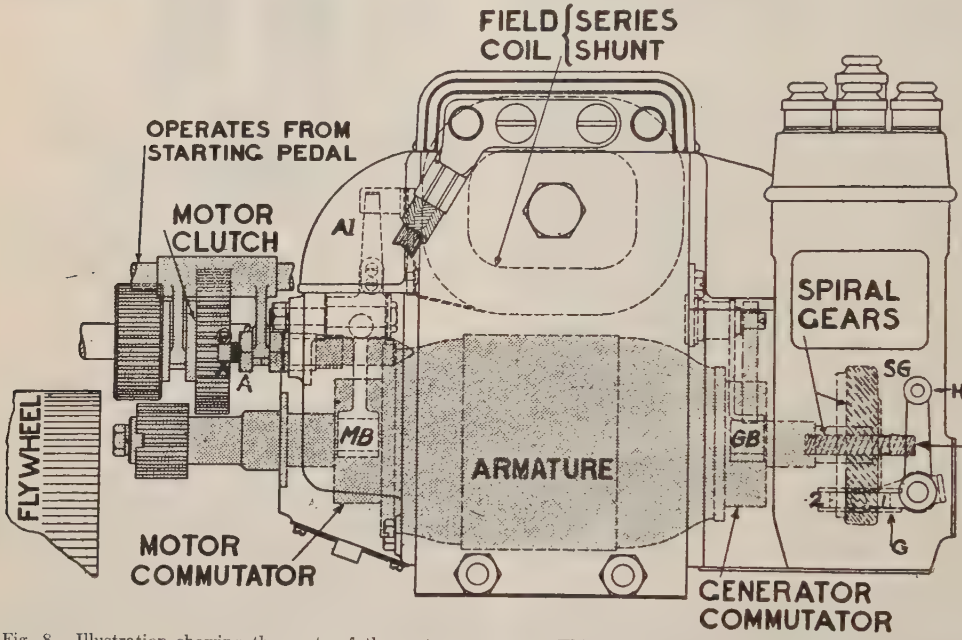

Fig. 8. Illustration showing the parts of the motor-generator. This is a "single-unit" system, the motor-generator and ignition unit being in one unit. (HC) is the manual control of the spark and connects with the spark lever on the steering wheel.

The cut-out is also eliminated. A circuit-breaker of the vibrating type is used to take the place of fuses. See Fig. 15, page 392, for an explanation.

Field windings: There are two windings, a series-field winding for the motor and a shunt-field winding for the generator.

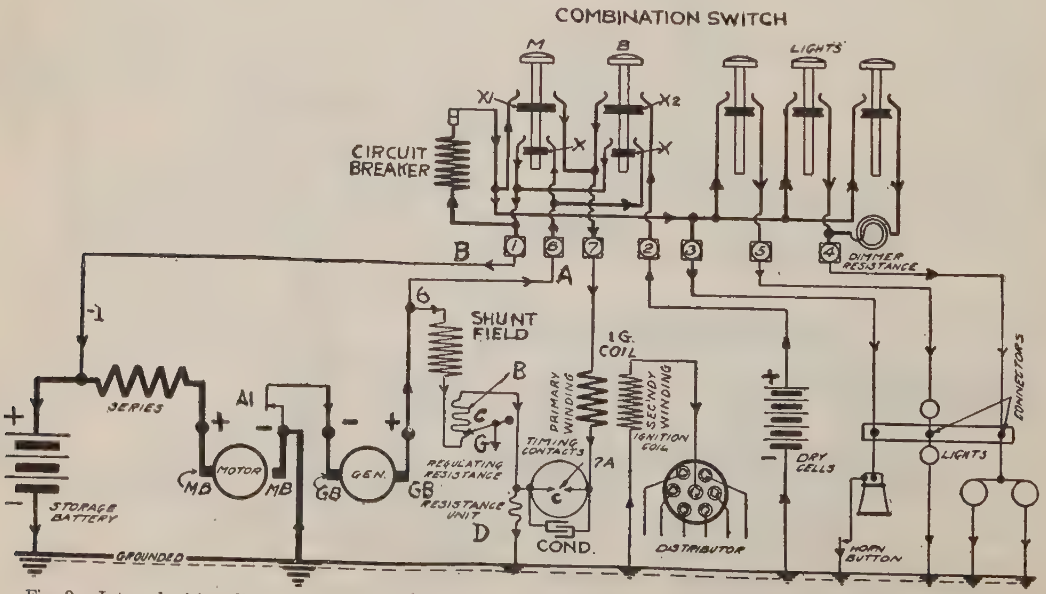

Fig. 9. Internal wiring diagram of the system shown in Figs. 7 and 8. Note the variable resistance (B), which is cut into the shunt field-circuit.

Motoring Generator

When first starting, the (**M**) ignition button (see diagram, Fig. 9) is pulled out and the starting pedal depressed. This causes rod (**A**) to shift gears into mesh with the flywheel gear, and at the same time connection is made from the battery (+) terminal to (1), through (**X**), to (6), to the shunt-field winding of the generator, to ground, also to the (+) generator brush, through the armature, to the (−) generator brush, to (**A**1), to ground, to (−) ground of the battery. This circuit causes about 5 amperes of current to pass through the generator, which permits the generator to revolve as a motor in order to make it easy for the gears to mesh. This is termed "motoring the generator."

The purpose of using the generator as a motor is to cause the armature to revolve slowly, so that the gears will mesh with the flywheel gears when starting. If the current was immediately applied to the starting motor, it would revolve at full speed immediately. By "motoring the generator," however, the armature revolves slowly until gears are meshed, and then the full current is applied to the starting motor.

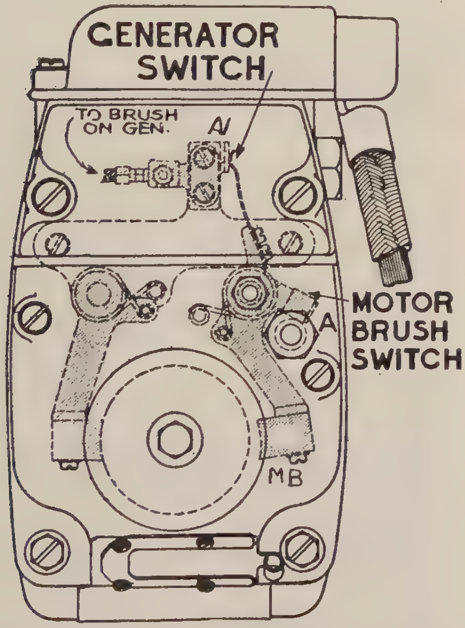

Fig. 10. View of motor-generator showing the motor brushes, also the generator switch (**A**1). The large wire on right of Fig. 10 connects with the battery. The generator circuit is opened and closed by action of switch (**A**1). When the motor brush (**MB**) is raised by rod (**A**), the generator circuit is closed at (**A**1). When the motor brush is lowered on to the commutator by rod (**A**), for starting purposes, the generator circuit is opened at (**A**1).

Starting Motor or Cranking Operation

As the starting pedal is depressed still farther, the motor brush (**MB**) makes contact with the commutator and the generator is opened at generator switch (**A**1). The full force of the current from the battery then passes (+) through the motor series-field winding and the armature, through closed brush (**MB**) on the right, to ground, to the (−) battery grounded terminal.

When the starting pedal is released and the engine starts, the motor brush (**MB**) is raised from the commutator, and the generator circuit is again closed at generator switch (**A**1).

Generator Operation

When the engine is not running, or when it is running below 300 r.p.m., and the circuit between the generator and the storage battery is closed either by the (**M**) or the (**B**) button on the combination switch, the direction or flow of the current is from the battery to the generator. If the speed is very low indeed, as when throttled down to three miles per hour, the generator will "over-run" and the clutch will be heard in operation.

A warning is given when the ignition button is pulled out or left pulled out (and the engine stopped) by the clicking of the ratchet type of driving clutch (Fig. 11), with which all these generators are equipped.

Cut-Out Not Used

On the Delco system described on page 384, the cut-out served the purpose of disconnecting the battery, when the generator was running at a slow speed, or not at all, or if generating less than 6 volts.

On the system now being explained and present-day systems, the "cut-out" is eliminated. The ignition buttons (**M**) and (**B**) in a way take the place of this cut-out. The operation of either button controls the circuit between the generator and the storage battery. Should the engine stop and the ignition button (**M**) or (**B**) remain pulled out, the amount of current that comes from the storage battery is that which is required to operate the generator as a motor when first starting, and is about 5 amperes.

When the engine is running below 300 revolutions, then this clicking of the ratchet will take place again, because the current from the battery is running back into the generator which is slowly revolving it. This indicates that the generator is not running fast enough to overcome the pressure of the battery. The amount of current that flows from the battery back to the generator at this slow engine speed is so small that it is negligible. Therefore the automatic "cut-out" is eliminated.

Generator Charging Circuit

At over 300 revolutions, the generator is running fast enough to overcome the battery pressure and the **generator charging circuit** would be as follows (see Fig. 9, wiring diagram): Start with the (+) generator brush, to (6), to (**X**), to (1), to (+) terminal of the battery, to (−) ground of the battery, to (−) grounded generator brush through the closed generator switch (**A**1). (Note that the motor brush (**MB**) is raised from the commutator.)

Generator Shunt-Field Regulation

The regulation of the shunt-field generator circuit is by means of a "variable resistance" (**B**), which is cut into the shunt-field circuit at high speeds automatically and mechanically, by a centrifugal governor arrangement (Fig. 11). This arrangement controls a lever (**C**), which is raised and lowered by the action of the governor and which cuts the resistance (**B**) into the shunt-field circuit at high speeds. This results in weakening the strength of the shunt fields, and consequently the output of the generator. This is termed a "variable resistance" method of regulation and is "mechanically" controlled.

When the generator is running at low or medium speeds, the lever (**C**) is at the lowest point, as shown in the wiring diagram (Fig. 9). Therefore, the resistance (**B**) is cut out and the circuit of the shunt field is from the (+) brush of the generator, to (6), to lever (**C**), to ground (**G**), to (−) ground of the generator brush (through the generator switch **A**1).

When the generator is running at high speeds, the lever (C) raises. As a consequence, the resistance (B) is cut into the shunt-field circuit. The amount of resistance cut into the shunt-field circuit depends upon the speed. The higher the speed, the higher the lever (C) is raised, with a consequent higher resistance being cut into the field circuit.

Control of the "Variable" Regulating Resistance—by Governor Action

Note the action of the governor which controls the cutting in and out of this resistance. (See Fig. 11, and diagram, Fig. 9.) The spiral gear (SG) is attached to the timer shaft (TS). This is operated by the pump shaft independently of the armature shaft, this gear being a part of the clutch which connects with the pump shaft.

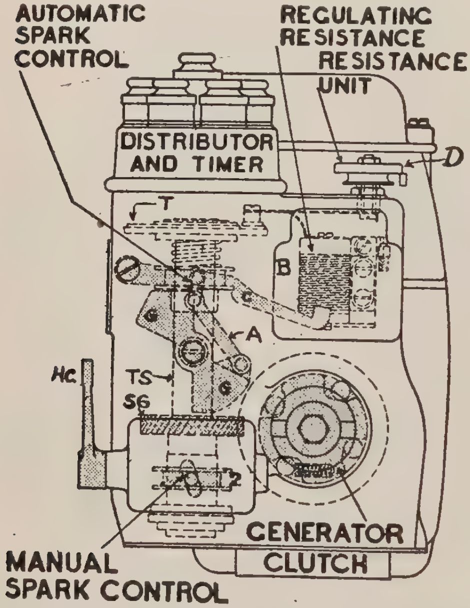

Fig. 11. View of the "variable resistance" mechanism, automatic advance of the spark and the generator clutch. The spiral gear on the generator clutch drives gear (SG), which drives the timer shaft (TS). The governor (G) tends to assume a horizontal position as the speed increases, and thus it operates arm (A) controlling lever (C), which cuts in the bare wire resistance (B) on the spool. This same action actuates the automatic advance of the spark as explained under the "ignition" section of this subject.

If the distributor was driven from the armature shaft the timing would be effected during the starting operation, at which time the armature operates at a different speed from that of the pump shaft.

The pump shaft runs at one and one-fifth times the crank-shaft speed, but the six-lobe cam and the shaft operate at half engine crank-shaft speed.

As the timer shaft revolves, the governor weights (G) assume a rising position which raises the arm (A), thereby raising the lever (C), which makes contact with the bare resistance wire (B), wound on an insulated spool. The principle is that as the speed of the engine increases, the speed of the timer shaft increases, and the governor arms (G) rise higher as the speed increases, thereby raising the arm (C) higher.

The higher arm (C) is raised, the more of this resistance wire is thrown into the field circuit, thereby weakening the output and keeping the current from gaining as the charging rate increases at the higher speeds.

Ignition

The ignition system consists of an open-circuit timer, ignition coil, mounted as shown in Fig. 7, and a distributor which distributes the high-tension current to the spark plugs.

The primary circuit (if the battery supplies the current, Fig. 9) is from (1), through the circuit breaker, to (X1), to (7), to the primary winding of the coil, to (7A), through the timer points, through ignition resistance (D), to ground, to the (—) ground of the battery.

The primary circuit (if the generator supplies current) is from 6, to (X), to and through the circuit-breaker, to (X1), to (7), and from there the same circuit as given in the preceding paragraph.

The dry cell batteries are used as an emergency set for ignition. The current is supplied in exactly the same manner as though it was coming from the storage battery; the (B) button on the combination switch closes the circuit between terminals No. 1 and No. 6 at (X), in order that the generator may be connected to storage battery for charging purposes.

The dry-cell primary ignition circuit would then be from (+) of the dry cells, to (2), to (X2), to (7), through the primary winding of the coil, to the timer, to resistance unit (D), to ground, to (—) ground of the dry cells.

The secondary ignition circuit is from the secondary winding, to the distributor, to the spark plugs, to ground, to ground of the secondary winding.

Automatic Advance of Ignition Controlled by Governor Action

At the same time the timer cam on the end of the timer shaft is automatically "advanced." As the speed is increased the action of the governor turns the timer cam in the direction of rotation, thereby causing earlier contact.

The ignition system consists of a non-vibrating coil mounted as shown in Fig. 7. The timer is an open-circuit system in this system, but the closed-circuit type is used on later systems. See Index for "Delco ignition systems."

The ignition resistance unit shown at (D) (Figs. 9 and 11) is a coil of resistance wire, the purpose of which was explained on page 198 in the instruction on ignition.

This ignition resistance unit has connected in parallel with it, the shunt-field regulating resistance (B) (Fig. 9).

When the arm (C) is in the lower position, the resistance of this path greatly exceeds that through the resistance unit, and practically all the ignition current passes through the ignition resistance unit.

But as the arm rises, as at high speed, this resistance is decreased, and when the arm is at the top position the full voltage is applied to the ignition coil.

In the event of the ignition resistance unit (D) being disconnected or burned out, it is impossible to get sufficient current through the regulating resistance, unless the arm (C) is held near the top.

Generator Clutch

A clicking sound will be heard during the "motoring of the generator." This is caused by the "overrunning of the clutch" in the forward end of the generator which is shown in Fig. 11.

The purpose of the generator clutch is to allow the armature to revolve at a higher speed than the pump shaft during the cranking operation and to permit the pump shaft to drive the armature when the engine is running on its own power. Spiral teeth are cut on the outer face of this clutch for driving the distributor. This portion of the clutch is connected by an Oldham coupling to the pump shaft. Therefore its relation to the pump shaft is always the same, and does not throw the ignition out of time during the cranking operation.

How to Remove Generator Clutch

Two views of the generator clutch are shown in Figs. 12 and 12**A**. This clutch is removed from the armature and end-frame assembly by loosening the screw in the end of the armature shaft and removing the lock washer and key washer. Cut a hole in the work bench about ¼″ larger in diameter than the armature. Insert the armature through this hole. Allow the armature and end frame to drop about two inches, being careful to have the end frame come squarely in contact with the bench. Hold the armature from below, so that it will not be injured by striking the floor.

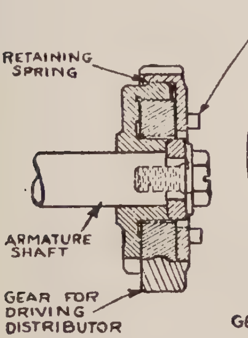

Fig. 12

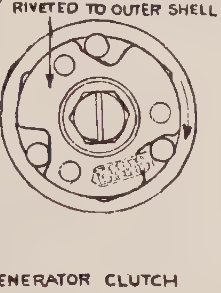

Fig. 12A

The clutch is held together by a retaining spring wire which, when removed, allows the clutch to be disassembled for inspection.

Motor Clutch

The "motor" clutch operates between the fly wheel and the armature pinion (Fig. 8), and is for the purpose of getting a suitable gear reduction between the motor generator and the fly wheel. It also prevents the armature from being driven at an excessively high speed during the short time the gears are meshed after the engine is running on its own power.

Single-Wire or Grounded System

The Delco wiring of the different parts is shown in Fig. 9. Note that the single-wire system is used in the illustration—the frame of the car being used to carry the return circuit.

The motor-generator, storage battery, lamps, horn, and ignition apparatus each have a connection "grounded" to some part of the frame of the car or engine. The other connections are made with copper wires or cables.

Circuit-Breaker

The circuit-breaker does not take the place of a cut-out. It is provided so as to open the circuit in case of a short circuit, and it thus takes the place of fuses. See Fig. 14, page 390.

DELCO MOTOR-GENERATOR THIRD-BRUSH REGULATION—CONSTANT CURRENT

As an example of a third-brush-regulated Delco motor-generator we will use the Delco electric system on one of the first models of the Hudson "Super-Six" cars, models "H" (1916–17) and model "J" (1918). The Hudson "Super-Six" was produced after the Hudson "6-40," which used a variable resistance regulation which was cut into the field winding automatically by a governor. The late Hudson "Super-Six" model uses a similar system, except that a "third-brush" regulation is used instead of "variable resistance," the combination switch is arranged differently, and there are differences in a few other minor details. See Index under "Wiring diagram of the 1921 Hudson."

The Delco motor-generator used on the Hudson consists of a motor and a generator contained in the same housing, thus forming a single unit. Electrically, however, they are just as separate as if they were built in separate housings.

There are two armature windings and two commutators entirely independent of each other. The commutator and brushes at the rear end belong to the motor part of the machine; those at the front belong to the generator part.

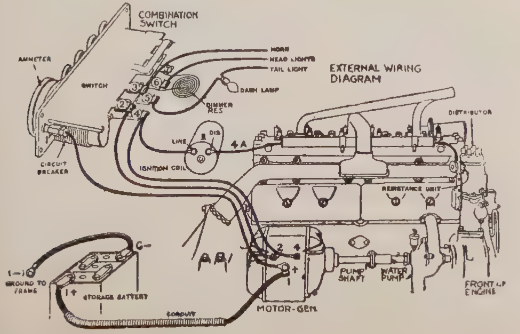

Fig. 13. External circuits of the Delco electric system on the Hudson "Super-Six," models "H" and "J."

There are two sets of field windings or coils: a set of "shunt-field coils" used for the generator action, and a set of "series-field coils" used for the motor to crank the engine.

"Motoring-Generator" Circuit

When first starting, the ignition button is pulled out (Fig. 14), which closes three circuits as follows:

1. **The ignition primary circuit,** from battery (+) to (1) on the ammeter, to a point on the switch above (3), to (**X**), to (**X1**), to (4), to the primary coil winding, through (4**A**), to the ignition resistance unit, to the timing contact points (closed-circuit type), to ground, to (—) ground of the battery. **The ignition secondary circuit** is from the lower ignition coil winding to the distributor, to the spark plugs, to ground, to (—) ground of the battery, to (1), to (**X**), to (**X1**), to (4), to the primary winding, to where the secondary joins the primary winding.

2. **The generator-field circuit** (for motoring generator) is from (+) of the battery, to (1), through the ammeter, to (**X**), to (**X1**), to (4), through the shunt-field windings, to the third brush, through the armature coils, to the (—) grounded generator brush, to (—) ground of the battery.

3. **The generator motoring circuit** is from (+) of the battery, to the ammeter, to (**X**), to (2), to the generator switch (which is closed), to the (+) generator brush, through the armature, to the (—) generator brush, to (—) ground of the battery.

These circuits from the battery give an ignition circuit for the spark plugs and also turn the generator armature over slowly (termed "motoring the generator"), so that the gears can easily be meshed with the flywheel gear.

Starting Motor Circuit

During the "motoring of the generator" operation, as explained, both motor brushes are raised from the commutator. They remain in this position at all times, and the generator switch is closed at all times, unless the starting pedal is depressed for starting the engine.

When motoring the generator, the first operation in starting, is to depress the starting pedal which meshes the drive gear with the flywheel driven gear on the rim of the flywheel. At the same time that the gears are meshed, the rod operating in contact with the lower brush arm of the motor moves, allowing both motor brushes to come in contact with the motor commutator, and at the same time the generator switch is opened, opening the circuit to generator and closing the circuit from battery to motor.

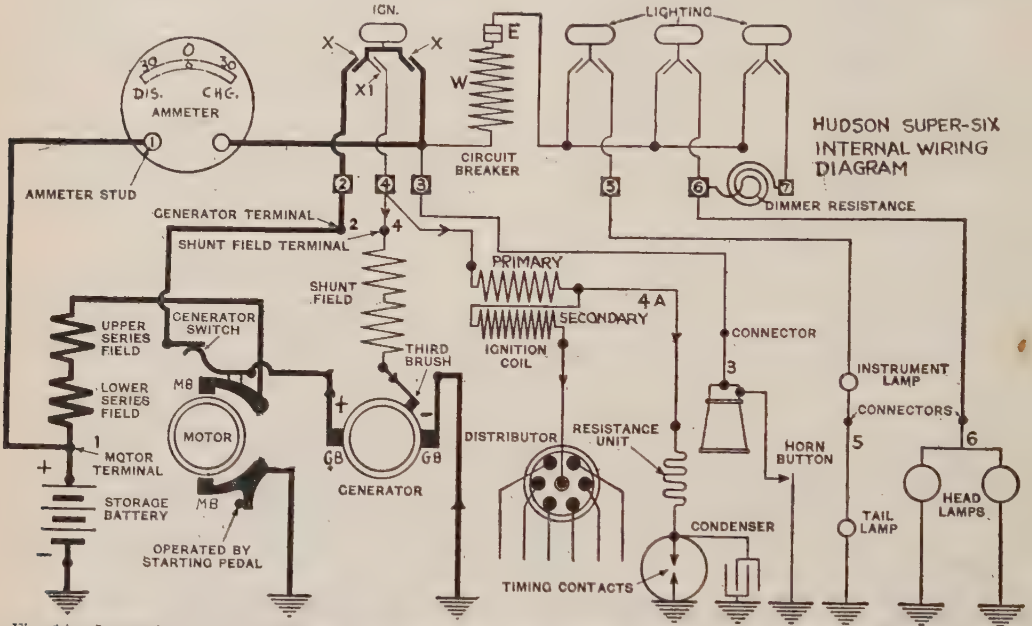

Fig. 14. Internal circuits of the Delco Electric system on the Hudson "Super-Six," models "H" and "J." The wiring is a single-wire, or grounded-return system.

The raising and lowering of the motor brushes, therefore, functions like a switch, i.e., when the brushes are in contact with the commutator, the circuit is closed; when they are raised away from the commutator the circuit is opened. Thus a starting switch is not used.

The motor circuit will then be from (+) of the battery, to motor terminal (1), through the series field winding of the motor, to the upper (+) brush, through the armature winding, to the lower motor brush, to ground, to (−) ground of the battery.

Generator Action

Now, let us assume that the engine starts. The starting pedal is released and the gears run out of mesh again. The plunger travels into place and lifts the motor brushes off the commutator, at the same time closing the contact at the generator switch. The generator circuits are complete again, and if the engine is driving the generator fast enough, current is being generated.

If, however, the generator is being driven by the engine at less than 300 r.p.m., the generator will "motor," as the pressure (voltage) from the batter is greater than from the generator at this slow speed Thus the battery current flows to the generato through the generator windings, as it did in th "motoring of the generator" operation, and th ammeter will show on the "discharge" side. A automatic cut-out could be used to prevent th battery from discharging in this manner through th generator windings at speeds lower than 300 r.p.m. but inasmuch as the current used is very slight (abou 3 or 4 amperes), and as the engine seldom runs a this low speed, the automatic cutout is eliminated

Generator clutch: When the engine is running a less than 300 r.p.m., the generator armature, a stated, turns as a "motor" and turns faster than it is being driven by the engine. Therefore a roller clutch, similar in action to the one described on page 324, and which is also similar in action to the free-wheel clutch on a bicycle, is used to allow the generator to over-run at speeds lower than 300 r.p.m., as explained above. This clutch also permits the armature to revolve when the ignition switch is first pulled out, as explained above under "Motoring the generator."

If the engine should be stalled or stopped without switching off the ignition button, a steady discharge from the storage battery of about 3 or 4 amperes would take place, causing the armature to revolve. Therefore the ignition button should be pushed in whenever the engine is not running.

Generator Charging Circuit

When the engine is revolving more than 300 r.p.m., the generator begins to generate current, and at higher speeds, sufficient voltage is generated to overcome the battery voltage and the generator sends current to the battery, as well as supplying current for ignition and lights.

The shunt-field circuit during the charging action is from (+) brush of the generator, to generator switch, to (2), to (**X**), to (**X1**), to (4), to third brush.

The main generator charging circuit is from (+) brush, to the generator switch, to (2), to (**X**), to a point above (3), to the ammeter, to (+) of the battery, to (−) of the battery, to ground, to the grounded (−) generator brush. The ammeter will now indicate on the "charge" side.

Generator Regulation

The regulation of the current (generator output) is obtained simply by varying the strength of the magnetic field, but this is brought about in a different manner to, and is an improvement over, the methods formerly used. By referring to Fig. 14, it will be seen that the lower end of the shunt field is connected to a "third brush" which is in contact with the generator commutator.

The strength of the magnetic field depends upon the amount of current flowing through the field windings, and this in turn depends upon the voltage (pressure) applied to the third brush.

This voltage depends upon two things: (1) the position of the brush on the commutator with relation to the other brushes, and (2) upon the speed of the armature.

The position of the brush on the commutator is set before leaving the factory, to give the best average charging rate, and must not be moved or interfered with as long as the charging rate is satisfactory.

If it becomes necessary to increase the charging rate, loosen the two screws by which the arm supporting the third brush is attached and move to the right (looking at the front end of the generator). A small movement makes a considerable difference in the charging rate. Then tighten the screws.

It is highly important after moving the third brush to sand it carefully down, so as to fit the commutator accurately, otherwise the generator will not deliver the full amount of current.[1]

If it becomes necessary at any time to decrease the charging rate, proceed exactly as outlined above, but move the brush to the left.

Third-Brush Effect of Generator Output

The third brush affects the generator output at varying speeds in the following way: **At low speeds** the voltage or pressure applied to the third brush is comparatively high; therefore a considerable amount of current will flow through the shunt field windings. This gives a strong magnetic field at low speeds, and the generator output will be good, considering the low speed. Increasing the speed under these conditions would increase the generator output too rapidly, and at high speeds there would be too much current produced. **With the increase in speed,** however, the voltage applied at the third brush decreases; consequently the magnetic field becomes weaker and the generator output is kept from becoming too great (see, also, pages 361, 408). In this way the generator output increases until a speed of about 20 to 24 miles per hour is reached. The current is then at a maximum which is arranged to take place at this speed, because experience has proved that this gives the best all-around results. **At still higher speeds,** the magnetic field becomes so weak that the output begins to diminish, thus preventing the storage battery from being charged at too high a rate.

The following table represents on an average the manner in which the charging rate should vary at different speeds.

Miles per Hour	Amperes
9	5
12	10
18	16
24	17
30	15
36	13
42	11

The Ignition System

The ignition system consists of a distributor, an ignition coil, a contact-breaker of the closed-circuit type, a condenser, and ignition resistance units—all fully explained under "Delco ignition systems."

The distributor-timer is driven by a vertical shaft and is located directly above the oil pump at the front end of the engine. On it is mounted the condenser and the resistance unit.

Timing the Ignition[1]

The cam which makes and breaks the contact points is adjustable. To move the cam it is necessary to loosen the screw in the center of the shaft. Before attempting to time the engine or ignition, see that the contact points are clean and set at a clearance of .018″, or the thickness of the gauge on the distributor wrench (in the tool kit) when on the highest point of the cam or at their widest opening.

Turn the engine over slowly with the hand crank until No. 1 cylinder is on compression stroke. To determine this, remove the other spark plugs and turn until you feel the resistance of compression. Turn the engine over very slowly until the pointer on the observation hole on the flywheel case is directly over the mark "A" which is stamped on the flywheel. See that the button on the rotor is directly under the contact in the distributor cap which leads to No. 1 cylinder spark plug. Loosen the set screw at the center of the cam and turn the cam until the contact points just start to separate. When checking the result, the cam should be held on tension in the opposite direction to rotation, and the back lash in the gears should then allow the points to start to separate when the cam is rocked back and forth. Then tighten the screw. Rub a very small quantity of vaseline on the track in the distributor cap, around which the contacts are spaced, and then rub off the free vaseline. Replace the rotor and distributor cap.

It is important to keep contact points clean and set at a clearance of .018″, or to the distributor wrench gauge. Use fine sandpaper for cleaning points. The small sandpaper disks used by dentists are excellent for this purpose.

Keep the distributor-cap track polished with vaseline. (Use sparingly.) Do not allow oil or dirt to accumulate on the contact points.

The distributor cap and high-tension wires should always be clean and dry. The resistance unit should be kept clean and all connections tightened.

Ignition Circuits

The ignition circuits, as explained on page 389, give the circuit when battery supplies current.

When the generator supplies current for ignition, the circuit is from (2), to (**X**), to (**X1**), to (4), and it then follows same path as described on page 389.

Purpose of the Circuit-Breaker

This is a protective device to prevent excessive current from flowing through the lighting circuit in the event of a ground or short circuit developing in the line. In other words, it takes the place of fuses.

There are two types of Delco circuit-breakers: the "vibrating type" and the "locking type." The vibrating type is used on the Hudson, as shown in Fig. 14, the details of which are shown in Fig. 15.

Construction of the Delco "Vibrating-Type" Circuit-Breaker

The Delco vibrating circuit-breaker is shown in Figs. 14 and 15. The coil (W) is connected in series

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[1] The third brush must make good contact with the commutator at all times. To realize the importance of this, raise the third brush with the finger while the engine is running, and watch the hand on the ammeter go back to zero. The same thing applies to the two main brushes.

[1] Also applies to Hudson "Super-Six," model "O."

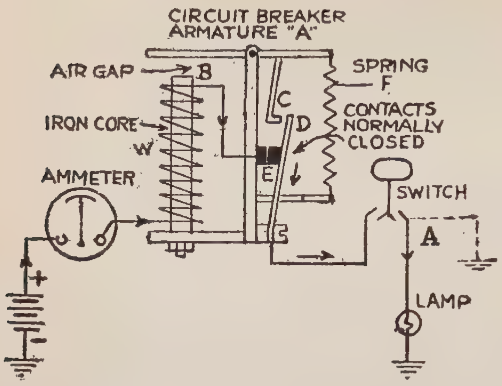

Fig. 15. Internal view of Delco vibrating type of circuit-breaker.

with the lighting circuit or other electric appliances. It consists of a single winding on a soft iron core.

It is set by adjustment of the air-gap, by spring (F) to carry a predetermined load of say 12 amperes, and the current passes through the winding (W), through points (E) which are normally closed, to the switch, to the lights, to ground, to battery ground. By the use of the circuit-breaker, fuses are eliminated from the circuits.

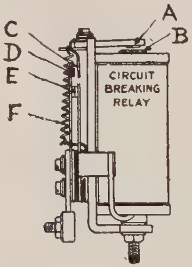

Fig. 15A. External view of Delco vibrating type of circuit-breaker.

If a short circuit occurs in the wiring, this would draw a greatly increased amount of current, and at from 27 to 30 amperes, the wire coil (W) becomes so strongly magnetized that the armature (A) is drawn to the core, thus causing arm (C) to push blade (D), separating points (E). The moment this occurs the circuit is broken; therefore contact will be made again, and again separated. Thus an action similar to a vibrating coil takes place, and the armature vibrates back and forth, but consuming only about 5 to 7 amperes. The vibrating action is kept up until the ground or short circuit is removed.

Note the point (A) (Fig. 15) in the circuit between the switch and the lamp. Should a ground occur at this point, the heavy flow of current would cause the circuit-breaker to operate.

When the vibrating type of circuit-breaker is used, it is mounted on the back of the combination switch.

Delco "Lock-Out Type" of Circuit-Breaker

Another type of Delco circuit-breaker is called the "lock-out" circuit-breaker. It is of similar construction, except that it has an additional fine wire voltage winding around the same core, the ends of which are connected across the contacts. When an overload occurs, as from a short-circuit or ground, the armature (A) (Fig. 15) is pulled down against the core, thus opening the circuit as in the vibrating type. The magnetism flowing through the fine wire winding will hold the armature (A) against the core and prevent it from vibrating. This limits the flow of current through the lock-out circuit-breaker to a small fraction of an ampere. The internal circuit of the lock-out type of circuit-breaker is shown in the wiring diagrams of Lafayette, Marmon, and Cadillac. See Index under "Wiring diagrams."

A double circuit-breaker is used on several cars, such as the Cadillac, Lincoln, and Lafayette, and is mounted in a single housing. One of these is the **vibrating** type and the other the **locking** type.

The vibrating type of circuit-breaker is used with the main lights, which are more frequently used. The locking, or lock-out type of circuit-breaker is used in connection with the tonneau lights, dome lights, and horn, as grounds are more likely to occur.

The ignition current in some cases is also taken through the vibrating type of circuit-breaker.

Delco Circuit-Breaker Pointers

If any part of the lighting circuit becomes grounded without first of all passing through the lamps, a heavy flow of current far in excess of the normal amount will take place. This heavy current magnetizes the iron core of the circuit-breaker so strongly that it attracts the small piece of iron called the armature, thus separating the contact points. This momentarily cuts off the flow of current, which in turn allows the contacts (E) to close again, and the operation is repeated, causing the circuit-breaker to give out a clicking sound.

The circuit-breaker thus not only gives warning of a ground in the lighting circuit, but also prevents injury to the wiring by permitting only from about 5 to 7 amperes to flow through it when vibrating.

When the circuit-breaker vibrates, push in the three lighting buttons. If the breaker continues to vibrate, the trouble should be looked for in the switch. If the breaker stops vibrating when the three lighting buttons are pushed in, pull them out one at a time and observe which one causes it to commence vibrating. The ground or short circuit must be in this line. The trouble may be located more accurately by disconnecting the wires at the junction block at the lower left-hand side of the dash. If the circuit-breaker continues to vibrate when these wires are removed, the ground must be in the wiring between the switch and the junction block; but if it stops vibrating, the trouble must be in the wiring between the junction block and the lights.

By testing each wire individually, the exact circuit wherein the trouble exists may be located.

In case the circuit-breaker vibrates repeatedly, do not attempt to increase the tension of the springs, as the vibration is an indication of a ground in the system. Remove the ground, and the vibration will stop.

Lights

Let us return to the point above switch terminal No. 3 (Fig. 14), where the line divides. The line going to the right leads to the circuit-breaker. After passing through the circuit-breaker winding, represented by the zig-zag lines and contact points, connection is made from this point to each of the three lighting contacts. The operation of each of the three lighting buttons will now be described.

Dash and Tail-Light Circuit

When the lighting button nearest to the ignition button is pulled out, the dash and tail-light circuit is completed, and the current passes out through terminal No. 5, then to the dash lamp socket, and through the lamp filament.

A wire leads from this lamp to terminal No. 5 of the junction block on the dash, and from there a wire leads to the tail lamp. After the current passes through the tail lamp, it goes to ground, i.e., the frame of car. Thus the lamps are "in series," and the current has to pass through both bulbs before it reaches ground. It follows, therefore, that if the filament of either lamp burns out or the line is broken or ground disconnected, both lamps will go out. The wiring is arranged thus to warn the driver when the tail light is out.

Headlights (Bright) Circuit

When the center one of the three lighting buttons is pulled out, the headlight circuit is completed and current passes out through terminal No. 6 to terminal No. 6 of the junction block on the dash, and from there a wire leads to the front cross member of the frame, where it branches out immediately back of the radiator. One branch wire feeds the right-hand headlight, the other the left. After the current passes through the lamp bulb, it goes to ground. Since both lamps are fed from branches of the same wire, they are "in parallel."

Therefore if one bulb burns out, the other circuit is still intact, and the lamp on that side will continue to burn.

Headlights (Dim) Circuit

When the end lighting button is pulled out, the headlight circuit is completed, but instead of the current passing directly out through terminal (6), it first of all passes to (7), through the dimmer resistance. This is a coil of wire that has the effect of choking the current supplied to the headlights, and they do not burn so brightly, nor do they consume so much current.

If the headlights are operating "dim," it is unnecessary to depress the "dim" button in order to get them to operate at full candle power. Simply pull out the second button. This operation cuts out the resistance, because the current takes the easier path. If the second button is again depressed, the lights will operate "dim," as the current then passes through the resistance.

The Junction Block

The junction block is located on the engine side of the dash, near the left-hand side frame. It provides a handy means of disconnecting the lighting connections in case of trouble on any particular line, or when removing the body. For instance, if the circuit-breaker commences to vibrate or click when any of the lighting switches are pulled out (indicating a ground), it is obvious that any of the junction-block connections can be reached quickly and the wires can be disconnected one at a time till the faulty line is discovered.

Storage Battery

The storage battery is a three-cell, six-volt battery. The (−) battery terminal, as well as the (−) generator brush is grounded.

Never run the generator with the storage battery disconnected from the car. This is a "constant-current" system, as explained on page 346.

Ammeter Readings

Ammeter readings during cranking operation: During the cranking operation the ammeter will show a "discharge." This is the current that is used both in the shunt-field winding and the ignition current. The ignition current being an intermittent current of comparatively low frequency, it will cause the ammeter to vibrate during the cranking operation. If the lights are on, the meter will show a heavier discharge.

The main cranking current is not conducted through the ammeter, as this is a very heavy current and it would be impossible to conduct this heavy current through the ammeter and still have an ammeter that is sensitive enough to indicate accurately the charging current and the current for lights and ignition.

When the generator is charging the battery, the ammeter needle will be on the "charge" side of the scale.

DELCO MOTOR-GENERATORS (1921) THIRD-BRUSH REGULATED

Delco motor-generators and electric systems installed on the 1921 Buick and McLaughlin are shown in Fig. 1; on the Cadillac, in Fig. 3; on the Hudson, in Fig. 5; on the Lafayette, in Fig. 7; on the Lincoln, in Fig. 9. Wiring diagrams and the various circuits of each are also shown.

Each of the cars mentioned use a Delco motor and generator as a single unit, termed a "motor-generator."

There are two windings in the field and armature, one set for operation as a generator and one set when used as a motor to crank the engine. The generator armature winding and its commutator, together with the generator winding in the field coil, are connected in the circuit at all times when the ignition switch is "on," except when the starting pedal is depressed. There is no electrical connection between the motor and the generator windings on the armature. Third-brush regulation is used on all.

When the motor-generator is used to crank the engine, the motor windings are brought into use, and it operates as a series-wound motor. These windings are not in circuit with the battery until the motor brush, or brushes, make contact with the commutator by the action of the starting pedal.

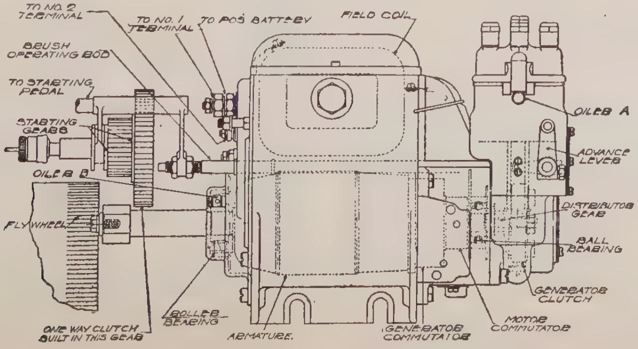

Fig. 1. Delco motor-generator used on the Buick and McLaughlin (1921).

When cranking the engine, the motor-generator drives the flywheel through a pair of sliding gears which are at the rear of the motor-generator and controlled by the starting pedal. An over-running clutch is built in the hub of these gears, so that the flywheel will not drive the generator through the starter gears after the engine starts running under its own power, and before the starter pedal is released.

The driver should make a practice of releasing the starter pedal as soon as possible after the engine has started running so as to insure long life and usefulness of the lubricant within the clutch.

When the engine is operating at slow speeds, the generator voltage is not sufficient to provide current for lighting or ignition. At such times the battery is the source of current. At low engine speeds also, current may flow from the battery through the generator windings and cause the armature to revolve faster than the engine drives it. Under this condition the over-running generator clutch at the forward end of the motor-generator permits the armature to revolve faster than the driving shaft, and makes a clicking noise.

During the time that the engine is driving the armature, the circuit between the generator winding and the storage battery is completed, allowing current from the generator to charge the storage battery and supply current directly for lights and ignition.

During the cranking operation, the generator circuit is interrupted by having one of the generator brushes raised off the commutator in the Buick model. The upper generator brush on the Buick type of motor-generator is raised.

A very great reduction in engine cranking speed will be the result if the generator circuit is not opened during cranking by the above method.

It may happen, through accident or otherwise, that the brush-lifting mechanism is bent in such a way that it fails to operate the generator brush as just described. Care should be exercised, in renewing the upper generator brush, to obtain one of the proper length. If too long, the brush-lifting mechanism may not function properly.

In the motor-generator applied on Cadillac and Hudson cars, this feature of opening the generator circuit during cranking is taken care of by a set of contacts in the rear end of the motor-generator housing, known as the generator switch and operated through the action of one of the motor brushes.

During the cranking operation the electrical current flows from the storage battery through the motor windings, causing the armature to rotate. The closing of this circuit is effected by the upper motor brush in the Buick model, and by both upper and lower motor brushes in the Cadillac and Hudson models. These are operated by the starting pedal.

The motor-generator performs three different operations, which are as follows:

1. **Motoring the generator:** This operation is necessary in order that the starting gears may be brought into mesh with the small gear on the armature shaft, and with the teeth on the fly-wheel. This takes place whenever the "ignition" switch lever is turned to position marked "on." This completes the circuit from the storage battery to the generator windings, and permits current to flow from the storage battery through the shunt-field coil and the generator windings on the armature, thus causing the armature to revolve slowly.

In meshing these gears, if difficulty is encountered, do not try to force them, but simply allow the starting pedal to come back, giving the gears time to change their relative positions.

The clicking sound heard during the motoring of the generator is caused by the over-running of the generator clutch in the forward end of the motor-generator. The "M.G. 82" used on 1918 Hudson cars was equipped with a smooth clutch. The motoring of the generator is one of the most important operations for the mechanic to familiarize himself with, as the same wiring and parts of the generator are used during this operation as when generating. Therefore, if this operation is performed properly, it is sure to generate when driven by the engine.

2. **Cranking operation:** The cranking operation is performed when the starting gears are brought fully in mesh and when the motor brush or brushes make contact with the commutator. It is arranged that the starting gears are properly meshed before the motor brush, or brushes, make contact on the commutator. The cranking operation requires a heavy discharge from the storage battery. There must be no loose connections in this circuit. All the battery connections, together with the ground-strap connections, the motor connections, and motor brushes must make good electrical contact.

3. **Generating electrical energy:** After the cranking operation is completed, the starting pedal is returned by a spring. This disconnects the starting gears, breaks the motor circuit, by raising the motor brush or brushes, and completes the generating circuit either through the generator switch, or, in the Buick model, by lowering the upper generator brush.

At car speeds of from five to seven miles per hour, the generator is generating a voltage sufficient to prevent current discharging from the battery through the generator windings. At higher speeds a part of the current generated is used directly for ignition and lighting purposes, while the remainder of the current is used to charge the storage battery.

The ignition distributor is located on the forward end of the motor-generator on the Buick models, and is for the purpose of properly timing and distributing the ignition current. Separate distributor units are installed on Cadillac and Hudson models, and are driven from the timing gears. See the instruction on "Ignition."

The operation of the distributor on the Buick car in no way affects the motor-generator, it being located in this manner simply as a convenient method of mounting and driving.

DELCO ELECTRIC SYSTEM ON THE BUICK (1921)

Generator field circuit: From (+) main brush, to (2) (Fig. 2), to (3), to (F), to the generator shunt-field winding, to third (−) brush (3B).

Generator charging circuit: From (+) main brush, to (2), to (1), to the ammeter, to (+) battery, to (−) ground of the battery (GB), to (−) ground of the generator (GG), to the (−) generator, main brush.

Ignition primary circuit: From (1) on the combination switch, if the current is from the battery as when starting, or from (2), if the current is from the generator after the engine is running, thence to (3), to the ignition resistance unit on the coil, to primary winding (PRY), to contact-breaker points (P), to ground, to (−) of battery or (−) of generator.

Starting motor circuit: From (+) of the battery, through the motor-series field coil, to the (+) motor brush, through the armature, to the (−) grounded brush, to (GM), to the (−) grounded battery terminal (GB).

Motoring generator field circuit: When first depressing the starting pedal, the generator is "motored," and current flows from (+) of the battery, through the ammeter, to (1), to (3), to (F), to (3B) for the shunt-field circuit. For this about 5 amperes are required. This makes it easy for the gears to mesh, as the generator armature turns over slowly.

The armature circuit, during the motoring operation of generator, is from (+) of the battery, through the ammeter to (1), to (2), to (A), to (+) brush, to the armature, to the (−) grounded brush, to (GG), to (GB).

As the starting pedal is depressed still more, the (+) motor brush is lowered to the commutator and the generator brush (A) is lifted; the series field of the motor and the armature winding of the motor receive the full current from the battery, and the engine is started through the starting motor circuit as first explained.

When the engine starts, and the starting pedal is released, the gears to the flywheel are thrown out of mesh, the (+) motor brush is raised, the generator brush (A) is lowered, and the generator begins to generate current at over 300 r.p.m. Thereupon the circuit is as explained under "generator circuit."

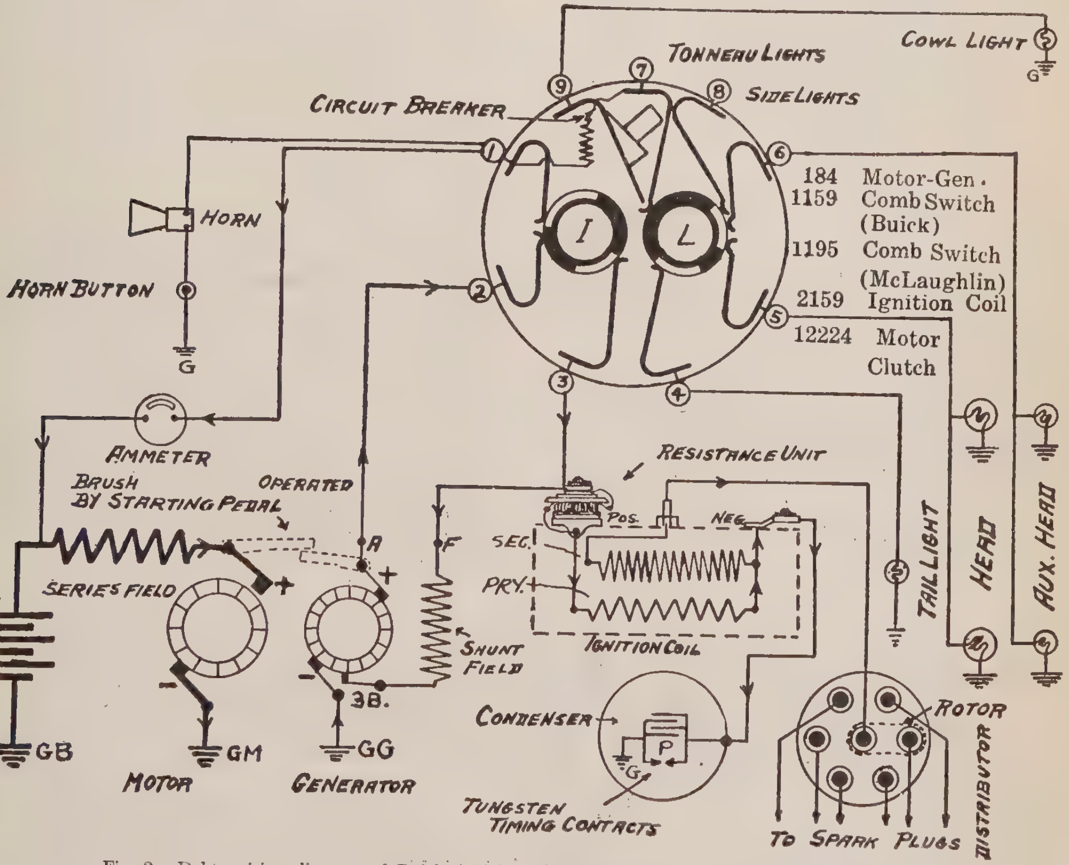

Fig. 2. Delco wiring diagram of Buick (1921), series 21; models 44 and 50, and also McLaughlin.

DELCO ELECTRIC SYSTEM ON THE CADILLAC TYPE 59 (1921)

The Delco motor-generator (Fig. 3) is used on the Cadillac. The regulation is by means of a third brush. It is therefore a constant-current-regulated generator of a 6-volt system.

A thermostatically controlled protective device operates in case of excessive charging current, to protect the generator from over-heating and the battery from over-charging. Provision is made for mounting the device on the third-brush arm in such a position that it may readily be influenced by radiated generator heat.

The thermostat consists essentially of a coil of resistance wire and a set of contacts. The blade holding one of the contact points is made from a piece of bi-metal—a strip of brass welded to a strip of nickel steel—a combination which warps at its free end when heated, owing to the greater expansion of the brass side. The contacts, normally closed, are caused to separate at a temperature of 195°-200° F. within the generator. Thus the field current which passed through the contacts is shunted through a resistance. The direct-field circuit is restored as soon as the temperature has again become normal.

No attention need be given to the thermostat, and its operation, which is accomplished by a sudden drop of 50 per cent in the ammeter reading, should cause no concern.

Motor-generators used on the Cadillac, Lafayette, Lincoln, and Wills cars, each have four field coils, two of them being shunt coils and two series coils. Each pair of coils is mounted opposite in the frame. Thus it operates as a four-pole shunt generator, although field windings are used on two poles only, the other two acting as consequent poles.

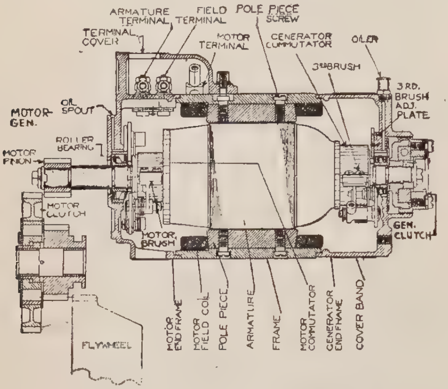

Fig. 3. Side sectional view of the Delco-Cadillac motor-generator.

Cranking operation: When the starting gears are meshed, the motor brush or brushes make contact with the commutator. Note that the motor brushes **take the place of a starting switch.**

Generating current: After the cranking operation is completed, the starting pedal is returned by the spring. This disconnects the gears, breaks the motor circuit by raising motor brushes, and completes the generating circuit through the generator switch.

These operations can be clearly understood by referring to the diagram (Fig. 4) and the illustration (Fig. 3).

Cadillac-Delco Circuits

Generator field circuit: From the (+) third brush (Fig. 4), through the thermostat points, to the shunt-field windings, to (8), to (6), to the (—) generator brush. When the thermostat points are open, resistance (**R**) is automatically cut into the shunt-field circuit.

Generator charging circuit: From the (+) grounded main brush (**G1**), to the (+) grounded battery, to the ammeter, to (5), to (6), to the generator switch (**A**), to minus (—) of the main brush.

Ignition primary circuit: From (+) ground of the battery, or the generator after it is running fast enough to charge the battery, to ground (**G**) of the contact-breaker points (note the two points in multiple), through the ignition resistance unit, through the coil primary winding (**P**), to (7) on the combination switch to (6) if the generator is supplying current, to the generator switch (**A**), to the (—) generator brush. If the battery is supplying the current, then to (5), to the ammeter, to the (—) terminal of the battery.

Starting motor circuit: From (+) ground of the battery, to the (+) grounded brushes (**G2**), which are lowered to the commutator by movement of the starting pedal which shifts the gear in mesh with the flywheel gear and at the same time opens the generator circuit at generator switch (**A**), then through the armature, to (—) brushes, through the series-multiple field windings, to the (—) terminal of the battery. Thus the action of the motor brushes serves as a starting switch. After the engine is started and the starting pedal is released, the motor brushes are again raised and consequently generator switch (**A**) is closed by this action.

The vibrating and locking circuit-breaker is made use of in the manner described and explained on page 392.

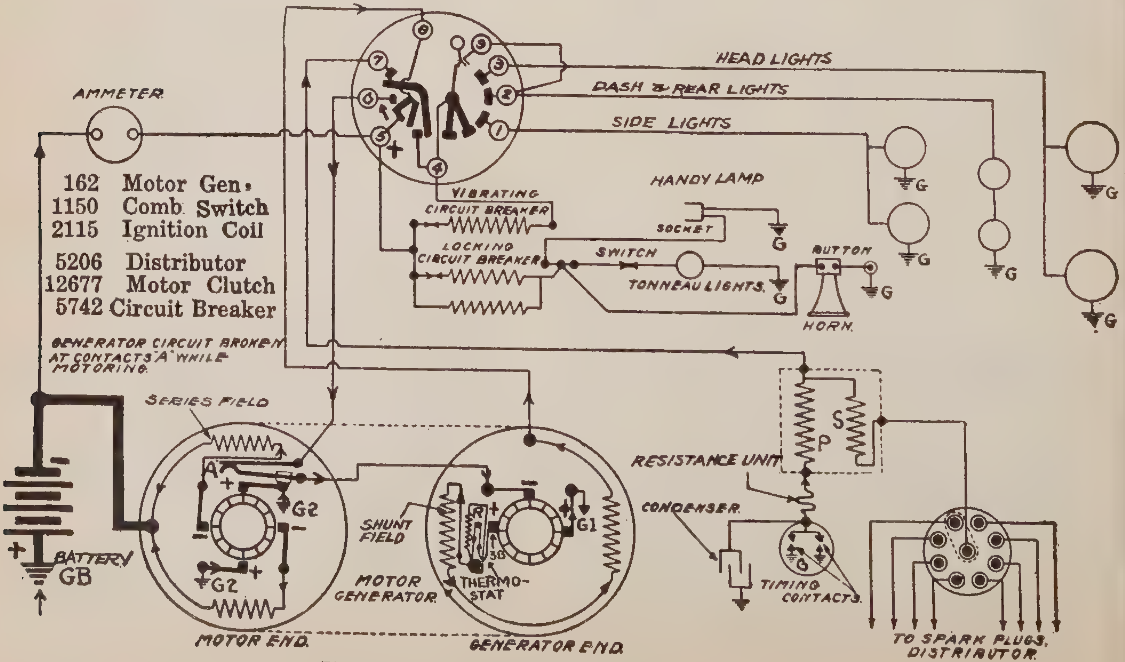

Fig. 4. Delco wiring diagram of Cadillac type 59 (1921).

DELCO ELECTRIC SYSTEM ON THE HUDSON MODEL "O" (1921)

The Delco motor-generator used on the Hudson "Super-Six," model "O," is shown in Fig. 5, and the explanation given on page 393 will serve in this case also.

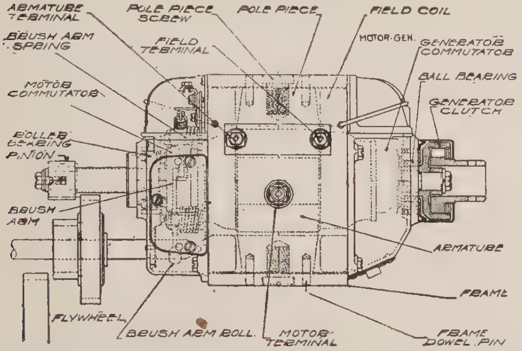

Fig. 5. Side sectional view of the Delco-Hudson model "O" motor-generator.

This is a two-pole machine with a single armature having a separate generator and motor windings connected to separate commutators. Above the armature is a motor series coil and a generator shunt-field coil. Below the armature is a series-field motor coil and a shunt-field generator coil.

Hudson-Delco Circuits

Starting motor: From (+) of the battery (Fig. 6), to the motor-series field coils, to the motor (+) brush, through the armature, to the (–) brush, to ground, to (GB) ground of the battery. The motor brushes are lowered by starting the pedal when the gears are shifted to mesh with the flywheel. At the same time, generator switch (A) is opened. Thus the action of the brushes serves as a starting switch. When the engine starts, and the starting pedal is released, the motor brushes are raised and generator switch (**A**) is closed.

Generator shunt-field circuit: From the (+) brush of the generator, to (2) on switch, to (3), to the generator shunt-field winding, to the third brush.

Generator charging circuit: From the (+) brush, to the generator switch (**A**), to (2), to (1), to the ammeter, to (+) of the battery, to the (–) battery ground (**GB**), to the (–) ground of the generator (**GG**).

Primary ignition circuit: From (1) on the combination switch, if from the battery, or from (2) if from the generator, to (3), to the coil primary winding (**P**), to the ignition resistance unit (**R**), to the contact-breaker points (**P**), to ground, to the (–) ground of the battery or to the minus ground of the generator.

Secondary ignition circuit: From secondary winding (**S**) of the coil, to the distributor, to the spark plugs, to ground, to ground of the battery or generator, to the other end of (**S**).

The circuit-breaker used in this model is of the vibrating type.

The following will assist in tracing the different circuits. To trace, **start** with the part mentioned in brackets: starting-motor circuit [+ of battery]; generator shunt field circuit [+ main brush of generator]; generator charging circuit [+ main brush of generator]; primary ignition circuit [start with 1 on switch if from battery, or 2 if from generator]; secondary ignition circuit [secondary winding S of ignition coil].

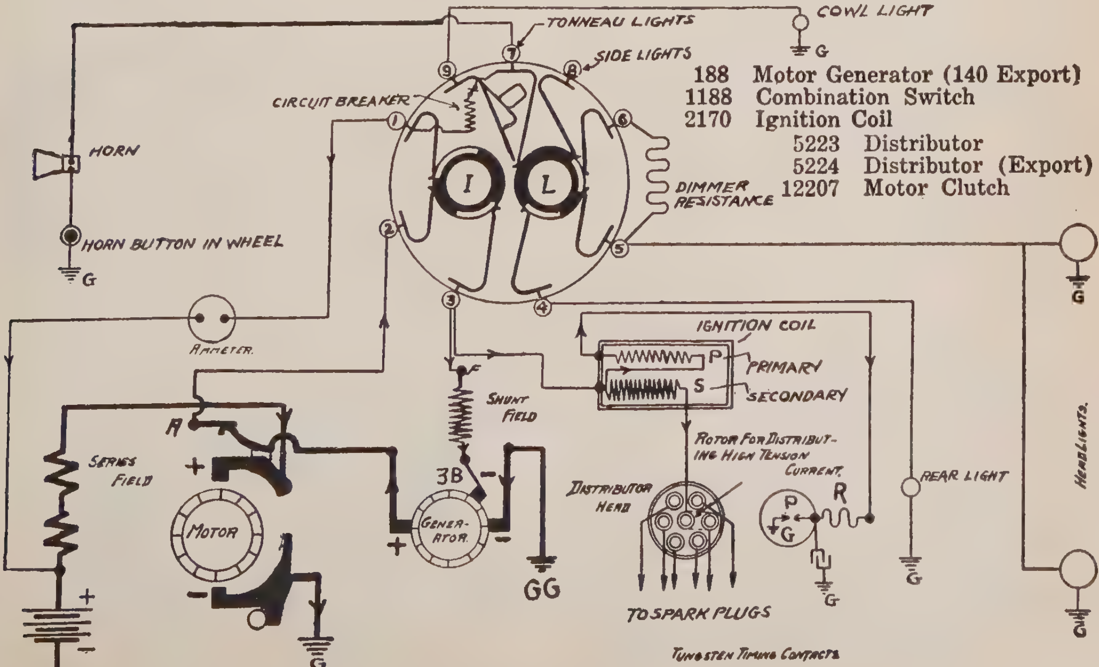

Fig. 6. Delco-Hudson model "O" wiring diagram (1921).

DELCO ELECTRIC SYSTEM ON THE LAFAYETTE (1921)

The **Delco motor-generator** used on this car is explained on pages 393 and 394. An illustration of this is shown in Fig. 7.

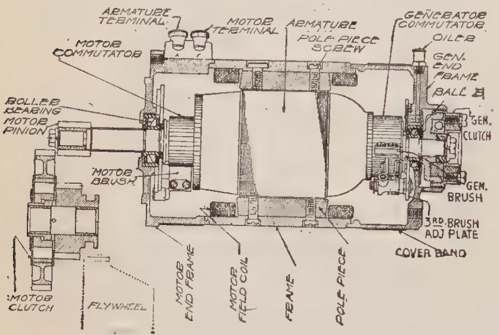

Fig. 7. Side sectional view of the Delco-Lafayette (1921) motor-generator.

Lafayette-Delco Circuits

Starting motor: From the (+) grounded battery terminal (Fig. 8), to the (+) grounded brushes of the motor, through the armature, to the (—) brushes, to the series-parallel field windings, to the (—) terminal of the battery. The motor brushes are lowered to the commutator by the action of the starting pedal, which thus serves as a starting switch.

Generator field-circuit: From the (+) third brush, through thermostat (T), to shunt-field coils, to (8) on switch, to (6), to (—) generator brush.

Generator charging circuit: From (+) grounded generator brushes, to (+) grounded battery terminal, to ammeter, to (5) on combination switch, to (6), to generator switch (A), to (—) main brush.

Primary ignition circuit: From the (+) ground of the battery, or generator, to ground (G) of the contact-breaker, through the resistance unit, to primary coil winding (P), to (7), to (6), if the current is from the generator, back to the (—) brush of the generator, or to (5), if from the battery, to the (—) battery terminal.

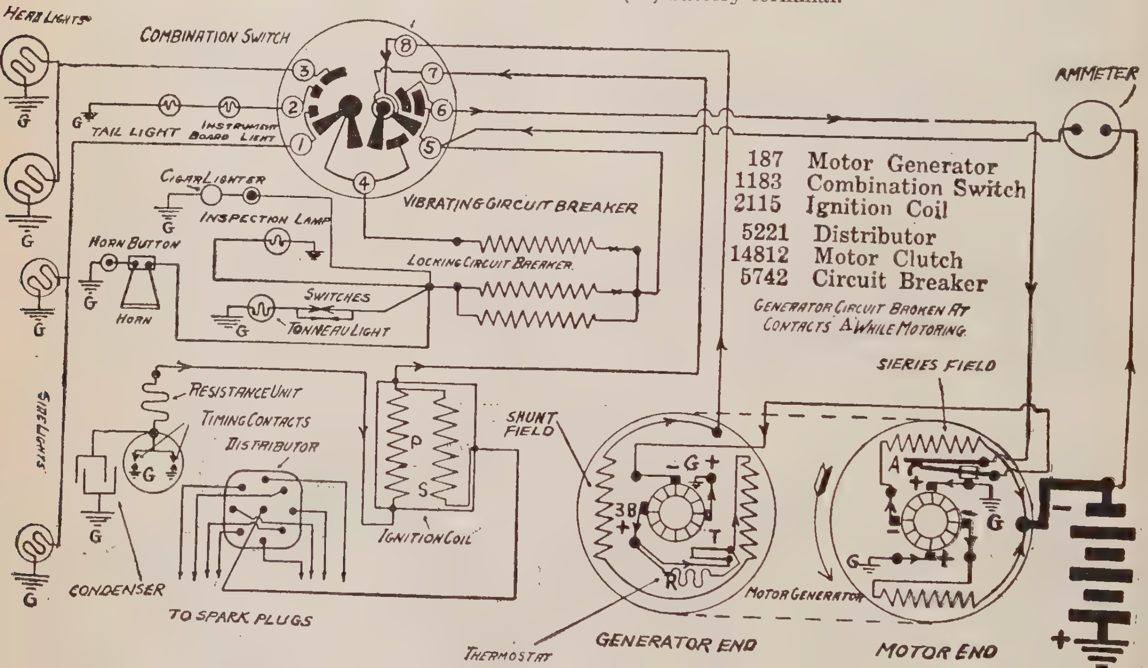

Fig. 8. Delco-Lafayette (1921) wiring diagram.

DELCO ELECTRIC SYSTEM ON THE LINCOLN (1921)

The **Delco motor-generator** used on the Lincoln is shown in Fig. 9; its principle is explained on pages 393 and 394.

Lincoln-Delco Circuits

Starting motor: From the (+) battery terminal (Fig. 10), to the series parallel fields, to the (+) brushes which are lowered to the commutator when the starting pedal shifts the gears into mesh with the flywheel through the armature, to (—) brushes (G) which are lowered by the same action, to (—) ground of the battery. Thus the action of the motor brushes serves as a switch. The generator switch (A) is opened when the brushes are lowered and closed when the starting pedal is released and the motor brushes are raised.

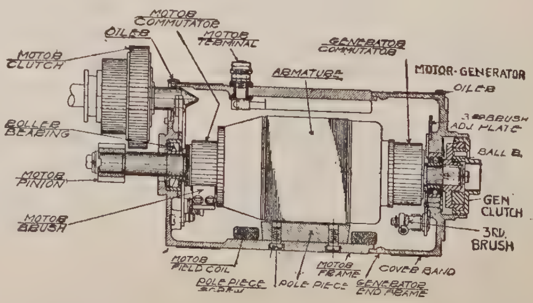

Fig. 9. Side sectional view of the Delco-Lincoln (1921) motor-generator.

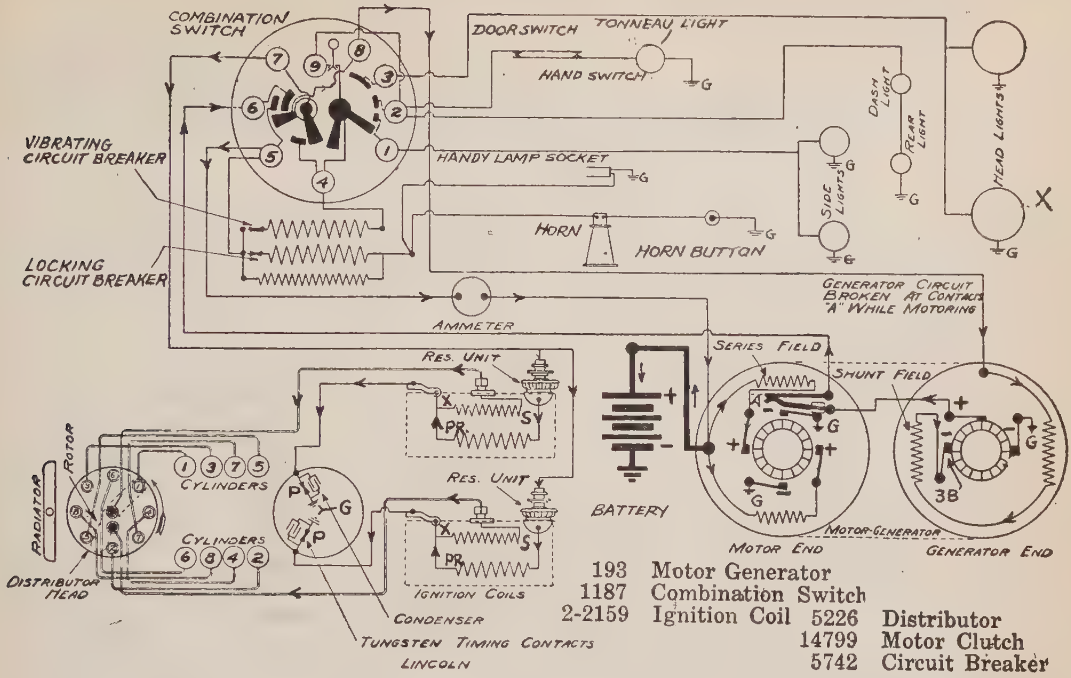

Fig. 10. Delco-Lincoln (1921) wiring diagram.

Generator shunt-field circuit: From (+) brush, to and through switch (**A**), to (6) on combination switch, to (8), to generator shunt-field windings, to (−) third-brush.

Generator charging circuit: From (+) brush, to generator switch (**A**), to (6), to (5), to ammeter, to (+) battery terminal, to (−) battery terminal, to (−) grounded main generator brush.

Primary ignition circuit: From (5) on the combination switch if the battery is supplying current, or from (6), if current is from the generator, then to (7), to the ignition resistance unit on the ignition coils, connected in multiple, to primary windings (**PR**), to contact-breaker points (**P**), to ground (**G**), to the (−) ground of the battery or generator. For details see Index under "Lincoln distributor and contact-breaker."

Secondary ignition circuit: From secondary windings (**S**), to the distributor, to the spark plugs on the right and left cylinder blocks, to ground, to the ground of the battery or generator, back to the primary windings of the coils, to (**X**), where the secondary joins the primary.

A vibrating and locking type of circuit-breaker is used.

DELCO SEPARATE GENERATORS AND MOTORS (1921)—THIRD-BRUSH REGULATED GENERATORS USING CUT-OUTS

Examples of Delco separate generators and motors with third-brush regulated generators using cut-outs are given in the pages following, the Marmon 1921, model 34B, H.C.S. 1921, Moon 1921, Westcott 1921, and Pierce-Arrow series 32, being selected for the purpose. The last-mentioned uses an electromagnetic principle of regulation in addition to the third brush.

MARMON 1921 MODEL, "34B"

The Delco electric system is used, consisting of a separate four-pole starting motor with a Bendix drive and field windings connected in multiple-series.

The generator is a four-pole generator, third-brush regulated, constant-current type, with the ignition unit attached to the generator, and it is thus a "two-unit" system.

A cut-out is used as shown in Fig. 12, mounted on the drive end of the generator.

Starting circuit: When the starting switch is depressed, the starting circuit is from (+) ground of terminal (**GB**) of the battery (Fig. 11), through the (+) grounded brushes (**G**), through the armature, through the (−) brushes, through fields, through starting switch to (−) terminal of battery.

The generator (Fig. 12) consists of a four-pole shunt-wound, third-brush-regulated constant-current generator which is separate and distinct from the motor. See also the wiring diagram.

The generator shunt-field circuit is from the third brush (+) through the four field windings, to the (−) main brush, through the armature coils, back to the third brush.

The cut-out[1] is placed on the top of the generator (Fig. 12), at the commutator end of the generator.

Cut-out voltage winding: After starting the engine, current from the generator (+) main brush passes from the (+) grounded main brush (**G1**),

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[1] Adjustment of this cut-out is shown elsewhere. See Index under "Adjusting Delco cut-out."

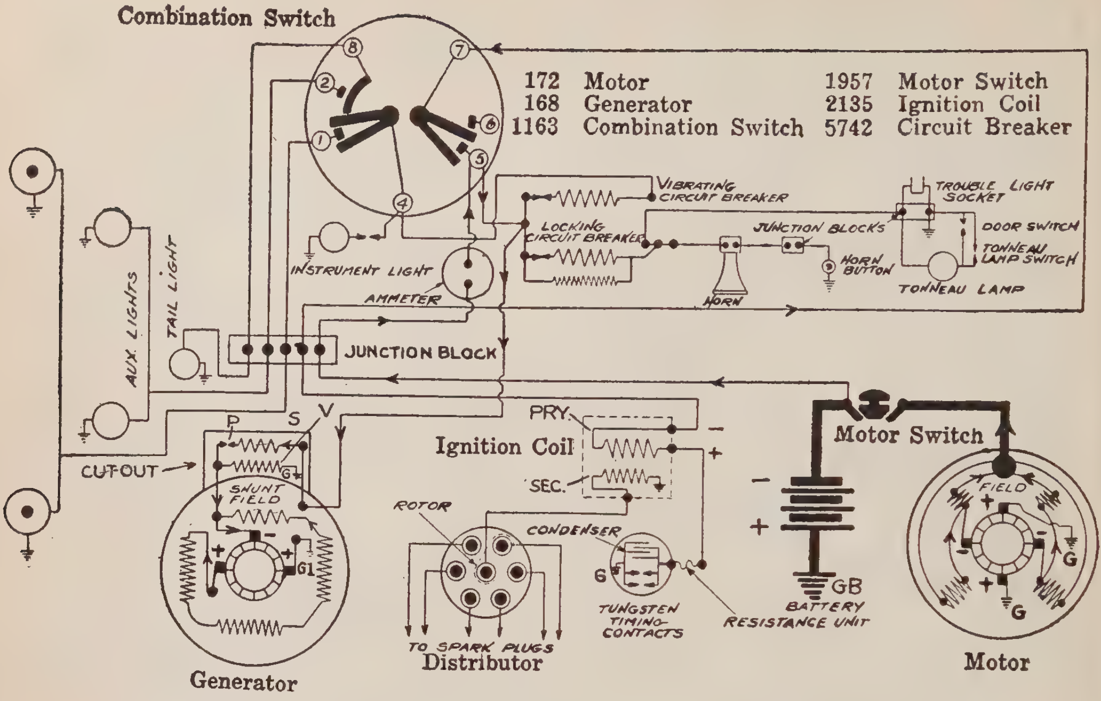

Fig. 11. Delco-Marmon model "34-B" wiring diagram. Note that the generator and motor are separate.

through the grounded end of voltage (V) fine wire winding (G) of the cut-out, to the (−) main brush of the generator. When the speed of the generator increases to where the generator voltage reaches 7 to 8 volts, the silver cut-out points (P) close.

Charging circuit: When cut-out points (P) close, the charging circuit is then from the grounded end of the (+) main brush (G1) of the generator, to the (+) grounded terminal of the battery (GB), through the battery, through the ammeter, to the switch terminal (5), to the cut-out current winding (S), through the cut-out points (P), to the (−) main brush of the generator.

When the generator speed decreases to where the generator voltage is less than the battery voltage, then cut-out points (P) should open. Just before doing so, however, the battery discharges back through the current coil (S) of the cut-out in a reverse direction, in order to demagnetize the iron core on which this winding is wrapped. This amount of current which passes in reverse direction from the battery should not be over 2 amperes.

Ignition: The interrupter and distributor and ignition coil are mounted on rear end of generator (Fig. 12). The distributor shaft is driven at half engine speed by spiral gears from the armature shaft.

An automatic governor spark-advance mechanism is incorporated in the vertical shaft.

Interrupter: Two sets of contact-breaker points are connected in parallel (see wiring diagram), and are separated at the same time by one cam with lobes opposite each other (see also page 214). The adjustment screw in center of cam is for timing.

The condenser, connected across both points, and is mounted on outside of distributor-timer housing.

For timing the ignition and adjusting the contact-breaker points see page 220.

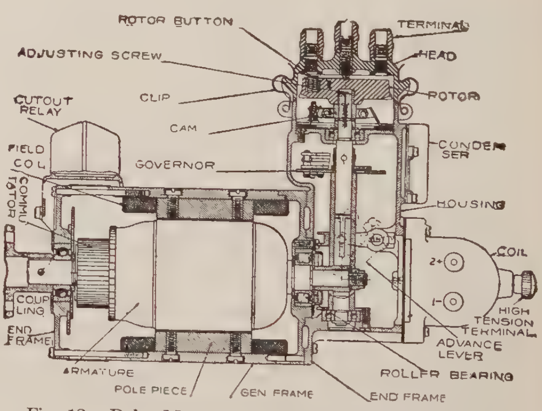

Fig. 12. Delco-Marmon (model "34-B") generator with ignition unit and cut-out mounted on the generator.

The ignition circuit (see wiring diagram) is from the grounded (+) terminal of the battery, through the grounded contact points on the left side of the contact-breaker at (G), through the resistance unit, through the primary winding (**PRY**) of the ignition coil, through the junction block, through the switch terminal (7), through the switch blade, through the ammeter, back to the battery (−) terminal.

If the generator is supplying the current, the circuit is from (5) to and through the cut-out series coil, to the (−) main generator brush.

The ignition resistance unit is connected in series with the primary winding and prevents excessive discharge from the storage battery when the engine is not operating and the ignition switch is turned "on." It also causes the spark to be more nearly uniform at all speeds of the engine (see explanation, page 198).

DELCO ELECTRIC SYSTEM ON THE H.C.S. (1921-22) AND MOON "6-68" (1921)

"H.C.S." stands for Harry C. Stutz. The generator and motor are each separate units on this car.

The generator is of the round type with a cut-out mounted on the generator similar to that of the Marmon. The third-brush regulation is used.

H.C.S.-Delco Circuits

Starting motor: From (+) of the battery to the starting switch, to the series-parallel field windings of the starting motor, to the (+) brushes, to the (−) brushes, to ground, to the (−) ground of the battery. The Bendix drive is used.

Generator shunt-field circuit: From the (+) main brush, to the shunt-field windings, to the third brush.

Cut-out voltage circuit:[1] From the (+) main brush, to cut-out voltage coil winding (V), to ground (G), to the grounded (−) main brush of the generator (G).

Generator charging circuit: From the (+) brush, to the cut-out points (P closed), to the cut-out series winding (S), to (5) on the switch, to the ammeter, to the (+) terminal of the battery on combination, to (−) ground of the battery, to the (−) grounded main brush of the generator.

Primary ignition circuit: When starting, and the generator is operating at low speed, current for ignition is from the battery, as follows: From the (+) battery terminal, to the ammeter which shows slightly on the "discharge" side, to (5) on the switch, to (7), to primary winding (PRY), to the resistance unit on the contact-breaker (interrupter), through points (P), to ground (G), to (−) ground of the battery.

When the generator supplies current: From (5), to (7), and thence along the same path. The ammeter will then indicate the amount of current passing to the battery (on the "charge" side of the ammeter).

Secondary ignition circuit: From the secondary winding, to the distributor rotor, to the spark plugs, to ground, to ground of the generator, if it is supplying current, or to the battery ground if it is supplying current, to (5) on the switch, to (7), to the primary winding, to point (X) in the coil where the secondary joins the primary winding.

The circuit-breaker is placed between the source of electric supply at (5) on the switch and the lighting circuits, to (4), to 3, 2, 1, 8, and 9.

Timing Delco-Moon Ignition

1. Place the spark lever on the steering-wheel sector in fully retarded position.

2. Turn the engine over with the crank until No. 1 piston is just past top dead center on the flywheel at the end of the compression stroke.

3. Loosen the timing adjustment screw in the center of the distributor shaft and turn the breaker cam so that the rotor button will be in position under No. 1 terminal, with the distributor head properly located. Locate the breaker cam carefully in this position, so that when the slack in the distributor driving gears is rocked forward, the contacts will be just opened by the breaker cam, and so that when the slack in the gears is taken up by rocking backward the contacts will just close.

4. Tighten the adjustment screw securely, and replace the rotor and distributor head.

Note. **The Moon ignition resistance unit** is mounted on the coil instead of on the contact-breaker.

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[1] See page 409 for cut-out adjustments.

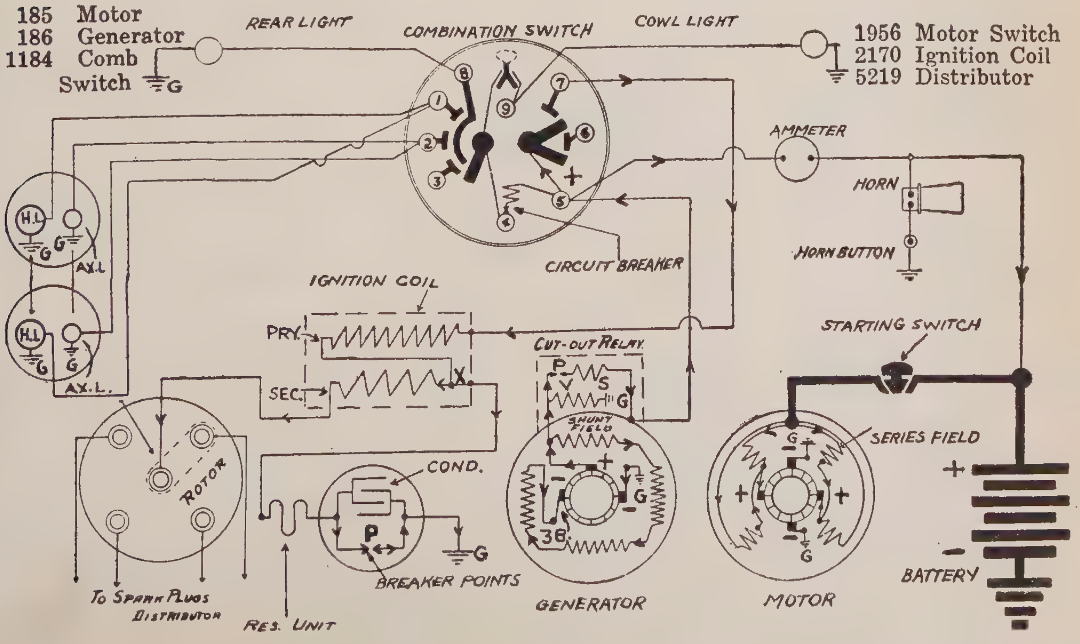


Fig. 13. Wiring diagram of Delco-H.C.S. (1921–22) electric system, using the Weidely "MB" engine. Note that the generator and motor are separate. On the first five-hundred cars the "headlights" were connected to No. 3 terminal on the switch.

DELCO-WESTCOTT ELECTRIC SYSTEM (1921)

The generator on Type "C-48" is mounted on the right-hand side of the engine, and on the Type "C-38" it is mounted on the left-hand side. It is so designed that it starts to generate at approximately seven miles per hour in high gear or at correspondingly lower speeds in low gear. The generator output is increased to speeds of 18 to 25 miles per hour. At higher speeds the charging rate decreases.

To adjust the charging rate, see directions given on pages 407 and 409.

Cut-out adjustments are effected as shown on pages 409 and 410.

The ignition distributor on the "C-48" is mounted on the right-hand side of the engine and is driven by the pump shaft, while on the "C-38" the distributor is mounted on the left-hand side. The distributor is equipped with both a manual and an automatic control.

Timing the Ignition (Types "C-48," "C-38")

1. Place the spark lever on the steering-wheel sector in fully retarded position.

2. Turn the engine over with the crank until No. 1 piston is 1⅜" past top dead center on the flywheel at the end of the compression stroke.

3. Loosen the timing adjusting screw in the center of the distributor shaft and turn the breaker cam so that the rotor button will be in the position under No. 1 high-tension terminal with the distributor head properly located. Locate the breaker cam carefully in this position, so that when the slack in the distributor driving gears is rocked forward the contacts will be just opened by the breaker cam; and when the slack in the gears is taken up by rocking backwards the contacts will just close.

4. Tighten the adjustment screw securely and replace the rotor and distributor head.

Westcott-Delco Circuits

Starting motor: From (+) of the battery to the switch, to the series-parallel windings, to the (+) brushes, to the (−) brushes, to ground, to (−) ground of the battery. Bendix drive is used.

Generator field circuit: From the (+) main brush, to the shunt field windings, to the (−) third brush.

Cut-out voltage winding: From the (+) main brush, to (V), to (G), to the (−) grounded main generator brush.

Generator charging circuit: From the (+) brush, to cut-out closed points (**P**), to cut-out series coil (**S**), to (1) on the combination switch, to the ammeter, to (+) of the battery, to (−) of the battery, to the (−) brush of the generator.

Primary ignition circuit (battery): From (+) of the battery, to the ammeter, to (1), to (3), through the ignition resistance unit, to the primary winding of coil (**P**), to contact-breaker points (**P**), to ground, to (−) ground of the battery.

Primary ignition circuit (generator): From (1) on the combination switch, to (3), through the same path as just described.

Secondary ignition circuit: From (**S**) on the ignition coil, to the distributor rotor, to the spark plugs, to the ground of the battery or generator, to (1), to (3), to the resistance unit on the coil, to (**X**), where the secondary circuit joins the primary.

The circuit-breaker is shown at (**C**) on the combination switch.

The ammeter should always indicate the charge when the car is being driven at speeds faster than eight miles per hour with the lights off. With the lights on a slight discharge will be indicated at slow speeds. The lamp load will also reduce the charging rate at high speeds, as there will be a corresponding reduction in the amount of current passing through the storage battery.

The ammeter indicates the amount of current passing to or from the storage battery, but does not indicate the actual generator output. Should the ammeter indicate discharge at normal driving speeds, it should be taken as an indication of trouble and the electrical equipment should be checked over.

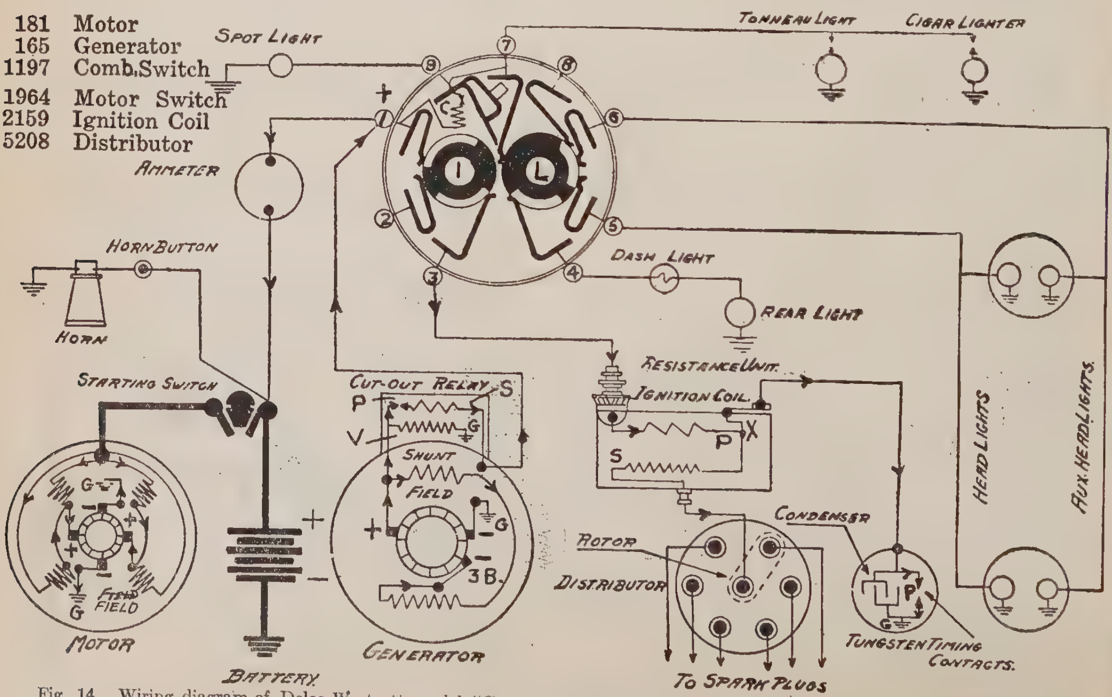


Fig. 14. Wiring diagram of Delco-Westcott model "C-38," using "7-R" Continental engine. Note that the generator and motor are separate.

PIERCE-ARROW (1921) MODEL SERIES 32—A DELCO THREE-UNIT SYSTEM

The generator is an example of a Delco shunt-wound, "constant-current," third-brush regulated generator and also of a "constant voltage" regulation (by means of an electromagnetic voltage regulator). The generator and starting motor are separate units.

Generator Circuits

Circuit from generator through voltage coil of cut-out: Start with the (+) grounded main brush (G) of the generator, to ground (G1) on the "apparatus box," through the cut-out voltage coil to (A), then to terminal (A) of the generator, to the (−) brush.

Charging current from generator to battery: When the generator voltage is more than the battery voltage, then the voltage through the cut-out voltage coil is strong enough to magnetize its core and the cut-out points (P) close (they close at 6¼ to 6½ volts) and the charging-current path is as follows: Start with the grounded (+) main brush (G) on the generator, to the grounded (+) terminal of the battery (GB), through the battery, through the ammeter to junction box terminal (2), through the 30-ampere fuse, through the bus-bar to (4), thence back to terminal (B) on the apparatus box, up through the current coil of the cut-out, through cut-out points (P), through ground (X) (dotted lines) to (A), thence to the (−) terminal (A) of the generator main brush.

Battery discharge circuit: When the generator is slowed down and the voltage drops to less than the battery voltage (less than 6¼ volts), then the battery will discharge back through the current coil of the cut-out in a reverse direction. While doing so, the cut-out contact points (P) should open with the discharge from the battery through the current coil of the cut-out of less than 3 amperes. The circuit is as follows: Start with the (+) grounded terminal of the battery, through the (+) grounded main brush of the generator, through the armature, to (A), to (A) on the apparatus box, up through the dotted lines and cut-out points (P), through the cut-out current coil (note that the current from the battery is now flowing in a reverse direction, thus demagnetizing the cut-out core), to (B), to (4) on the junction box, to (2), then back to (−) terminal of the battery.

Generator shunt-field circuit: Start with the (+) third brush at left, then through the four shunt-field coils (this is a four-pole generator) to the (F) terminal of the generator, thence to the (F) terminal on the "apparatus box," through the regulator closed points (RP), down dotted lines to (A), thence to terminal (A) of the generator, to the (−) brush of the generator. Note that in this instance the generator field current is flowing around the regulator coils, and is, therefore, not generating too high an output.

Purpose of the Voltage Regulator

With a discharged battery, insufficient current is forced through the voltage coil of the regulator to cause the regulator vibrating points (RP) to operate. Hence these points remain closed, thus causing the generator to operate as a third-brush machine.

As the battery approaches a condition of full charge (approximately 1.250 specific gravity or more), sufficient current is forced through the voltage coil of the regulator to cause contact points (RP) to open and to begin to vibrate. This action cuts down the field current of the generator, which in turn reduces the generator's charging rate. This is a desirable condition when the battery approaches full charge.

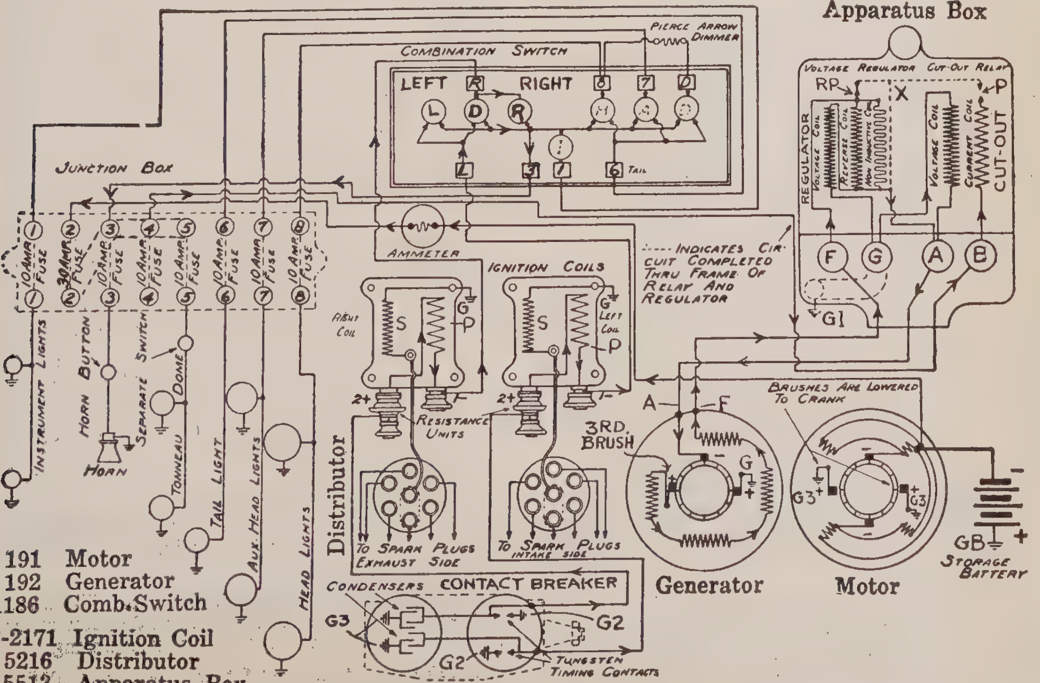


Fig. 15. Wiring diagram of Delco-Pierce-Arrow (1921, series 32). Note that the generator and motor are separate.

The vibrating voltage regulator consists chiefly of an electro-magnet having three windings and a set of contact points (RP) normally closed, which can be opened by the magnetic influence of the current through the regulator voltage winding.

The winding of the voltage coil consists of a large number of turns of fine copper wire around the core. This winding is connected directly across the main generator circuit.

The two other coils consist of: first, a reverse winding consisting of a large number of turns of fine wire wound around the core in the opposite direction to the voltage winding; and, second, the non-inductive winding having half its turns wound in each direction around the core. The reverse and non-inductive windings are in parallel with the contacts and add resistance to the field circuit when the contacts (RP) are open. This prevents the generator output from becoming excessive at high car speeds by weakening the strength of the generator field. Arcing at the contacts is prevented by the non-inductive winding.

The **reverse coil of the regulator** is balanced in ampere turns to counteract the action of the voltage coil and to allow the spring to close the contacts. This action is sluggish, owing to the high resistance of the reverse coil, so the non-inductive coil is connected in parallel with the reverse coil to cut down the resistance in the field-circuit. It has no magnetic effect on the regulator core, but gives a high-speed action to the regulator armature, as the generator will build up more rapidly.

To Test Opening of Regulator Points

A reliable voltmeter must be used to check the voltage of the generator. Connect the voltmeter leads: one to the main generator terminal (**A**), and the other to ground. With the storage battery in a fully charged condition, or removed entirely from the circuit, a maximum voltage with the generator in operation should be 7¾ volts. Above this voltage the regulator points (**RP**) will open and thus cause the resistance of the regulator reverse coil and the non-inductive coil to be cut into the field circuit. This reading should be checked at different engine speeds. Increasing the tension in the spring by means of the adjustment nut on the regulator will raise the voltage when points (**RP**) open, and decreasing the spring tension will lower the voltage.

Cut-in voltage limits of the cut-out in the "apparatus box," which is a part of the Pierce-Arrow equipment, are from 6¼ to 6½ volts.

Cut-out points open when the generator voltage is less than the battery voltage, and the battery should discharge back through cut-out current coil with less than 3 amperes. The correct amount shown on the dash ammeter (all lights off) should be approximately 4 amperes, as ignition is included.

For cut-out adjustment, see page 409.

Pierce-Arrow-Delco Ignition

Refer to the wiring diagram, and note that there are **two sets of tungsten contact-points** on the circuit-breaker, as well as two distributors and two ignition coils. Each set of contact-points is connected to separate coils.

There are **two sets of spark plugs:** one set in the "exhaust side," and the other set on the "intake side" of the "T-head" type of engine with dual valves. Thus "double ignition" is provided, or either the "single" or "double" system may be operated by the ignition switch control.

The double ignition is recommended, where two spark plugs are fired in each cylinder simultaneously. The result is an increase in power and greater mileage per gallon of gas than if the single system is used. The reasons for this are explained on pages 263 and 216.

The single ignition system would probably only be used for testing out one system independently, or under special conditions where the storage battery might be badly discharged. It is therefore desirable to use no more battery current for ignition purposes than necessary, until the battery has been recharged.

Automatic advance: The double distributor is equipped with a device which automatically advances the spark in proportion to the speed of the engine.

Ignition switch: The ignition system is controlled by the three buttons (see wiring diagram) to the left of the key opening in the panel. The first, or the one marked "L," when pulled out operates that ignition set terminating in the spark plugs on the left or inlet side of the engine. The button (**R**) controls the ignition set terminating in the spark plugs on the right or exhaust side of the engine. Each button operates the respective single systems. These buttons should only be used when the necessity arises to test out one system.

The button marked (**D**) "double" operates both systems, and should be used at all times for starting and running purposes.

The panel or switch key cannot be withdrawn unless all ignition switches are in the "off" position.

To lock the ignition, push in all ignition buttons, turn the key to the right, and withdraw.

Note that the switch panel can be locked with the "Aux" and instrument panel light (1) on.

Ignition coil primary circuit (right coil): Start with the (+) terminal of the battery (**GB**), to ground (G2) of the upper contact-points of the contact-breaker, to the (+2) terminal of the right coil, through primary winding (**P**), to terminal (−1) of the coil, to the switch at (**R**), to (3), to (3) on the fuse block, thence to (2), to the ammeter, to the (+) terminal of the battery (if the battery supplies current for ignition), or to (4) on the fuse block, to (**B**) below the cut-out, through the cut-out series winding, to (**X**), to (**A**), to (**A**) on the generator, to the (−) brush of the generator (if the generator supplies current when charging the battery).

Ignition coil primary circuit (left coil): The circuit is practically the same as for the right coil, except that the path is through the lower contact-points of the circuit-breaker, to the primary winding of the coil, to (**L**) on the switch, to (3), and thence as above.

Note. If the systems (right or left coils) are used separately, the (**L**) switch button or the (**R**) switch button is used. If both coils are used, then the double switch button (**D**) is used.

Note that **there are two condensers,** one for each set of contact points, which are connected across the primary circuit.

The secondary circuit is from the secondary coil (**S**) to the distributor, through the spark plugs to ground of the engine, to grounded end (**G**) of the secondary winding.

See **Figs. 8 and 9, page 216,** for an illustration of the Pierce-Arrow double ignition distributor, and **pages 217, 220, and 221,** for "Ignition timing."

Breaker points are set for an opening of .018″ to .027″; **spark-plug gaps,** .030″, or about 1/32″; size of spark plug, ⅞″ A.L.A.M.

Pierce-Arrow Starting Motor

The starting motor is a separate unit on the Pierce-Arrow, as well as in the Marmon, and many other Delco systems.

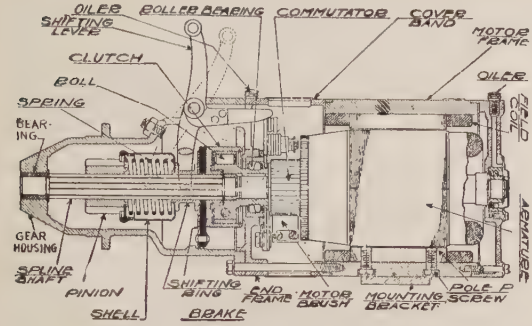


Fig. 16. Delco-Pierce-Arrow starting motor. The word "brake" refers to the black section shown above the words "shifting ring."

Some unusual features of construction are incorporated in the starting motors used on Pierce-Arrow passenger cars and trucks. Both starting motors are identical, except for the starting pinion housings, which are designed with the flywheel openings on opposite sides, the passenger car motor being mounted on the right side of the engine, and the truck motor on the left side.

This motor, shown in Fig. 16, employs a mechanically operated pinion shaft, shifting the starter pinion in and out of mesh with the flywheel. The same shift lever operating the starter pinion also raises and lowers the grounded set of brushes, thus taking the place of a starting switch. The shift lever in turn is operated by the starting pedal located on the floor boards in front of the driver.

When the starting pedal is pressed down, the lever moves the starter pinion along the splined shaft into mesh with the flywheel, and at the same time lowers the two grounded motor brushes on to the commutator, closing the circuit and causing the motor to revolve. The design is such that the pinion teeth engage with the flywheel teeth before the brushes touch the commutator.

To provide for the few occasions **when the starter pinion teeth butt squarely against the flywheel teeth** to prevent immediate meshing, a compression spring within a cup housing is attached to the pinion and mounted on the splined shaft.

When the pinion does not mesh, the control lever moves on, compressing the spring until the brushes are lowered to the commutator. Then with the slightest motion of the shaft the pinion moves enough to clear the flywheel teeth, and the compressed spring instantly forces it into mesh before the motor can turn fast enough to cause clashing, or damage to the gear teeth.

There is **an over-running clutch** of special design between the pinion shaft and the armature shaft. When the engine starts running, the pinion shaft over-runs and prevents the motor armature from being driven by the engine at a dangerously high rate of speed.

The brake shown at the inner end of the splined shaft in Fig. 16 causes the armature to come to rest almost instantly when the starter pedal is released, permitting the operator to make a second application of the starting motor without delay, if necessary.

There is only one motor terminal, and to this, connection is made direct from the negative terminal of the battery, using very heavy starting motor cable.

The very small spring and plunger located on the inner face of the flange of the small gear on many of the Bendix drives should not bear excessively against the spiral shaft lest the proper movement of the gear be prevented. Should the small spring around the plunger become weakened, the gear will occasionally jingle against the flywheel teeth while the engine is operating.

The driver should operate the starting motor in cranking the engine only when the ignition spark has been retarded. If the engine for some reason only runs for a second or two after the first application of the starting motor, be sure to wait until the engine flywheel has ceased rocking backward and forward and has come completely to rest before applying the starting motor the second time. Observance of these two rules will very largely eliminate breakage of starting motor gear housings.

DELCO ELECTRIC SYSTEM ON THE ESSEX MODEL "A"

Separate starting motors and generators are used on the Essex and Cole, but cut-outs are not used. The motor brushes serve as a starting switch.

Electric system: This is the Delco three-unit single wire system. The starting motor drives through the flywheel and a mechanically shifted pinion is used. In place of a starting switch, the motor brushes are used instead (explained below).

The generator is driven from the right side of the engine, and has the third-brush regulation. To change the output of the generator, shift the third brush; 16 amperes is maximum.

Ignition: Delco closed-circuit timer and distributor driven at one-half crank-shaft speed with automatic advance. The condenser and ignition resistance unit is mounted on the side of the timer.

The adjustment of the timer gap is .018″; of the spark-plug gap, .030″; the firing order is 1, 3, 4, 2.

The ignition timing: Place the spark lever full advanced. Turn the engine until No. 1 piston starts to come up on compression stroke and stop when the D.C. 1-4 mark on the flywheel is in line with the pointer on the flywheel of the engine. Then loosen the timer adjustment screw in the center of the distributor shaft and turn the breaker cam so that the rotor button will be in position under No. 1 high-tension terminal, or that which leads to No. 1 cylinder, when the distributor head is down in place. Locate the breaker cam carefully in this position, so that when the slack in the distributor driving gears is rocked forward, the contacts will be opened by the breaker cam, and when the slack in the gears is rocked backwards, the contact will just close.

For the valve timing, see the Index.

Owing to the wearing to a seat of the fiber rubbing block of the contact-breaker arm against the cam, the contacts will require one or two adjustments during the first season's driving, after which no attention is necessary. The timing contacts are of tungsten metal, and are very hard. They should require no attention other than to maintain the proper adjustment.

Essex-Delco Circuits

Starting motor: From the (+) terminal of the battery (Fig. 17), to the series parallel field windings of the starting motor, to the (+) brushes, through the armature, to the (−) brushes, to (−) ground of the battery.

Instead of a starting switch, the motor brushes are lowered to the commutator when starting, and are raised after starting by the action of the starting pedal.

When the starting pedal is depressed it performs two distinct operations. The first of these takes place when the button is part way down, at which time the starter gear mounted to the rear of the starting motor is caused to mesh with the flywheel. The second action occurs when the pedal is all the way down, bringing the motor brushes in contact with the motor commutator, thereby closing the circuit and energizing the motor, which results in the revolving of the armature and the consequent cranking of the motor through the over-running clutch and thence through the flywheel. Release the starting button as soon as the engine starts.

The brushes on this motor are of a special composition, and must not be replaced with brushes of any other material, as this is almost sure to lower its efficiency very materially. Neither the brushes nor commutator should be lubricated, as lubrication of the commutator with a compound of any kind is almost sure to cause the brushes to fail to make contact at all, or at least to make insufficient contact to permit the cranking operation.

Generator shunt-field circuit: From the (+) main brush to (**A**), to (2), to (3), to (**F**), through the shunt field windings, to the (−) third brush.

A cut-out is not used on the Essex. See page 387, explaining the reason why it can be eliminated. The explanation on page 387 is for a Delco motor-generator, whereas the Essex generator is separate from the motor; however, the principle is the same.

Generator charging circuit: From the (+) brush, to (**A**), to (2), to (1), to the ammeter, to the (+) battery, to the (−) battery ground (**GB**), to the (−) main brush of the generator (**G**).

Ignition primary circuit (from the battery when starting): From (+) of the battery, to the ammeter, to (1), to (3), to the ignition coil primary winding, to ignition resistance unit (**R**), to contact-breaker points, to ground (**G**), to (−) ground of the battery.

Ignition primary circuit (from the generator after the engine is running at sufficient speed for the generator to charge the battery): From (+) of the generator, to (2), to (3), and over the same path as in the preceding paragraph.

Note. The ammeter shows the ignition current on the "discharge" side (also lights, etc.) used from the battery. It shows on the "charge" side only, the current going from the generator to the battery when the generator is charging the battery.

Secondary ignition circuit: From the secondary coil winding, to the distributor, to the spark plugs, to ground, to ground of the generator or battery, to (3), to the other end of the secondary circuit.

The condenser is placed across the ignition contact-breaker points.

The lighting circuit, when from the generator, is from (2) to (1), and when from the battery, from (1). The **circuit-breaker** of the vibrating type is placed in series with the lighting circuits. The purpose is explained on page 391.

The combination switch is located in the cowl. It is for the purpose of controlling the lighting and ignition circuits, and the circuit between the generator and storage battery. The lever (**I**) on the left controls the ignition and generator circuit. The lever on the right (**L**) controls the lights and has three positions, "off," "dim lights," and "bright lights." The cowl and tail lights are lit when the headlights are either dim or bright.

By controlling the circuit between the generator and storage battery with the ignition switch lever, an automatic cut-out, which is commonly used for this purpose, is not required. The ignition button should never be left in the "on" position when the engine is not operating, as the storage battery would run down.

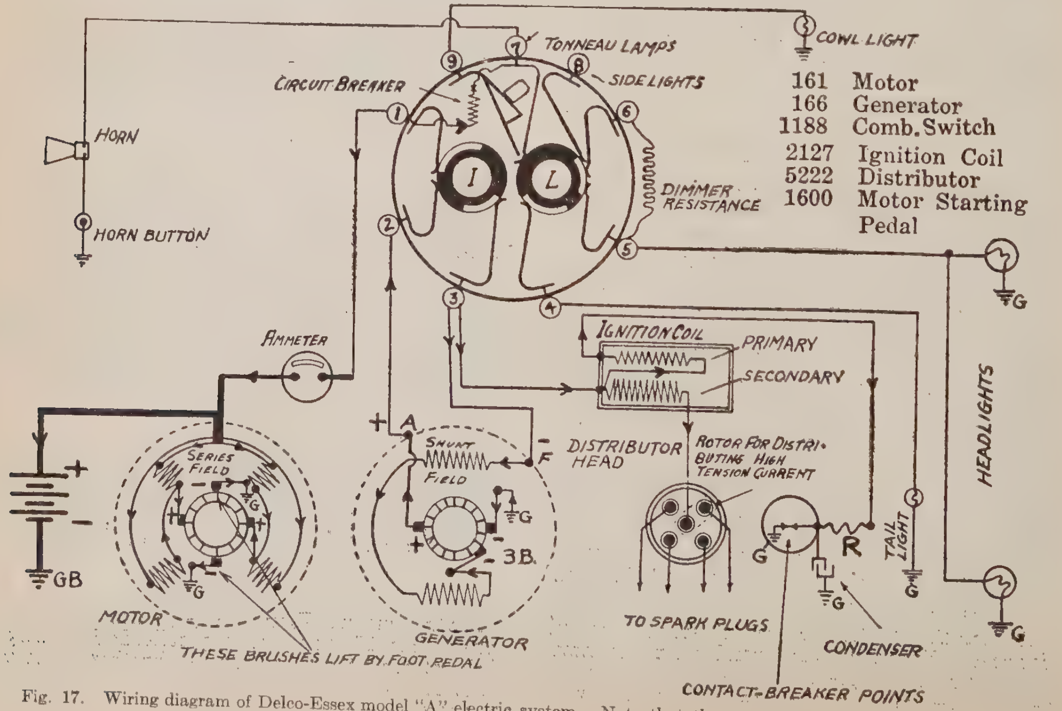


Fig. 17. Wiring diagram of Delco-Essex model "A" electric system. Note that the generator and motor are separate.

DELCO ELECTRIC SYSTEM ON COLE MODEL 870 (1921); SEPARATE STARTING MOTOR AND GENERATOR; CUT-OUT NOT USED

The generator and motor are separate units. The circuits are as follows:

Starting motor circuit: From (+) of the battery, to switch (**S**), to the two series-parallel field windings, to the (+) brushes, to the (−) brushes, through the two field coils, to ground, to (−) ground of the battery.

Generator field circuit: From the (+) main brush to the shunt field coils, to the third brush (3**B**).

Generator charging circuit: From the (+) main brush, to (6), to (5), to the ammeter, to (+) of the battery, to the battery (−) ground, to the (−) grounded brush (**GG**) of the generator.

Primary ignition circuit: From (6) if the generator is supplying current, or from (5) if current is supplied from the battery, to (7), to primary winding (**P**), to the resistance unit, through the two contact-breaker points connected in multiple, to ground (**G**), to ground (**GG**) of the generator, or to ground of the battery.

Secondary ignition circuit: From the secondary winding of coil (**S**), to the distributor, to the spark plugs, to ground, to ground of the generator, or of the battery, to (**X**) on the coil, where the primary and secondary circuits connect.

The circuit-breaker is of the vibrating type.

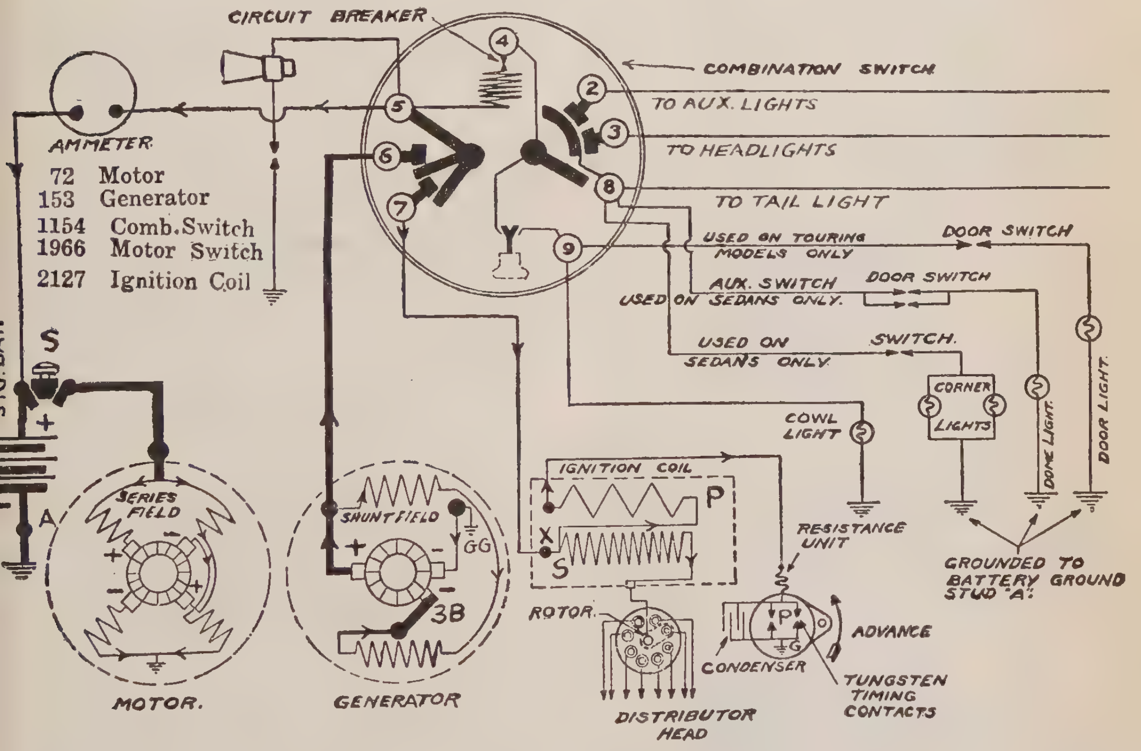


Fig. 18. Wiring diagram of the Cole (1921) model "870" using the Northway "M-309" engine.

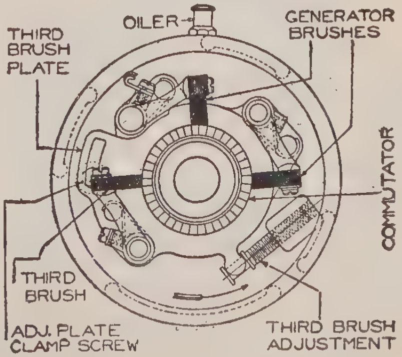
ADJUSTING GENERATOR CHARGING RATE ON DELCO GENERATORS

The charging rate may be increased by moving the third brush in the same direction as the armature rotates; or in the opposite direction, to decrease the rate.

An ammeter should be connected in the charging circuit and should be carefully observed while the engine is gradually speeded up, and the maximum rate noted. With all lights off, the charging rate should not, in any case, exceed 16 amperes.

In some instances the charging rate is too high, yet the driver of the car does not complain in regard to the charging rate. His complaint is on the short **life of the lamps,** and the necessity of **frequent addition of distilled water to the storage battery.**

It is possible to adjust the charging rate to give satisfactory results, by studying the driving conditions of individual cars.



TO DECREASE CHARGING RATE MOVE ADJ. PLATE IN DIRECTION OF ARROW

Fig. 19

To adjust the position of the third brush on generators applied to Cadillac and Marmon models, first remove the cover band over the generator brushes. Loosen the clamp nut on the front end of the generator one or two turns. **To increase the charging rate,** turn adjusting screw (Fig. 19) slightly in a clockwise direction, which **shifts the third brush in the direction of the armature rotation.** The reverse operation decreases the charging rate. After adjustment is complete, tighten the clamp nut securely. Make sure that all brushes are well seated.

When the position of the third brush is changed, it is necessary to reseat the brush on the commutator to obtain the maximum true charging rate. To refit the third brush, place a strip of fine sandpaper or sand-cloth, having a width slightly greater than that of the brush, around at least half of the commutator, with the rough side next to the brush. Drawing the sandpaper back and forth a few times will properly seat the brush. Never use emery cloth (explained farther on).

The design of many of the generators is such that in adjusting the third brush, the brush arm on the inside of the generator is moved after loosening two adjusting screws as in Fig. 20. Certain of the later type generators (Fig. 21) are provided with a plate on the end of the generator which can be moved within certain limits after loosening the three adjusting screws. An arrow on this bearing retainer plate through which the screws pass indicates the direction in which the brush is to be shifted to increase the charging rate.

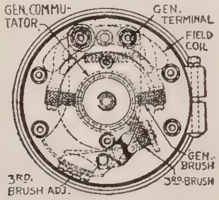


Fig. 20

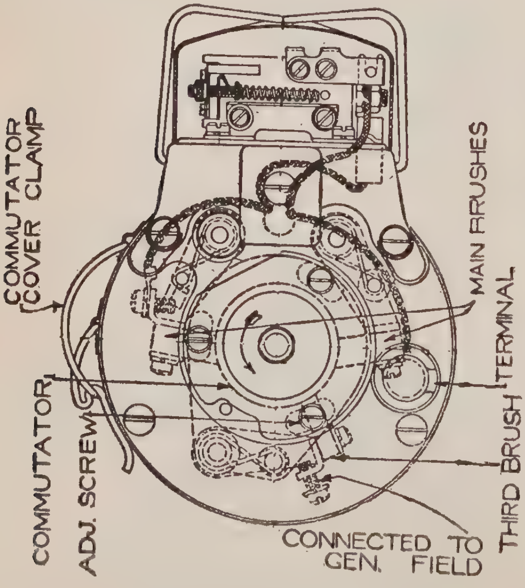


Fig. 21. Separate generator (motor not attached) as used on Marmon, Moon, Jordan, and Westcott cars.

Procedure of adjustment (Fig. 21): The charging rate can be changed by loosening the three screws holding the third-brush plate, as shown in the illustration, and by shifting the brush in the direction of rotation of the armature to increase the charging rate, and against the rotation to decrease the charging rate. In no case should the ammeter indicate a charging rate in excess of 14 amperes when the generator is hot; as this rate is beyond the capacity of the generator, serious damage will result. Whenever the third brush is moved in either direction it should be fitted to the commutator by sanding the brush with fine sandpaper between the brush and the commutator, with the sand side next to the brush. If this is not done, the brush will fit the commutator imperfectly and the charging rate will be lower than when the brush fits properly.

Explanation of Delco Third-Brush Regulation

The voltage generated by the generator varies directly with the speed of the armature. In order to maintain a nearly constant voltage with variable speed, it becomes necessary to decrease the magnetic field as the speed increases.

Since the magnetic field of the generator is produced by the current in the shunt-field winding, it is evident that should the shunt-field current decrease as the speed of the engine increases, the regulation would be affected. In order to understand this explanation fully it must be borne in mind that a current of electricity always has a magnetic effect, whether this is desirable or not. Referring to Fig. 22, the theory of this regulation is seen to be as follows: The full voltage of the generator is obtained from the large brushes (**C**) and (**D**). When the magnetic field from the pole pieces N and S is not disturbed by any other influence, each coil is generating uniformly as it passes under the pole pieces. The voltage from one commutator bar to the next one is practically uniform around the commutator.

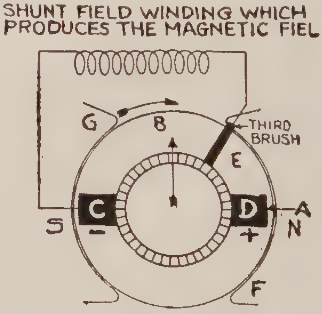


Fig. 22. Explanation of the third-brush principle (see also Index).

Therefore, the voltage from brush (**C**) to brush (**E**) is about 5 volts when the total voltage from brush (**C**) to brush (**D**) is 6½ volts, and 5 volts is applied to the shunt-field winding. This 5 volts is sufficient to cause approximately 1¼ amperes to flow in the shunt-field winding.

As the speed of the generator is increased the voltage increases, causing the current to be charged to the storage battery.

This charging current flows through the armature winding, producing a magnetic effect in the direction of the arrow (**B**). This magnetic effect acts upon the magnetic field which is in the direction of the arrow (**A**), with the result that the magnetic field is twisted out of its original position in very much the same manner as two streams of water coming together are each deflected from their original directions (termed "armature reaction," see page 361). This deflection causes the magnetic field to be strong at the pole tips, marked (**G**) and (**F**), and weak at the opposite pole tips, with the result that the coils generate a very low voltage while passing from the brush (C) to the brush (E) (the coils at this time are under the pole tips having a weak field), and generate a greater part of their voltage while passing from the brush (E) to (D). The amount of this variation depends upon the speed at which the generator is driven; with the result that the shunt-field current decreases as the speed increases, thus holding the output of the generator constant.

Regulating Charging Current (Delco)

The output of these generators can be increased or decreased by changing the position of the regulating brush. Each time the position of the brush is changed it is necessary to sandpaper the brush, so that it fits the commutator. Otherwise the charging rate will be very low because of the poor contact of the brush. The charging current should be carefully checked, and in no case should the maximum current on this generator exceed 22 amperes. Also careful watch should be kept on any machine on which the charging rate has been increased, to see that the generator is not being overloaded.

Considerable variation in the output of different generators will be obtained, as the output of the generator is affected by temperature and battery conditions.

AMMETER, DELCO COMBINATION SWITCH, AND CIRCUIT-BREAKER

Ammeter: On the later models of cars the ammeter is not incorporated with the lighting and ignition switch, but is mounted in the cowl separately, as will be noticed in the circuit-wiring diagrams of some of the 1921 Delco systems.

This instrument is for the purpose of indicating the net amount of current that the generator is supplying to the storage battery when the engine is running, and indicates the amount of current that the battery is furnishing for lights when the engine is not operating.

If the ammeter hand remains on the "discharge" side of the scale, and vibrates violently at each revolution of the armature during the motoring of the generator, and when the engine is running at low speeds, it is conclusive evidence that the armature has either a ground, open coil, or a shorted coil.

Combination switch: Although the appearance of the different combination lighting and ignition switches may vary, their internal construction and operation in controlling the charging, ignition, and lighting circuits is quite similar.

On those cars whose equipment does not include a cut-out relay the ignition switch controls both the charging and ignition circuits, through the same switch lever. In these cases, therefore, the ignition switch completes the circuit between the storage battery and the generator. It should therefore always be in the "off" position, except when starting or when the engine is running, as otherwise the storage battery would discharge through the generator windings and ignition circuit.

Cars not equipped with two large and two small headlight bulbs carry a dimmer resistance unit on the back of the switch.

The switch levers can be securely locked by Yale or Sargent locks. The majority of ignition switches carry the circuit-breaker on the back of the switch.

The ignition and lighting switch used on Pierce-Arrow cars (see page 403) carries a large round button at the top of the switch connected with a plunger which extends through the back of the switch about six inches. The plunger engages the starting switch which is not a part of the Delco equipment.

The starting switch is mounted on the back of the ignition and lighting switch.

The circuit breaker assembly on the systems used on Cadillac (page 396) and Marmon (page 400), Lincoln and Lafayette cars includes the lock-out as well as the vibrating type. Such accessories as the horn, trouble lamp, and tonneau light are as a rule placed on the circuit protected by the lock-out circuit-breaker. See page 392.

If a ground occurs, the points of the lock-out circuit-breaker remain open until the ground is removed. This action is controlled by the use of an additional small coil around the core of the circuit-breaker through which will pass a sufficient amount of current to magnetize the core sufficiently to keep the points open after they have been separated.

DELCO CUT-OUT (1921 TYPE)

As stated, a cut-out is not used with Delco motor generators for reasons stated on page 387.

On Delco generators which are separate from the motor, as two and three-unit systems, as on the Marmon and Pierce-Arrow, Westcott, Moon, Jordan and other cars using the separate generator (see Delco wiring diagrams), the cut-out is used.

The cut-out consists of a set of magnetically operated contacts that are held open by a tension spring and closed magnetically. When the engine is not running the contacts should be open. They are open also when the speed of the generator is too low to enable it to charge the battery.

Around the core of the magnet is a double winding consisting of **a voltage coil** of a large number of turns of very fine wire, connected across the generator terminals, and a **current or series coil** made up of a few turns of very heavy wire.

The current coil is connected in the charging circuit in series with the contacts, and is energized only when the contacts are closed. The actual closing of these contacts is caused by the magnetism created by the voltage coil, or fine winding, when the generator operates at sufficient speed to charge the battery.

Adjustment of Delco Cut-Out

Should adjustment become necessary, the following directions should be carefully followed:

1. **The air gap** (S) (Fig. 23) between the armature (A) and the end of the core should be .025″ to .035″

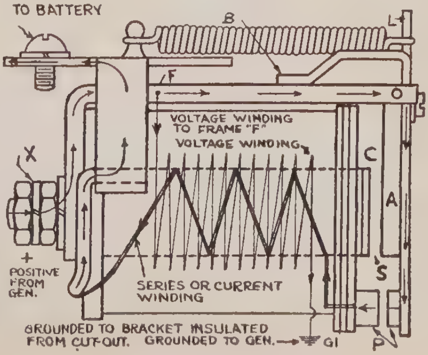

TO BATTERY
B
L
F
VOLTAGE WINDING TO FRAME "F"
VOLTAGE WINDING
X
C
A
+ POSITIVE FROM GEN.
S
SERIES OR CURRENT WINDING
GROUNDED TO BRACKET INSULATED FROM CUT-OUT.
GROUNDED TO GEN.
GI
P

Fig. 23. Delco 1921 type of cut-out.

when the contacts are closed. Secure this adjustment by properly bending with a pair of pliers the armature blade attached to the outside point of (P). This adjustment is important, as the amount of the air gap largely governs the "cut-in" point.

2. **The gap between the contacts** (P) is automatically taken care of by the adjustment of the air gap. This gap is .046″ to .062″ when the points are open, and it can be adjusted by bending the brass stop (B). Contacts should meet squarely, and the brass blade carrying the moving contact should be straight and parallel with the surface of the armature (A).

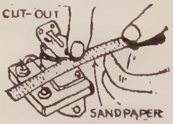


Fig. 24

To clean the contacts or square them up, a strip of fine sandpaper should be drawn between the contacts while they are lightly closed by hand. The end of the blade carrying the moving contact may be prevented from rubbing inside of the relay cover by grinding or filing off the end of the blade to a point 1/64″ from the side of the contact.

3. **In checking the voltage** at which the cut-out relay points close, use a voltmeter capable of indicating at least 10 to 15 volts. Connect one of the voltmeter leads to the terminal (X) (Fig. 23) and the other lead to the cut-out relay base, or generator frame. If the needle of the voltmeter deflects in the wrong direction, reverse the voltmeter lead connections.

4. Slowly speed up the engine and **observe the voltmeter reading.** The contacts should close at 7 to 8 volts on all relays, except those on Pierce-Arrow equipment, which are adjusted to 6¼ to 6½ volts. Any necessary adjustment should be made by bending the lug (L) slightly (a thumb-nut adjustment is provided on the springs of the earlier relays of this type). Increasing the spring tension will raise the "cut-in" voltage. Decreased tension lowers it. An ideal adjustment is an air gap as small as the limits will permit, so that there will be an appreciable tension in the spring.

5. **The cut-out relay contacts** should be closed above a car speed of approximately 6 to 8 miles per hour in high gear, or a correspondingly lower speed in lower gears.

6. **Contacts should separate** with the discharge from the battery through the relay at less than 3 amperes. The correct condition will be indicated by the ammeter on the cowl indicating approximately 4 amperes with all lights off. This reading includes current used for ignition which does not pass through the relay.

As soon as the cut-out relay contacts close, the ammeter on the dash should indicate that the generator is beginning to charge the battery.

If it becomes necessary to drive the car in high gear at a speed materially faster than 7 to 9 miles an hour before the ammeter shows, by indicating a "charge," that the relay points have closed, do not judge conclusively that the cause is a defective relay or that its adjustment is incorrect. The real cause of the trouble may be **an oily generator commutator** resulting from excessive lubrication of the generator bearings. This condition may prevent the generator building up sufficient voltage to close the relay contacts, though the relay be in perfect condition and adjustment.

Before making any changes in cut-out relay adjustment, clean the generator commutator carefully of any oil, grease, or black greasy coating, and examine the spring tension and seat of all generator brushes, particularly the third brush. If the generator is given this attention without any improvement in the performance of the cut-out relay resulting, the cut-out may then be carefully adjusted in accordance with previous instructions.

Should a considerable amount of trouble be experienced on an individual generator through the presence of an oil film on the commutator, it **may be necessary to install a new third brush to eliminate the effect of excessive oil on the commutator.** Take care to avoid excessive lubrication of the generator bearings; three or four drops of oil in each oiler every 500 miles is sufficient.

Delco 1920 Cut-Out

Should the cut-out not operate properly, the voltage at which the contacts close should be checked.

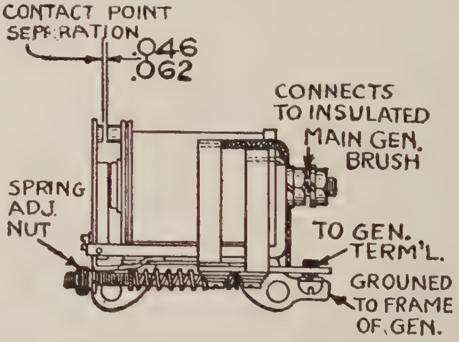


Fig. 25. 1920 type of Delco cut-out. The principle is the same as in Fig. 23. See Fig. 12, page 400, showing cut-out mounted on top of the generator; see also the wiring diagrams of the Marmon.

The contacts should close, completing the circuit between the generator and storage battery, when the voltage of the generator reaches approximately 7½ volts. This can be checked by connecting a voltmeter to the terminal on the cut-out (Fig. 25) marked "connect to insulated main generator brush," the other side of the voltmeter being connected so as to make a good contact with the generator frame at some point. By slowly increasing the engine speed, the voltage should gradually increase to approximately 7½ volts, and the contacts should then close. With the contacts open there should be a separation of from .046″ to .062″.

The cut-out can be adjusted by tightening or loosening the spring adjustment nut as the occasion demands.

Seating and Sanding Delco Brushes to the Commutator

This subject is treated farther on. See Index.

INSTRUCTION No. 36

A STUDY OF LEADING ELECTRICAL STARTING AND GENERATING SYSTEMS: Pointers for Studying Electric Systems; Wiring Diagrams[1]

POINTERS FOR STUDYING ELECTRIC SYSTEMS

The fundamental principle of the starting and generating systems has been treated in the preceding instructions. If the reader will master the principles as laid down in the foregoing pages, it will not be a difficult matter to understand any and all systems, because each system embodies one or more of the principles explained. Although the methods of operation or construction may vary, the purpose remains the same.

The external parts of the electric system consist of:

1. Battery.
2. Generator.
3. Ignition system.
4. Starting motor.
5. Switches: starting, ignition, and lighting.
6. Lamps.
7. Wiring system: the "single-wire" or the "two-wire" system.
8. Horn (electric), and push button.
9. Fuses.

The "single-wire" system is where one insulated wire is used and the frame of the car is used for the return circuit. This system is used most, and hence it will be noted in diagrams following.

The "two-wire" system is where there is no ground to the frame, but two insulated wires are used.

Although there are many different makes of cars, there are **only a comparatively few different makes of electric systems,** and each of the different cars uses one or a combination of these systems

The specifications of leading cars (see Index) will give the make of the particular electric systems that are used on the different cars.

The ignition system on a car is usually one of the following makes: Delco, Remy, Westinghouse, North East, Atwater-Kent, Connecticut, K-W Ignition Company, which employs the battery and coil system. This latter is explained under the head of "Ignition."

If **magneto ignition** is used, it will be of one of the makes mentioned in the list of magneto manufacturers (see Index). The K-W is a very popular magneto ignition used on trucks and tractors.

The ignition system most used is the battery and coil system. The interrupter is either an "open-circuit" or "closed-circuit" type, the latter being the most generally adopted system. Some few manufacturers of passenger cars use magneto ignition in addition to the coil and battery. Magnetos are used extensively on trucks and tractors.

Storage battery makes are the Exide, Vesta, Willard, Prest-O-Lite, U.S.L., Philadelphia, Witherbee, and several others. Some of the car manufacturers use 12-volt or 24-volt batteries, but most of the systems are 6-volt.

Electric starting motors and generators are usually of the Delco, Remy, U.S.L., Westinghouse, Bijur, Simms-Huff, North East, or other makes. The two last mentioned, and the Delco, have the motor and the generator combined in one unit. The motors and generators are also manufactured separately. The U.S.L. also produces a motor-generator.

The generator is either a plain shunt-wound generator, with an external electromagnetic principle of regulation, or a third-brush-regulated generator, or a combination of a third-brush and electromagnetic regulation. The third-brush-regulation prin-

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[1] It is impossible to show wiring diagrams of all cars. See the advertisements on the wiring diagram book and the Service Manuals in the advertising pages of this book.

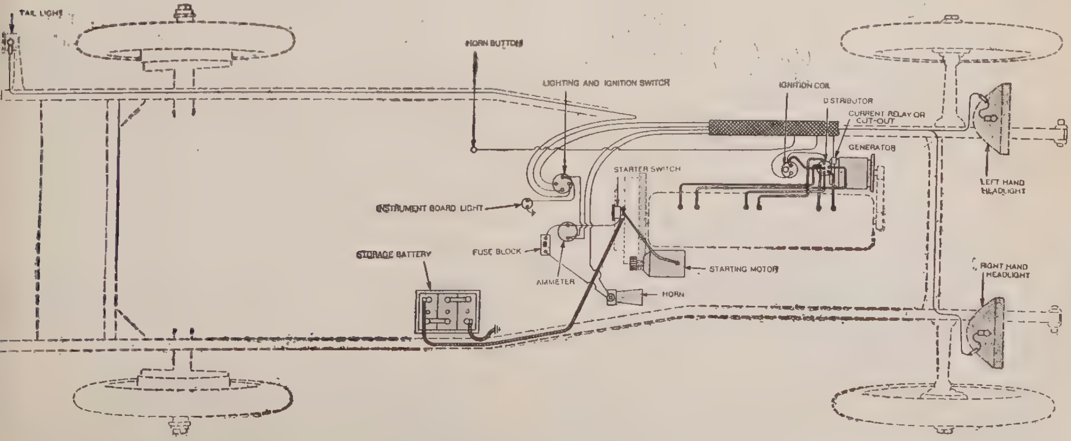

Fig. 1. Location of the electric parts on a car (Remy electric system on the Mitchell model "F," as an example). Note that the generator is driven by gears from the crank shaft of the engine. The distributor and the contact-breaker are mounted on the generator and are driven from the armature shaft.

ciple is used most. The Remy and Delco use a thermostatic control (see pages 362, 395) in connection with the third-brush regulation on some of their systems.

Ground connection of generator and battery. If the positive (+) terminal of the battery is grounded to the frame of the car, then the (+) terminal of the generator must also be grounded. Likewise, if the negative (−) terminal of the battery is grounded, then the (−) terminal of the generator must be grounded. Most manufacturers ground the negative (−) terminal of the battery and generator. The Westinghouse Co. grounds the positive (+) terminal in a number of its systems.

HOW TO STUDY WIRING DIAGRAMS

Electrical symbols: Before studying the different diagrams, the reader should become thoroughly familiar with the electrical symbols and abbreviations, as illustrated and described; for instance, the sign which denotes a "ground," or that which stands for a "storage battery," or for the point where "wires connect" or "pass over each other." They will be used quite freely in these instructions, as will also many of the other signs. The symbols vary slightly with the different manufactures of cars. It is also advisable to refer to page 415 for the addresses of the leading manufacturers of electrical systems. If the explanations are not clear, their catalogs will no doubt be of assistance.

In the illustration below, each symbol is numbered. The explanation of each is given with its appropriate number against it.

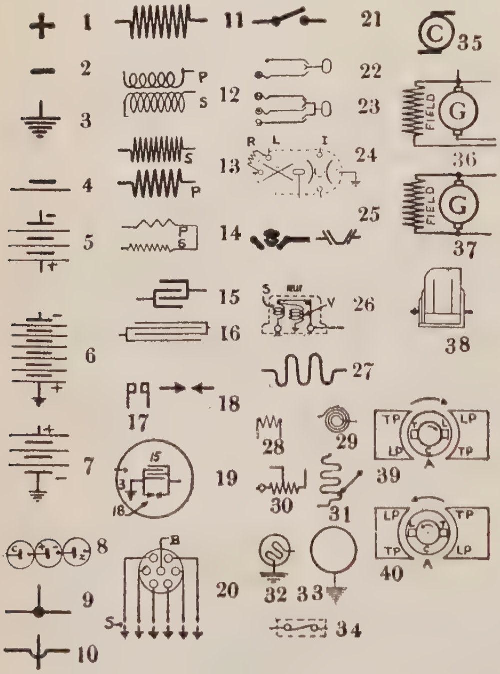

Fig. 2. Electrical symbols

Electrical Symbols and the Terms Applied to Them

1. **Positive terminal,** the point at which the electric current starts to flow.
2. **Negative terminal,** the point to which the electrical current returns.
3. **Ground,** where connection is made to metal, as the frame of the car, the engine or generator frame, etc.
4. **One cell of a battery:** A term usually applied to cells of a storage battery. The short black line represents the negative (−) terminal, and the long line the positive (+) terminal. On a dry cell the positive plate is the carbon, and the negative, zinc. On a storage-battery cell there are usually several positive and several negative cells, but this symbol represents the terminals of each group. Each storage-battery cell gives 2 volts when charged.
5. **Three cells of a storage battery connected in series:** Note that there are three sets of negative and positive terminals or cells. Thus this would represent a 6-volt storage battery.
6. **Six cells of a storage battery connected in series:** 12 volts. Note the (+) terminal of this battery of six cells grounded at the end cell.
7. **Three cells of a storage battery connected in series:** 6 volts. Note that the terminal of one end of this battery is grounded.
8. **Dry cells:** The illustration shows three connected in series. (C) is the carbon or (+), and (Z) is the zinc or (−).
9. **Wires connected.**
10. **Wires crossing,** but not connected.
11. **Coil:** Could represent a field-coil, or ignition coil. Supposed to surround an iron core.

12, 13, 14. **High and low-tension ignition coil windings:** There are several methods of showing the primary winding (P) and the secondary winding (S), as, for instance, those shown by 12, 13, and 14. The two windings are usually shown separate, although they are wound on one core. The current is induced into the secondary by lines-of-force produced by the primary winding, and there is no metallic connection between the primary and secondary windings. The secondary is a much finer wire, and consists of several thousand turns, whereas the primary has only a few hundred turns of heavy wire.

15, 16. **Condenser:** Placed across the coil points to absorb the spark when the points separate, and to permit the discharge back through the primary coil to demagnetize the core.

17. **Contact-points:** Usually refers to the cut-out or regulator points; also refers to the contact-breaker points.
18. **Interrupter or contact points** (as used by Delco): The Remy Co. uses this symbol to designate the spark jumping a gap at the spark-plug points, or at the safety-gap on an ignition coil.
19. **Interrupter or contact-breaker:** A method used by Delco. Note the "interrupter points" (18); also the "condenser" (15), and the "ground" (3).
20. **Distributor of high-tension ignition current to spark plugs:** (B) connects with the secondary terminal of the coil, and a high-tension current is distributed to the spark plugs and jumps the gap of the spark plugs (gap represented at S), then flows through the metal part of the engine back to the grounded secondary terminal.

21. **Lighting switch.**

22. **Delco ignition and lighting switch,** as used on some of the Delco systems.

23. **Double switch,** of the same type.

24. **Remy lighting and ignition switch** of the "pole-changing" type. Lighting switches (**L**) at left, with dimming resistance (**R**). Ignition switch (**I**) at right represents a "pole-changing" type of switch (see Index). Note the "ground" on the side of the switch case.

25. **Starting-motor switches.**

26. **Cut-out:** Also called a relay, with two windings. The "voltage or shunt" winding (**V**) is a winding, and is always placed **across** the circuit. The "voltage winding" of a cut-out can be found by noting that it has more turns of wire than the "series" or "current winding." The series or current winding (**S**) has a less number of turns and is a coarser wire and is always placed **in series** with the charging circuit. Cut-out windings are often on one core. Sometimes they are on two cores. The illustration shows two coils, or windings, on two separate cores (model 264-D Remy).

    Regulator winding: This is usually on one core and is a single winding. It is always placed in series with the "shunt-field winding." If it consists of a coarse heavy wire, this indicates that it regulates the **current output;** if it consists of a fine wire winding, this indicates **voltage regulation.**

27. **Resistance** coil.

28, 29. **Resistance** coil for dimming lights.

30. **Resistance** divided into two paths.

31. **Resistance** which can be varied.

32, 33. **Lamp bulbs:** Note that one side is grounded.

34. **Fuse** mounted on a fuse block.

35. **Commutator and brushes** for either a generator or a motor.

36. **Series-connection of field-coils,** with commutator and brushes of a motor or generator (internal circuit). The series connection is generally used on motors. If (**G**) appears as shown, it means that the connection is for a generator; if (**M**) appears in place of (**G**), the connection is for a motor.

37. **Shunt-connection field-coils,** with commutator and brushes (**G**) of a motor or a generator. (Internal circuit.) Shunt windings are generally used on generators; they are seldom used on motors for automobile work. (**G**) indicates generator, and (**M**), motor.

38. **Magneto.**

39. **Trailing** pole tips are indicated by (**TP**). **Leading** pole tips are (**LP**).

40. Same as 39; but since the armature (**A**) and the commutator (**C**) are in opposite positions, the order is changed.

    The **"trailing"** pole tip is the one (**A**) or (**C**) moves **from.**

    The **"leading"** pole tip is the one (**A**) or (**C**) moves **to.**

Abbreviations Commonly Used to Represent Electrical Terms

A: Ampere or Ammeter.
AC: Alternating current.
B: Brush; also used for Battery
BAT: Battery.
C: Current.
C or **COM:** Commutator.
CARB: Carburetor.
C.E.M.F.: Counter-electromotive force.
DC: Direct current (usually written d.c.).
DIS. or **DIST'R:** Distributor. The word "distributor" is often used to express the inclusion of the interrupter and distributor in one unit.
E.M.F.: Electromotive force.
GB: Generator brush; also grounded brush.
G or **GEN:** Generator.
G or **GRND** or **GR:** Ground.
HL: Headlights or lamps.
H.P.: Horse power (746 watts) (usually written h.p.).
I or **IG:** Ignition.
IS. or **IG.S:** Ignition switch.
INT: Interrupter.
KW: Kilowatt (1,000 watts).
L: Light, or lamps.
LS: Lighting switch.
M: Motor.
MB: Motor brush; also main brush.
N: North.
RES: Resistance.
S: South.
S or **Sec:** Secondary.
ST.M.: Starting motor.
SEF: Series field winding.
SHF: Shunt field winding.
3B: Third brush.

TRACING CIRCUITS OF WIRING DIAGRAMS

The electric system should be divided into circuits as follows:

1. Starting-motor circuit.
2. Generator circuit.
3. Ignition circuit.
4. Lighting circuit.

When tracing circuits, remember that the positive (+) terminal at the source of current is where to start. **If a battery** supplies the current, start at the (+) terminal. **If the generator** supplies current, start at the (+) brush or brushes of the generator.

Tracing Starting-Motor Circuits

See Fig. 3: The battery supplies the current, therefore start with the **battery** (+) **terminal,** thence to starting switch, to terminal (**T**) on the motor, to the field-circuit. In this instance the field-coils or windings on the four field-poles are connected in "series parallel." The current divides when passing into the field-coils, and flows through the two field-coils on each side, then to the (+) main brushes, through the armature, through the grounded (−) main brushes, to the grounded (−) terminal of the battery, thus completing the circuit.

Sometimes the (+) brushes are grounded instead of the (−) brushes. In this case, the (+) terminal of the battery would be grounded instead of the (−) terminal, and the flow of current would then be from the (+) grounded terminal of the battery to the (+) grounded terminal of the motor brushes.

Sometimes the fields are grounded. In every instance, however, start with the (+) terminal of the battery where the source of current for the motor starts.

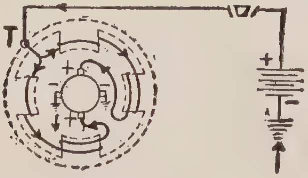

Fig. 3. Starting motor of the four-pole type, with the field-coils connected in "series parallel."

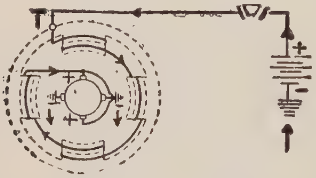

Fig. 4. Starting motor with the field-coils connected in "series."

See Fig. 4: This represents a four-pole motor with straight "series" field-winding. If the (−) brushes are grounded (they are, in this example), then **start with the (+) terminal of the battery.** The (+) brushes are sometimes grounded. The usual method, however, is to have the (+) current flow to the field-windings in a motor, although this is not always the case.

Tracing Generator Circuits

There are three circuits to consider always:

1. Field-circuit.
2. Voltage coil cut-out circuit.
3. Battery charging circuit.

The field-circuit is the winding around the field-poles, and is the circuit through which current passes to build up the magnetic lines-of-force around the field-poles. There is a slight amount of magnetic lines-of-force in the iron poles to start with (called "residual magnetism"); therefore as the armature revolves, it generates current from the lines-of-force and part (about 10 per cent) of the armature current flows through the field-windings. The faster the armature revolves, the greater the strength of the current in the field-coils; therefore the regulation of the field-circuit at high speed by cutting down the current in the field-coils is important, otherwise the armature would generate too great an output.

Under the subject of **"generator regulation"** this subject is fully treated. Three principles are involved:

1. Compound field (two windings and inherent regulation).
2. Shunt field, with external regulation system.
3. Shunt field with a third-brush or inherent regulation.

1. **The compound-field regulation** is explained on pages 354, 355, 356. There would be two field-circuits to trace.

2. **The straight "shunt-field" generator with an electromagnetic type of voltage[1] regulator is shown in** Fig. 5: The "shunt-field-circuit" would start with the source of current, which is the **(+) main brush of the generator,** to the regulator blade **(H),** to points **(E),** through the field-coils, to the (−) brush of the generator. If the generator speed is high, the points **(E)** will open and resistance **(M)** will be cut into the field-circuit, thus weakening it, through the generator speed producing a high voltage through the voltage winding **(H).**

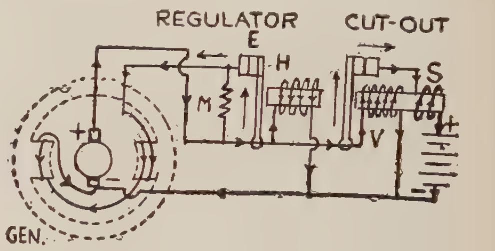

Fig. 5. Shunt-field generator using an electromagnetic voltage regulation.

The cut-out "voltage winding" circuit (V) is from the (+) main generator brush, back to the (−) main brush. This would be the next circuit. This builds up magnetism around the cut-out core.

The charging circuit to the battery is the next circuit, which is **from the (+) main brush of the generator,** through the blade and points of the cut-out, to the cut-out series or "current" coils **(S),** to the (+) terminal of the battery, to the (−) terminal of the battery, to the (−) main brush of the generator. At high speeds the voltage increases. Thus the regulator winding **(H)** exerts a magnetic pull on the blade, opening points **(E).** The shunt-field-circuit then has resistance **(M)** inserted in its circuit which reduces its strength.

3. **A third-brush regulated generator with a cut-out on top of the generator** would have its circuits as follows:

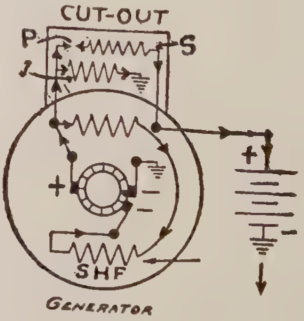

Fig. 6. Shunt-field generator using a third-brush regulation.

Shunt-field-circuit: Start with the (+) main brush of the generator, through the shunt-field-windings **(SHF),** to the (−) third brush. The third brush is always connected to one end of the field-windings and regulates the output of the generator at high speeds. It is sometimes on the (+) side of the armature.

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[1] You can instantly tell when an electromagnetic regulator controls the voltage, because its winding is finer, and it is placed across the circuit, as at (H) (Fig. 5). When the regulator winding is in series with the circuit, it controls the amperage or current, and is usually of heavier wire.

The cut-out voltage winding circuit (V) **is from the (+) main generator brush,** to the cut-out fine wire voltage winding (V), through the grounded end of this coil (V), back to the (−) grounded main generator brush.

Charging circuit to battery: When the generator voltage reaches about 6.5 volts, or above battery voltage, the voltage coil (V) has sufficient magnetism in its core to close cut-out points (P). The charging circuit will then be **from the (+) main generator brush,** through cut-out points (P), through the cut-out series, or current winding (S), to the ammeter (not shown), to the (+) terminal of the battery, to the (−) grounded terminal of the battery, to the (−) grounded main brush of the generator.

If the (+) main brush of the generator was grounded, then the circuit would start at the **grounded (+) brush of the generator,** which would be the reverse of the circuit described. The (+) terminal of the battery would then be grounded.

Tracing Ignition Circuits

This circuit includes:

1. Ignition coil.
2. Interrupter.
3. Distributor.

Coil windings: There are two windings, the primary and the secondary (Fig. 7). The current must first flow through the primary winding.

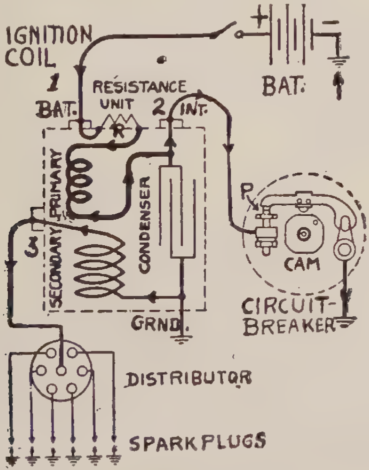

Fig. 7. A simplified diagram explaining how to trace the ignition system.

Coil terminals: Some coils have 3 or 4 terminals (see page 209). Most of the coils use 2 terminals as in Fig. 7.

Note. When referring to the number of the coil terminals, the secondary terminal is not considered.

Primary and interrupter circuit: Suppose the (−) terminal of the **battery and generator** was **grounded.** The flow of current would then be **from the (+) side of the ignition switch,** which is usually connected to the circuit at the ammeter. The current path would then be from (+) of the battery (or the generator if running fast enough to charge the battery), to the switch, through ignition resistance (**R**) on the coil, through the primary winding, out terminal (2), through the insulated and stationary interrupter point, through the grounded interrupter point and arm, to the (−) grounded terminal of the battery or generator.

If the (+) terminal of the battery and generator was grounded, then the circuit would be **from (+) of the battery,** to the grounded arm of the interrupter, through points (**P**), through the primary winding and resistance (**R**), to the switch, to the (−) terminal of the battery or generator.

Note that the interrupter is for a four-cylinder engine, because there are four high points on the cam. Thus it will raise the arm four times during one revolution.

The condenser is across the circuit of the interrupter points, as one end of the condenser is also grounded. (See Index for the construction and purpose of the condenser.) Condensers are often placed in the interrupter housing.

The secondary circuit is an induced current in the secondary winding from the primary winding, and would flow **from the secondary terminal** (3) to the distributor, through the spark-plug points, through the engine frame which would be termed a ground, to the grounded end of the secondary fine wire winding (**GRND**).

Note. In Fig. 7, owing to an error in drawing, a 6-cylinder distributor is shown. It should be a 4-cylinder distributor.

The primary and secondary coil windings are supposed to be on one soft iron core.

The foregoing explanation will give an idea as to the method of procedure in tracing wiring diagrams. All wiring diagrams do not have arrow points showing the path of the circuits. It is therefore necessary to make a point of starting with the **source of supply** of electric current which is **(+) of the battery or generator.** If (+) is grounded, then start at (+) just the same, and go to the grounded end of the part of the circuit you are tracing.

Tracing the Lighting Circuits

See Index under "Wiring diagrams."

ADDRESSES OF MANUFACTURERS OF ELECTRIC SYSTEMS

"Apelco": C. F. Splitdorf, Newark, N.J.
"Auto-Lite": Electric Auto-Lite Co., Toledo, Ohio.
"Bendix": Eclipse-Bendix Mfg. Co., Elmira, N.Y.
"Bosch": American Bosch Magneto Co., Springfield, Mass.
"Bijur": Bijur Motor Appliance Co., Hoboken, N.J.
"Dixie": C. F. Splitdorf Co., Newark, N.J.; Cutler-Hammer Co., Milwaukee, Wis.
"Detroit Ward-Leonard": Detroit Starter Co., Detroit, Mich.
"Disco": Disco Electric Starter Co., Detroit, Mich.
"Dyneto": Dyneto Electric Corp., Syracuse, N.Y.
"Delco": Dayton Engineering Laboratories, Dayton, Ohio.
"Eisemann": Eisemann Magneto Co., 32 Thirty-Third St., New York City, N.Y.
"Gray & Davis": American Bosch Magneto Co., Springfield, Mass.
'Heinze": Heinze Electric Co., Lowell, Mass.
"GE": General Electric Co., Schenectady, N.Y.
"Leece-Neville": Leece-Neville Co., Cleveland, Ohio.
"North East": North East Electric Co., Rochester, N.Y.
"Owen Magnetic": R. & L. Baker Co., Cleveland, Ohio; General Electric Co., Fort Wayne, Ind.
"Remy": Remy Electric Co., Anderson, Ind., and Detroit, Mich.
"Rushmore": American Bosch Magneto Co., Springfield, Mass.
"Simms-Huff": Simms Magneto Co., East Orange, N.J.
"Splitdorf": Splitdorf Electrical Co., Newark, N.J.
"U.S.L.": United States Light and Heating Corp., Niagara Falls, N.Y.
"Westinghouse": Westinghouse Electric Mfg. Co., Springfield, Mass.
"Wagner": Wagner Electric and Mfg. Co., St. Louis, Mo.
"Ward-Leonard": Ward-Leonard Electric Co., Bronxville, N.Y.

Parts and repairs for all electrical systems can be secured of A. L. Dyke, Elect. Dept., Granite Bldg., St. Louis, Mo. See also advertisement of Wiring Manual and Service Manuals in the advertising pages of this book.

REMY ELECTRIC SYSTEM ON STUDEBAKER "EJ"

Studebaker (Model "EJ") Circuits

Starting motor: From the (+) ground of the battery to the (+) grounded motor brushes, to the (−) brushes, to the field coils, to the starting switch, to the (−) of the battery. A Bendix drive is used.

Generator field-circuit: From the (+) brush of the generator, to ground (G) of the thermostat, to the field coils, to third brush (3B).

Cut-out voltage circuit: From the (+) grounded brush of the generator, to ground (G) of the voltage coil, through cut-out series coil (S), to the (−) main generator brush.

Generator charging circuit: From the (+) grounded brush (G) of the generator, to the (+) ground of the battery (GB), to the starting switch, through the ammeter, to cut-out points (P), to cut-out series coil (S), to the (−) main brush of the generator.

Regulation of the shunt field of the generator is by means of a third brush.

Ignition primary circuit: From the (+) ground of the battery (GB), or the (+) ground of the generator (G), to ground (G) of the contact-breaker, to arm (A), to points (P), to primary coil winding (PR), through ignition resistance unit (RES), to the switch, to the ammeter, to the generator (−) brush, through the cut-out if the generator is supplying current, or from the ammeter to the (−) terminal of the battery, if the battery is supplying current for ignition, as is the case when starting.

The secondary circuit is from the secondary winding of coil (SC), to the distributor, to the spark plugs, to ground, to the grounded end of the secondary winding.

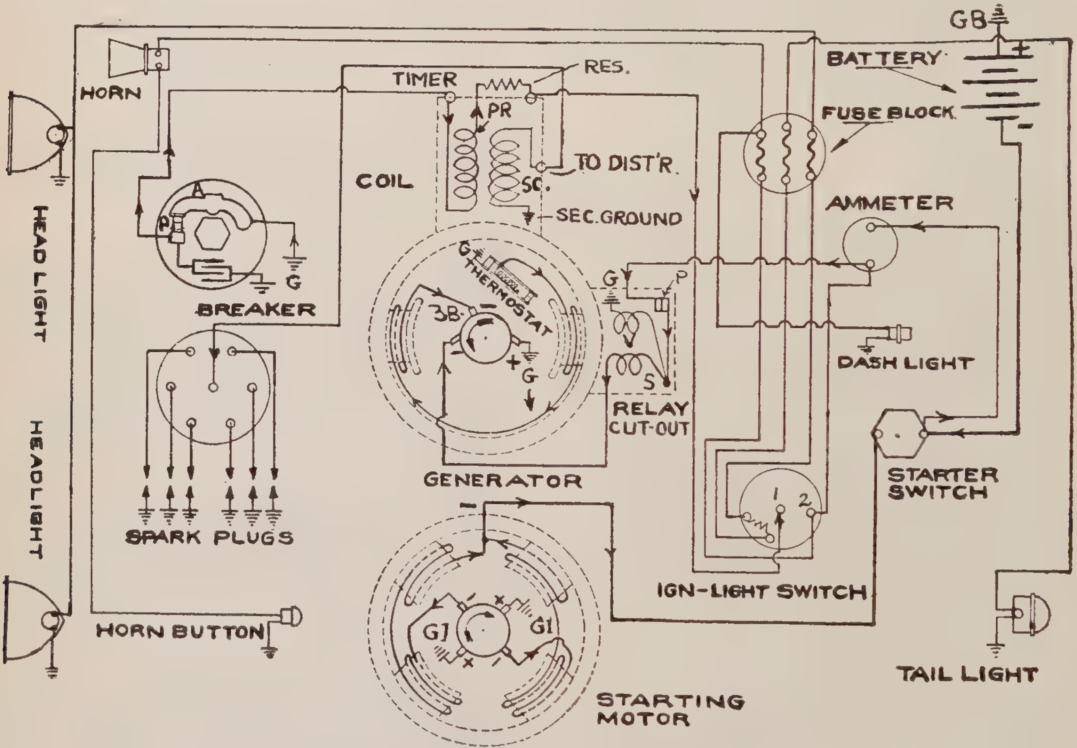

Fig. 8. Wiring diagram of the Remy-Studebaker model "EJ" electric system.

STUTZ SERIES "K": REMY GENERATOR AND MOTOR; DELCO IGNITION

Remy generator and starting motor with Delco ignition together constitute the system used on this car. The distributor principle is similar to that on the Pierce-Arrow, explained on page 216.

Stutz (Series "K") Circuits

Starting-motor circuit: From (+) ground (GB) of the battery, to (+) ground (G) of the starting motor brushes, through the field coils, to the starting switch, to the (−) terminal of the battery.

Generator field circuit: From the (+) main brush of the generator, to ground (G2) of the cut-out (relay), through fuse (F), through the shunt-field winding, to the third brush.

Cut-out voltage circuit: From the (+) generator brush, to ground (G2), through cut-out voltage coil (V), to cut-out series coil (S), to the (−) main brush.

Generator charging circuit: From the (+) main brush of the generator, to the (+) grounded terminal of battery (GB), through the ammeter, to cut-out closed points (P), through series coil (S), to the (−) main brush of the generator.

Ignition primary circuit (intake coil): From (+) ground of the battery, if starting, or (+) ground of the generator, if the generator is running at proper speed, to ground (G) of contact-breaker points at top, through points (P), through ignition resistance unit (R), through primary coil (P), to switch (6), to (B), to the ammeter. If the current is from the battery, then through the ammeter, which will show "discharge," to (−) of the battery. If the current

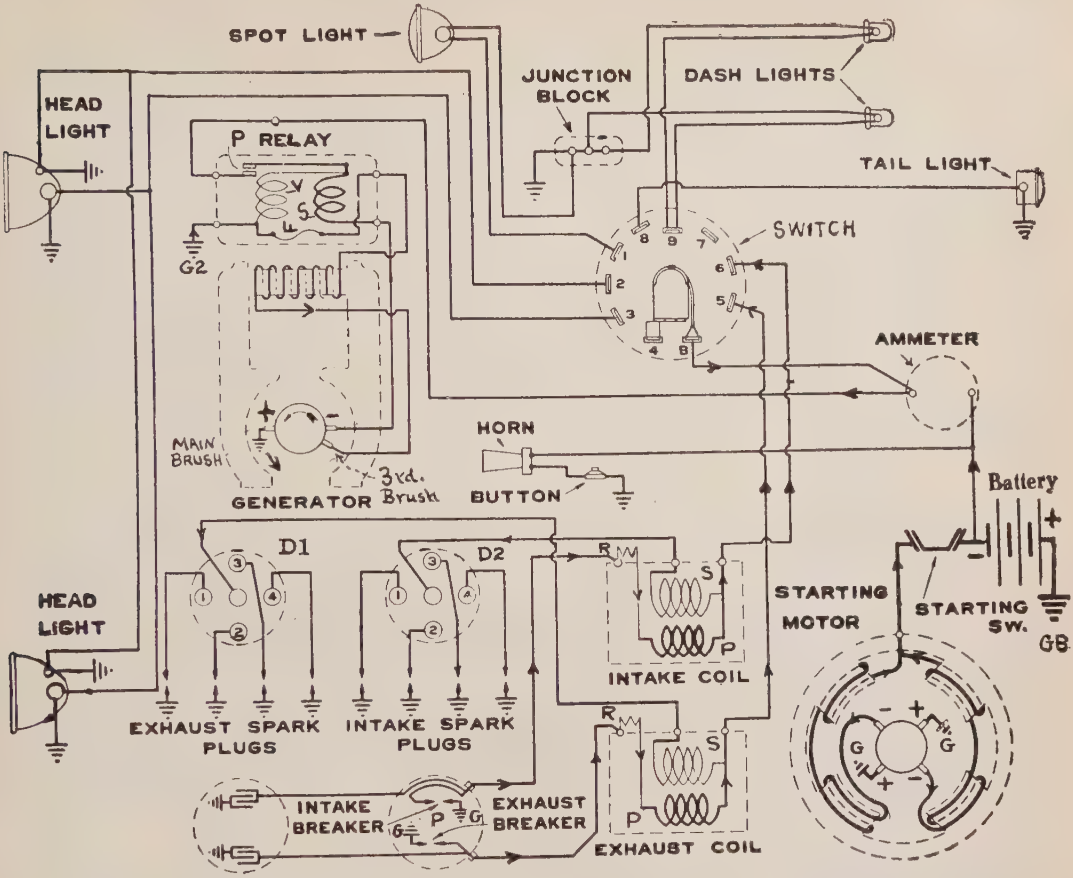

Fig. 9. Circuit diagram of Stutz series "K."

is from the generator, then from the ammeter, to the cut-out, to the (−) brush of the generator.

Ignition primary circuit (exhaust coil): The circuit is exactly the same as for that of the intake coil, except that contact-breaker points for exhaust coil are at the lower part of the interrupter, and circuit is through the lower, or exhaust coil, to (5) on switch. From this point it is the same as previously described.

The secondary circuit from the secondary coil (**S**) on both coils can easily be traced to the center terminal of the distributor, to the spark plugs, to ground, to ground of the battery or generator, to (**B**) on the switch, then to (5) and (6), to the other end of the secondary winding. (The contact points on the interrupter are open when the secondary spark occurs at the spark plugs. The circuit could not, therefore, pass back through this side.)

The Stutz engine is a dual-valve engine. The intake valves are on one side of the cylinder and the exhaust valves on the other.

There are two spark plugs per cylinder: one on the intake side, and the other on the exhaust side. See explanation of the Pierce-Arrow (Delco) ignition distributor on page 216, which is similar.

REMY ELECTRIC SYSTEM ON OAKLAND "34C," McLAUGHLIN "K-62," AND "K-63"

Circuits

Starting motor: From (+) of the battery, to the starting switch, to the series field-winding, to the (+) motor brushes, to the (−) grounded motor brushes, to (−) ground of the battery.

Generator field-circuit: From the (+) main brush, through (closed) thermostat points (**R**), through the shunt-field-windings, to the third brush.

Cut-out voltage circuit: From the (+) main generator brush, to cut-out coil (**C**), to voltage coil (**V**), to the (−) main generator brush.

Generator charging circuit: From the (+) main generator brush, to cut-out series coil (**C**), through (closed) points (**P**), to ammeter (**A**), through the ammeter to (**M**), to (+) of the battery, to (−) ground of the battery, to (−) ground of the generator (**GG**), to (−) main grounded brushes (**G**).

Ignition primary circuit: From (**A**) on the ammeter, which takes current direct from the generator without passing through the ammeter, if the generator is supplying current, or from (**A**) to (**M**), through the ammeter, which would show "discharge," if current is taken from the battery, to (1) on the switch, to (2), to the ignition resistance unit, to primary winding (**PR**), to the insulated contact-breaker terminal, through points (**P**), through arm (**A**), to ground (**G**), to (−) ground of the generator or battery.

Secondary ignition circuit: From secondary winding (**SC**), to the distributor, to the spark plugs, to ground, to the grounded end of the secondary (**G**).

The condenser is in the coil and across the points of the contact-breaker.

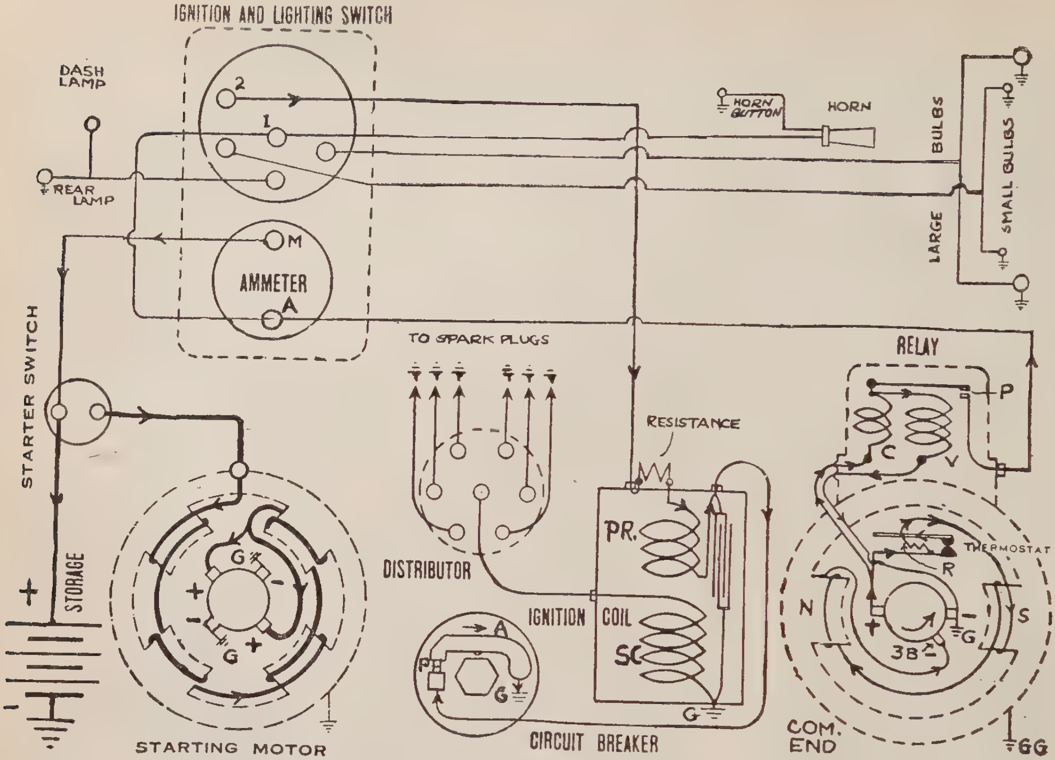

Fig. 10. Wiring diagram of Oakland "34-C" and McLaughlin "K-62," "K-63" (Remy system).

OVERLAND "4" ELECTRIC SYSTEM

Electric system: Auto-Lite two-unit, 6-volt starting and lighting system, with Bendix drive. U.S.L. Battery, 6-volt, 80-amp. hour. Model GK 1001 generator with third-brush regulation. Starting motor model MG 1001.

Ignition: Connecticut timer and distributor driven from the armature shaft of generator (Figs. 12 and 13).

See page 40 for engine illustration and description.

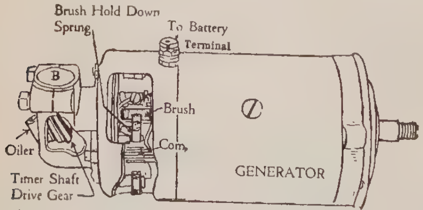

Fig. 12. Generator, driven from the right side of the engine, by helical gears, from the crank shaft.

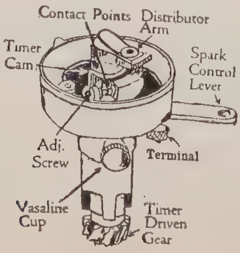

Fig. 13. Timer, driven from the armature shaft through opening (B, Fig. 12) by helical drive gear.

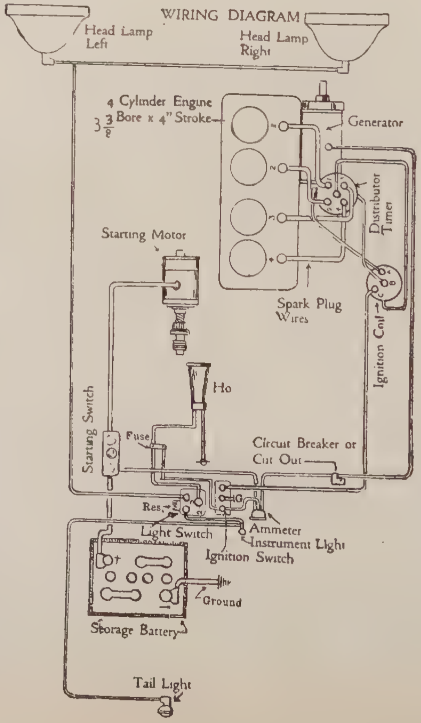

Fig. 14. External circuit of the electric system on Overland "4."

Overland "4" Circuits

Generator field-circuit: From the (+) third brush of the generator, through the field windings, to the (−) main brush.

Cut-out voltage circuit: From the (+) main brush, to the fine wire voltage winding (V) on the cut-out (circuit-breaker), to ground, to the (−) main grounded brush of the generator.

Generator charging circuit: From the (+) main brush of the generator, through cut-out points (P), to cut-out series coil (S), through the ammeter, to the (+) terminal of the battery, to the grounded (−) terminal of the battery, to the (−) grounded brush of the generator.

Starting-motor circuit: From the (+) terminal of the battery, through the closed starting switch, to the terminal on the starting motor, through the two "series parallel" windings on each side, to the (+) brushes, through the armature, to the (−) grounded brushes, to (−) ground of the battery.

Primary ignition circuit (from battery when starting): From (+) of the battery, to (D), to the ignition button switch, to the thermostat switch,[1] through wire (I) to the primary winding of the ignition coil, to the timer (contact-breaker of the closed-circuit type), through the timer points, to the ignition coil where the primary and secondary windings are grounded, thence to ground (G1), to (−) ground of the battery. On the circuit just described, the ammeter would not indicate, as the current is flowing **from** the battery, but not through the ammeter.

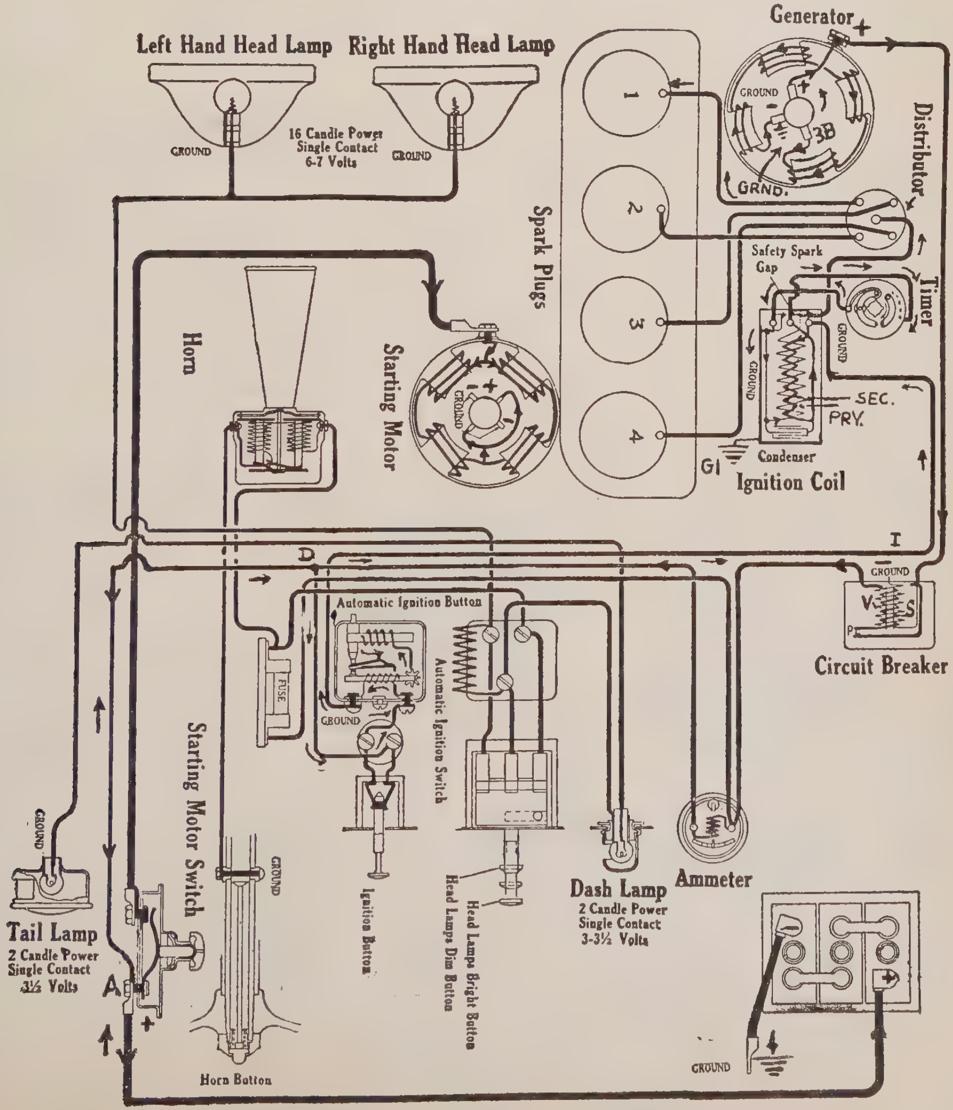

Fig. 11. Wiring diagram of the Overland "4"; Auto-Lite electric system.

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[1] The "Connecticut ignition thermostat switch" is illustrated and described elsewhere. See Index.

Primary ignition circuit (from generator): From point (**D**), which takes current from the generator which must pass through the ammeter. Thus the ammeter would read on the "charge" side, because the current would be flowing from the generator to the battery, and the ammeter is between point (**D**), where the ignition is taken, and the generator. The rest of the circuit would then be the same from point (**D**), as explained above.

Light circuits, if from battery, would be from (+) of the battery, to the ammeter, then through the ammeter, to the inside wire at the right-hand connection of the ammeter, to the fuse, thence to the lighting switch, through the different lighting circuits. The ammeter would read on the "discharge" side.

If current for lights comes from the generator, then start with (+) of the generator, to the cut-out, to the ammeter (but not through the ammeter), to the wire from the same connection on the ammeter, to the fuse, and from this point on, as before. In this instance, the current for lights would not pass through the ammeter, but the generator would be charging the battery and supplying current for lights and ignition also. Thus the ammeter would read on the "charge" side, indicating the amount of current flowing to the battery and used for ignition.

Data Concerning Overland "4" Electric Equipment

Battery: USL CD 311, 11-plate, 6-volt, 80-ampere hour capacity; located underneath driver's seat.

Generator: Auto-Lite GK 1001, 4-pole, third-brush regulation type; mounted on right front side of engine.

Starting motor: Auto-Lite MG 1001, 4-pole type; mounted at side of engine.

Cut-out: Auto-Lite CB 1069, rectangular type; mounted on right gasoline tank bracket.

Switches: Auto-Lite XA 265 for ignition and lights, and resistance coil to dim head lamps, and with ignition cut-out; mounted on instrument board.

Starting switch: Auto-Lite SW 1600, mounted on left frame member, with button protruding through toe board in front of driver's seat.

Current indicator (**ammeter**): Auto-Lite XA 191, mounted on instrument board.

Ignition: Battery ignition, Connecticut GA type, spark coil with timer and distributor; mounted on right side of engine.

Horn: Vibrator type, mounted on left side of engine; control button on top of steering column.

Lamps: Four; head lamps, single-bulb, single-contact, 6-volt, 16-candle power; dash and tail lamps, single-contact, 3-volt, 2-candle power.

Fuse block: For lights; mounted on left gasoline tank bracket.

DELCO ELECTRIC IGNITION ON PACKARD "SIX," MODEL 116-1921

The Delco ignition is used on this car, but **Atwater Kent starting motor and generator** are provided for generating current and for starting.

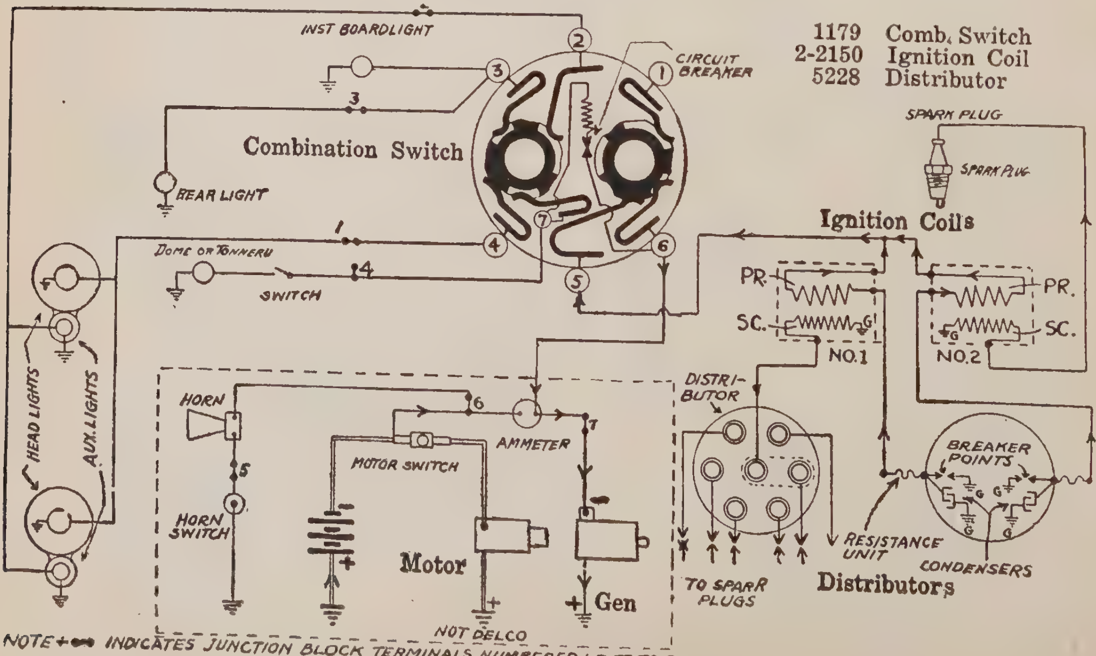
Packard (Model 116) Circuits

Starting motor: From (+) ground of the battery, to (+) ground of the starting motor, to the switch, to (−) terminal of the battery.

Generator charging circuit: From (+) ground of the generator, to (+) ground of the battery, to (6), through the ammeter, to (7), to (−) terminal of the generator.

Primary ignition circuit (battery): From (+) ground of the battery, to grounded (**G**) contact-breaker points (on the left), through the ignition resistance unit, to primary winding (**PR**) of the ignition coil No. 1, to (5) on the switch, to (6), through the ammeter, to (−) terminal of the battery.

Primary ignition circuit (generator): From (+) ground of the generator, to contact-breaker-point ground (**G**) on the left, and through the same path, but to the (−) generator terminal instead of to the battery.



NOTE ←•→ INDICATES JUNCTION BLOCK TERMINALS NUMBERED LEFT TO RIGHT

Fig. 15. Wiring diagram of the Delco-Packard (model 116) electric system.

Secondary circuit to ignition spark plugs: From secondary winding (SC), on coil No. 1, to the distributor rotor, to the spark plugs in the engine, to ground, to ground (G) of the secondary winding.

Fuelizer ignition coil is No. 2. This coil is used for the single spark plug used in the Fuelizer. (See pages 108 and 140 for an explanation of the Fuelizer.)

The primary circuit is the same as for the other coil, except that the contact-breaker points on the right of the contact-breaker are used.

The contact-breaker and distributor for this system are shown on page 219. Note that two sets of interrupter contacts are provided, each set being connected in series with a separate ignition coil.

PACKARD "TWIN-SIX" 1920-1921 ELECTRIC SYSTEM

The Delco ignition is used on this car. **Bijur generator and starting motor** are used. See also pages 217, 84, 85, 86, for other illustrations pertaining to the Packard "Twin-Six."

Packard "Twin-Six" (Models 325, 335) Circuits

Charging circuit: Start with the generator (+) grounded terminal, to (+) ground of the 6-volt, 120-ampere-hour battery, to combination switch (6), through the ammeter, to (−) terminal of the generator.

Ignition circuit: Start with (+) ground of the battery if the engine is running slow, or with (+) ground of the generator if the generator is charging the battery, to ground of interrupters (CP), but first through the resistance units.

Note that there are **three interrupter points** (CP), 1, 2, and 3. The Nos. 1 and 2 are for the No. 1 and No. 2 coils and distributors, and 3 is for the No. 3 coil and spark plug (3P) for the fuelizer. See also, pages 140, 217, giving an explanation of "Fuelizer" and "Distributor."

The engine ignition primary circuit of No. 1 distributor is through ignition resistance unit (R1), through contact points (CP–1), through primary coil (1), to junction (J), to the ignition switch, to 5 and 6, to (−) of the battery or generator. Note condenser (1) is connected across the points (CP–1). If the current is from the battery, it will not pass back through the ammeter. If current is coming from the generator, it will pass through the ammeter, but as the generator would then be charging the battery, the ammeter would indicate the current flowing from generator to battery and the ignition, and would indicate on the "charge" side of the ammeter.

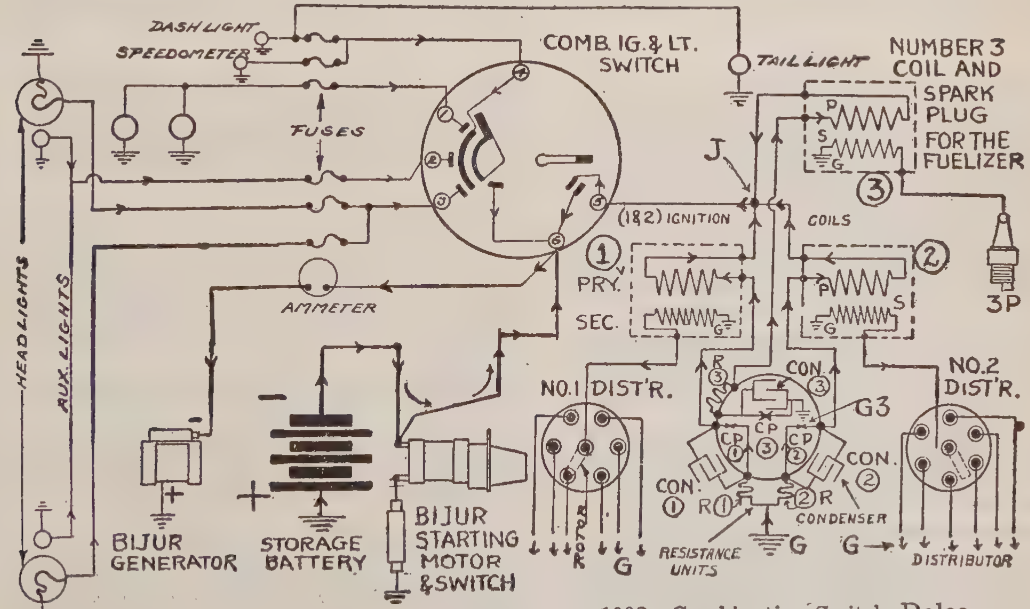
Secondary circuit of No. 1: From the secondary winding on coil (1), to the distributor arm or rotor, to the spark plugs, to ground, to grounded secondary terminal (G) on No. 1 coil.

Engine ignition primary circuit of No. 2 distributor is similar, except that the circuit is through resistance (2R), through points (CP–2), through primary winding (P) of coil 2, to junction (J).

The secondary circuit of No. 2 is similar to that of No. 1, except that it passes to No. 2 distributor.

The fuelizer ignition primary circuit is from (+) of the battery or generator, to ground (G3) of the interrupter, through points (CP–3), through resistance (R3), to primary winding (P) of coil 3, to junction (J), to switches (5 and 6), to (−) terminal of the battery or generator.

The secondary circuit for the fuelizer spark plug is from (S), coil 3, to spark plug (3P), to ground, to ground (G) of coil 3.



1092	Combination Switch-Delco
3-2150	Ignition Coil .... "
5220-5238	Distributor .... "

Fig. 16. **Packard "Twin-Six" wiring diagram:** Note the twin or dual set of interrupters. The breaker arms are operated by one three-lobe cam. There are three high-tension coils, one used for ignition for the right block of the cylinders, and the second, for the left block. The third coil (3) is used in connection with a spark plug (3P) in the fuelizer. An auxiliary contact-breaker mechanism, mounted on top of the distributor, is connected with the latter.

Starting-motor circuit: From (+) of the battery, through ground, to the ground terminal of the starting-motor switch, through the starting switch, through the starting motor, to (−) terminal of the battery.

The automatic gear-shift principle, connected with a flywheel is used. The starting motor is a 4-pole, series-wound motor.

Regulation of the output of the generator consists of a constant voltage electromagnetic device which cuts resistance into the shunt-field circuit. The generator regulator keeps a constant electrical pressure or voltage, slightly higher than the voltage maintained by a fully charged battery, this pressure being maintained regardless of speed.

The voltage being constant, the current generated naturally varies, being small when the battery is fully charged and increasing as the lights are turned on or the battery is partially discharged.

The cut-out is a reverse-current electromagnetic type of the usual cut-out principle. The generator field-winding is a straight shunt winding.

The cut-out and regulator are wound on separate cores and mounted on top of the generator. The circuit is not shown but is shown in the Wiring Manual, details of which will be found in the advertising pages of this book.

Fuse Board

All lamp circuits and the horn circuit pass through the fuse board on the front side of the dash. When the horn or lamps fail, examine the fuses. If the fuse is in proper order, then look for loose wires.

Fuses are of the glass-tube type. If fuses continually blow, look for a short circuit as the cause.

Ammeter

The ammeter is located on the instrument board. It is connected between the generator and battery through the switch; thus, with the engine idle, the ammeter does not indicate whether the lights are on or off. Should it register to the left of zero with the engine idle, remove the disconnect plug from the regulator, to prevent discharging the battery.

When the engine is running, the ammeter registers the amount of charging current passing from the generator to the storage battery and lights.

If the ammeter fails to register when the engine is running at about 750 revolutions, or over 20 miles per hour, look for loose connections or broken wires between the generator and battery; also see that the generator commutator is clean and that the brushes are making good contact.

If the ammeter shows a high current continuously of 25 or 30 amperes, it indicates a heavy ground or short circuit in wiring or battery. Disconnect the battery to prevent discharging, and examine the wiring for short circuits.

Electric Lighting

Light circuits can be traced by starting with (+) of the battery or generator, to ground of the lamps, through the fuses, through the switch terminals, to (−) of the generator or battery.

Auxiliary headlights are smaller than the headlights. They are placed in front, to be used in place of headlights. The headlights are 24 c.p., 7-volt and the auxiliary headlights are 6 c.p., 7-volt. See diagram of wiring. They are sometimes called dimmer lights.

REMY ELECTRIC SYSTEM ON OAKLAND "32" AND McLAUGHLIN "D-60"

The Remy "relay-regulator" system, described on page 350, was used on these cars (1916). The system is shown here in order to give an example of the Remy relay-regulator in connection with a plain shunt-wound four-pole generator using an "electromagnetic current regulation" of the shunt-field-circuit. See Fig. 17 on the next page.

Circuits

Generator: Plain shunt wound, with an electromagnetic vibrating-current type of regulator (see also page 350). This regulator is operated by the amount of current flowing from the generator to the battery through the regulator winding (D). It would thus be termed an electromagnetic "constant-current" regulation method.

Generator shunt-field circuit: From the (+) main brush of the generator, to the fuse, to (Y), to closed regulator points (E), to (H), to the shunt-field windings, to (−) main brush (G) of the generator.

Note. This is **not a third-brush regulated generator,** although there are three brushes. The brush on the left is used for grounding purposes. All brushes bear on neutral points of the commutator, and are therefore "main brushes." See, also, page 359.

Cut-out (relay) voltage circuit: From the (+) main brush of the generator, to the fuse, to (Y), to cut-out voltage coil (J), to ground (G1), to the (−) grounded generator brush.

Generator charging circuit: From the (+) main brush, to the fuse, to (Y), to closed cut-out (relay) points (A), through cut-out series coil (C), through regulator winding (D) (note that the charging circuit flows through the **regulator** winding), to (K), to the fuse block, through the ammeter, to (+) terminal of the battery.

When the generator speed is high, the regulator comes into action by cutting resistance (F) into the shunt-field circuit of the generator, thus reducing the magnetic strength of the field, and consequently also the output of the generator. The action is as follows: from the (+) brush, to (Y). Points (E) are now open, because of the high charging current value flowing through regulator coil (D), drawing points (E) apart. Thus the field circuit must then pass from (Y), through resistance (F), to (H), to the other end of the field winding.

Note. It will be noted in the diagram that half of the resistance coil (F) is shunted across one set of regulator points, and half across the other set (there are two sets of regulator points). It is essential that the two sets be adjusted equally, so that the same current through regulator coil (D) will separate both points at the same time; otherwise the generator output will be high. See Index for Remy "relay-regulator" adjustments, etc.

Ignition primary circuit (from battery, when starting): From (+) of the battery, to the ammeter, to the fuse block, to switch (Z), to (I), to primary winding (P) of the coil, to the contact-breaker (closed-circuit type), to the right terminal on the coil, to the switch, to ground (G3), to (−) ground of the battery.

The ammeter would now read on the "discharge" side, as the current is coming from the battery.

Note. This switch is termed a **"pole-changing"** switch. If switch blades (B) and (B1) were reversed, the current would flow through the contact-breaker points in the opposite direction. See page 203, explaining this type of switch.

Ignition primary circuit (from generator): The current would be taken from the fuse block, to (Z), and the same path would be followed. The ammeter would not indicate the ignition current, but would indicate the amount of current going to the battery.

Starting-motor circuit: From the (+) terminal of the battery, to the starting-motor straight-series field-winding, through the field-windings, to the (+) brushes, through the armature, to the grounded (−) brushes, to (−) ground of the battery (G2).

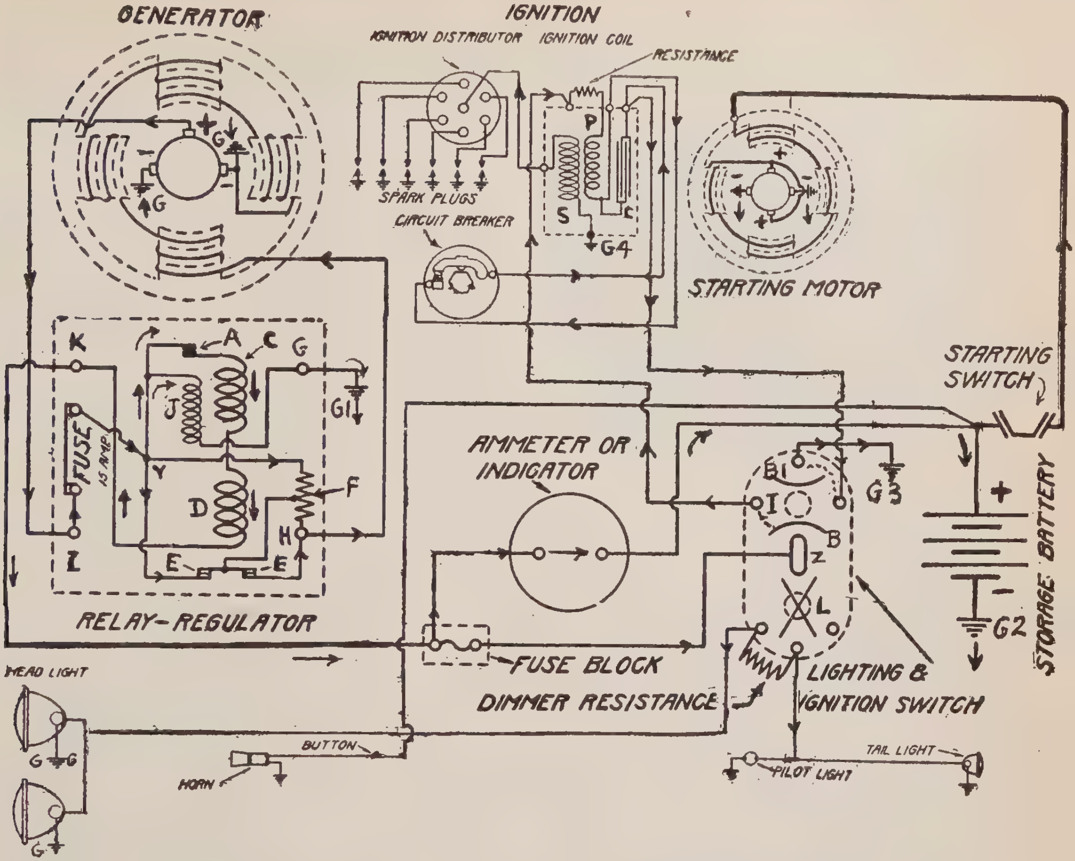


Fig. 17. Wiring diagram of the Oakland 32 and McLaughlin "D-60" explaining the Remy "relay-regulator" and the "pole-changing" switch (see Index for these subjects).

FRANKLIN (Up to July, 1921) ELECTRIC SYSTEM

The Franklin air-cooled, six-cylinder engine automobile electric system used on models "9A" and "9B" until July, 1921, is shown in the illustration (Fig. 18). Note that the **ignition system** is the Atwater-Kent **open-circuit** type. A master vibrator is used for starting purposes.

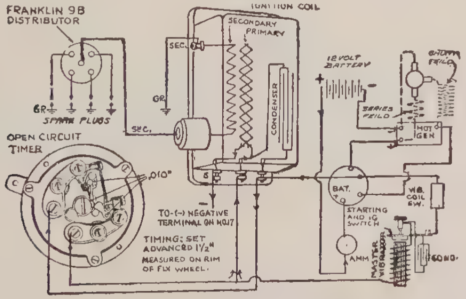


Fig. 18. Franklin electric system.

On later models, the Atwater-Kent **closed-circuit** ignition system is used, and the master vibrator is dispensed with. Instead, the switch is so arranged that on starting position, it cuts out a part of the primary coil winding, thus lowering the resistance of the coil, so that in cold weather, when the battery is used excessively for starting and is more or less weak during these periods, the ignition coil resistance is cut down, as mentioned above, and the spark is sure to occur. After starting, and when the battery is "boosted up" by the generator, the switch movement cuts in the full primary coil winding.

Motor-generator: The 12-volt single-unit **Dyneto motor-generator** is used. The motor-generator is directly connected to the crank shaft of the engine. The motor-generator acts as **a generator** at car speeds over 8½ m.p.h., and as **a motor** at speeds below this point.

The current output is regulated by a compound winding "differential in action," consisting of a series and a shunt-field winding which oppose, or "buck," each other, as a generator. This is termed "differential action," and the windings assist each other as a motor, or "cumulative action."

The regulation is also by a "third brush," which reduces the voltage through the shunt-field winding, which, in turn, is caused by "armature reaction" at high speeds.

Starting motor: A Dyneto motor-generator connected to the crank shaft of the engine by a silent chain; operated from the cowl board by the same switch that controls the ignition.

Generator: A Dyneto motor-generator; shunt winding, and a series-field winding are both used for the generator.

Ignition: Atwater-Kent open-circuit timer and distributor, using a box type of coil, with a condenser in the coil. A master vibrator is used for starting, which gives a continuous series of sparks instead of a single spark operated by a switch on dash. The distributor rotor takes care of the time at which the spark occurs. This device is used only for starting purposes.

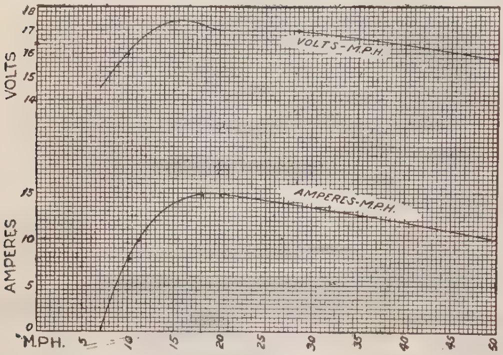


Fig. 19. The diagram or curve shows the voltage and amperage at various speeds of the car.

For instance, at a speed of 10 m.p.h. (lower line of figures), the amperage is 8 amperes; the voltage is 16 volts. At 18 m.p.h., the highest amperage peak is reached, which is 15 amperes, and at this speed, the voltage is 17 volts. The highest voltage is reached at 15 m.p.h.

The voltage begins to drop at a car speed of 28 m.p.h. (from 17 volts to slightly below 16 volts at 50 m.p.h.). The amperage begins to drop at 20 m.p.h., from 15 amperes to 10 amperes, at 50 m.p.h.

Circuits

Starting motor: From (+) of the battery, to the indicator,[1] through the indicator, to the switch, to the (+) terminal on the motor-generator, through the field-windings, to the (+) brush, through the armature, to the (−) brush, to the (−) terminal of the battery.

Generator shunt-field circuit: From the (+) main brush, or terminal of the motor-generator, to the switch, to the connection on the lower right of the switch, through a fuse (not shown), to the terminal on the motor-generator connecting with the shunt-field winding, to the (−) main brush of the generator. A 10-ampere fuse is in series with the shunt-field circuit.

Generator charging circuit: From the (+) main brush, to the switch, through the current indicator marked (**AMM**), to (+) of the battery, through the battery, to the (−) battery terminal, to the (−) brush of the motor-generator.

Ignition master-vibrator circuit: This ignition system is equipped with a master-vibrator coil which is used for starting. There is only one winding (primary) on this coil. When the switch or starting circuit is closed, the current is from (+) of the battery, to the switch, to the right-hand switch terminal, to the vibrator blade of the master vibrator, to the vibrator screw, to the primary winding of the master vibrator, to the lower center terminal of the coil, through the coil primary winding, to junction block (No. 17) which connects with (−) of the battery. This master vibrator gives a continuous succession of sparks to start with, and the distributor takes care of the time of the spark to the engine. The switch is thrown to the regular ignition after the engine is under way, and when the generator is "boosting" the battery.

The primary ignition circuit of the ignition coil is from the battery or generator at the right-hand switch terminal in the illustration, to the left, to the first terminal on the coil, to the timer, through the points, to the center coil terminal, to the primary winding of the coil, to the left-hand coil terminal, to No. 17 on the junction block, to (−) of the battery.

The secondary ignition circuit is from the secondary winding, to the distributor, to the spark plugs, to ground, to ground of the secondary.

The ignition timing (Atwater-Kent open-circuit type): The timer is set so that it fires at 1½″ advance, measured on the rim of the flywheel.

To check timing: Remove the distributor cover and turn the engine over slowly until the click of the contact-maker is heard. Stop exactly at this point, raise the toe-boards, and see if any center line corresponds to the position of "C. L. 1–6" shown on the flywheel.

To reset timer: Turn the flywheel until No. 1 cylinder completes its compression stroke and the 1–6 center line is 1½″ ahead of the center point in the diaphragm (Fig. 20). Loosen the clamp screw in the aluminum base plate of the timer, so that the body can be turned in its bearing. For accurate setting, the body should be clamped tight enough to turn hard.

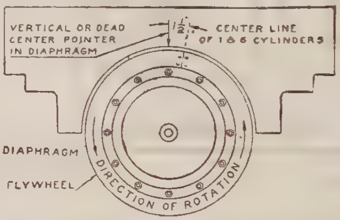

VERTICAL OR DEAD CENTER POINTER IN DIAPHRAGM
1½″
CENTER LINE OF 1 & 6 CYLINDERS
DIAPHRAGM
FLYWHEEL
DIRECTION OF ROTATION

Fig. 20. Flywheel markings for spark setting.

Turn the distributor-timer body in a clockwise direction until the distributor arm is opposite the terminal on the cover leading to No. 5 spark-plug wire. Then turn the body slowly and steadily counter-clockwise until the click of the contact maker is heard. Stop exactly at this point, and tighten the clamp screw.

Adjustment should then be checked by moving the flywheel backwards about 16″ on the flywheel rim, so that it is off the firing point. Then move ahead to the firing point again, and stop the moment a click is heard. If "C. L. 1–6" is then 1½″ ahead of the center pointer on the diaphragm, the timer is set right. Rewire the clamp-screw in the base plate.

Timer contact points are set .010″ apart on the open-circuit type, and .007″ on the closed-circuit type. To adjust the contact screw, take it out of the holder and remove one of the thin steel washers from under its head. This brings the points a little closer together (see also page 203). The points should be examined every 3,000 miles. **The spark-plug gap** should be set at .031″.

Firing order: 1, 4, 2, 6, 3, 5.

Master vibrator adjustment: When operating properly, the vibrator should buzz on an 8-volt circuit, i.e., on 4 cells of a fully charged storage battery. A more accurate way of setting the vibrator is to turn the ignition switch to "neutral" (the engine should not be running), take out whichever spark plug is firing at that time, and set the adjusting screw on the vibrator so that a spark of the highest possible frequency can be observed at the plug points. When the vibrator draws about 1.1 amperes on a fully charged battery, it will give the hottest spark.

For Franklin gear shift and controls, see Index. See the Index also for the Franklin engine.

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[1] An ammeter of the usual construction generally used, cannot be connected in series with a starting-motor circuit. An **"indicator,"** however, which is used on the Franklin, is so designed that it is capable of carrying the starting current. See pages 469, 468 for explanation of the construction of an "Indicator" and also of an "Ammeter."

INSTRUCTION No. 37

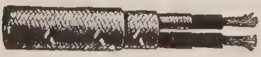
WIRING OF A CAR: Starting, Generating, and Lighting

KINDS OF WIRE USED FOR AUTOMOBILE ELECTRIC SYSTEMS

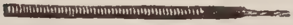
Primary wire is used for **low-tension** (voltage) work, such as for the ignition circuit, from switch to coil, and from coil to timer, and is also used for lighting circuits. See Fig. 1 below. It is flexible, consisting of several fine strands covered with a waterproof insulation.

When wiring is used for **lighting purposes,** it can be "duplex" (Fig. 2), or it may even consist of four wires together in one double-covered insulation.

1— PRIMARY WIRE—Single

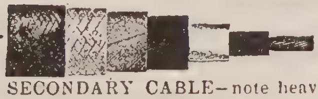


2— PRIMARY WIRE—Duplex

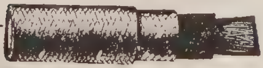


3— PRIMARY WIRE in metal armor

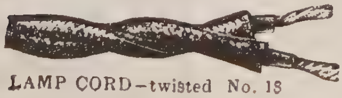
4— PRIMARY WIRE metal armor



5— SECONDARY CABLE—note heavy insulation



6— STARTING MOTOR WIRE note heavy wire



7— LAMP CORD—twisted No. 18

Flexible steel-armored wire is where the wire is protected by being covered in a **metal casing** (Fig. 3). This type of wire is extensively used for automobile work. It can also be secured in "duplex" form (Fig. 4). The wire cannot be withdrawn from the armor.

Secondary cable is used for **high-tension** ignition current from coil to distributor and from distributor to spark plugs. The wire itself is small and flexible, but the **insulation** (usually rubber) is **very heavy,** as it carries a high voltage, but a low amperage.

Starting-motor wire: This **wire** must be **very large,** because it carries a very heavy current. No. 0 is generally used on small and medium-sized cars, and No. 1 or 2, or 00, is used if the distance is greater; as on a large car. The No. 00 measures .36" diameter over the copper strands. This wire is flexible (Fig. 6), being made up of a large number of copper wire strands heavily insulated with rubber and with a braided cover over the rubber. This wire is much heavier than the secondary cable, as it carries a high amperage, but a low voltage.

For example, the **wire running from the storage battery to the starting motor,** when it is first starting, must carry from 80 to sometimes 400 amperes (the quantity of current, which depends on the size of the motor and condition of the engine). This is used only for a few seconds. But large wires must necessarily be used to carry this great quantity, even for a few seconds. Compare the size of the starting-motor wire (Fig. 6) with that of the primary wire (Fig. 1), which can be used for the generator or for lighting. Note the difference in size of the wire.

The wires running from the generator to the storage battery are much smaller (see Fig. 1), as the quantity of current which passes through this wire is only 5 to 25 amperes.

By way of a comparison, imagine water pipes. If you desired to pass 150 gallons of water through a pipe in one hour it would require a larger pipe than one through which you passed only 25 gallons in an hour.

Flexible lamp cord (Fig. 7.) is used **for extension or trouble lamps,** and is not suitable for any other part of the wiring system.

Voltage Drop and Wire Size

When current flows through a wire (conductor), a certain amount of pressure (voltage) is lost in overcoming the resistance that the conductor offers to the flow of current (amperage).

The greater the distance that current flows through a conductor, the greater the loss of pressure. This is known as **"voltage drop."**

The resistance of a wire depends upon two things: (1) the kind of metal in the wire (copper offers less resistance to the flow of current than iron); (2) the area or size of the wire. The resistance of a small copper wire is greater than the resistance of a large wire; that is, the resistance decreases as the size increases.

The size of wire to use depends upon the amount of current that must flow through it, and the length of the wire. The longer the wire, the greater the resistance offered to the flow of current. Therefore there will be too much drop in voltage at the wire terminus, if the wire is not of sufficient size.

A conductor must be large enough to carry the required amount of current to a certain point with less than 5 per cent drop.

Ohms multiplied by Amperes equals Voltage Drop.
Voltage Drop divided by Ohms equals Amperes.
Voltage Drop divided by Amperes equals Ohms.

Almost all automobiles are using a single wire with a grounded return system of wiring, and the length of wire in one direction is seldom over 12 feet.

Voltage Drop and Connections

All connections should be bright and clean, for a dirty connection will add **resistance,** and consequently will cause a **voltage drop.** Binding posts, screws, and the ends of the wire must be scraped clean before the wire is attached—this is very important, especially on low-voltage wiring.

Grounded connections should be filed or scraped bright before attaching the wire, and the connection when made should be firm in position—and tightly drawn up, otherwise resistance will be added, thus resulting in a **voltage drop.**

Ampere Capacity of Copper Wire

The carrying capacity of copper wires (B & S gauge)[1], as given by the National Board of Underwriters for rubber-covered wire, is shown opposite.

The higher the number, the smaller the wires. No. 0 is many times larger than No. 18. No. 18 is .04 or 3/64″ diameter; No. 0 is .32 or 5/16″ diameter.

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[1] B & S gauge means Brown & Sharpe gauge, and is a recognized standard.

Carrying Capacity of Copper Wire

No. 18	B & S gauge.	3 ampere
No. 16	B & S gauge.	6 ampere
No. 14	B & S gauge.	15 ampere
No. 12	B & S gauge.	20 ampere
No. 10	B & S gauge.	25 ampere
No. 8	B & S gauge.	35 ampere
No. 6	B & S gauge.	50 ampere
No. 4	B & S gauge.	70 ampere
No. 3	B & S gauge.	80 ampere
No. 2	B & S gauge.	90 ampere
No. 1	B & S gauge.	100 ampere
Nos. 1 & 0	B & S gauge.	125 ampere
Nos. 2 & 0	B & S gauge.	150 ampere

AVERAGE LENGTH AND SIZE OF WIRE USED FOR WIRING A CAR AND EXTERNAL CIRCUITS

An example of the size of wire used for wiring a car and the length for the different circuits of an average car is shown in the accompanying illustration, which is the wiring diagram of the Lexington Series "S" model (Fig. 8). Connections of the wires to the fuse block and other details are also shown.

Generator: Third-brush regulated Gray & Davis.

Starting motor: Gray & Davis.

Ignition: Connecticut system using type 96Y switch.

Wiring system: Single wire, grounded return.

Eight External Circuits of an Electric System

The diagram (Fig. 8) **clearly shows the eight external circuits.** The internal circuits of the generator, and its field-winding circuit and cut-out circuit are not shown. The cut-out is mounted the generator, but is not shown.

Starting-motor circuit: From the grounded (- terminal of the battery, to the grounded terminal the motor, through the starting switch, to the (- terminal of the battery.

The ignition circuit, when starting, is from grou (**G**) of the ignition coil, to coil terminal (**A**), throu the primary wire, to contact-breaker terminal (T through the closed contact-breaker points, to (E through the coil primary winding, to (C), throu a jumper (J) on the fuse block, through igniti thermostat (H) on the switch, to switch (1G to ammeter (1), through a jumper on the fu block, to the (−) terminal of the battery at t starting switch.

If the generator is supplying the ignition curren the circuit is then from (+) of the generator, throu

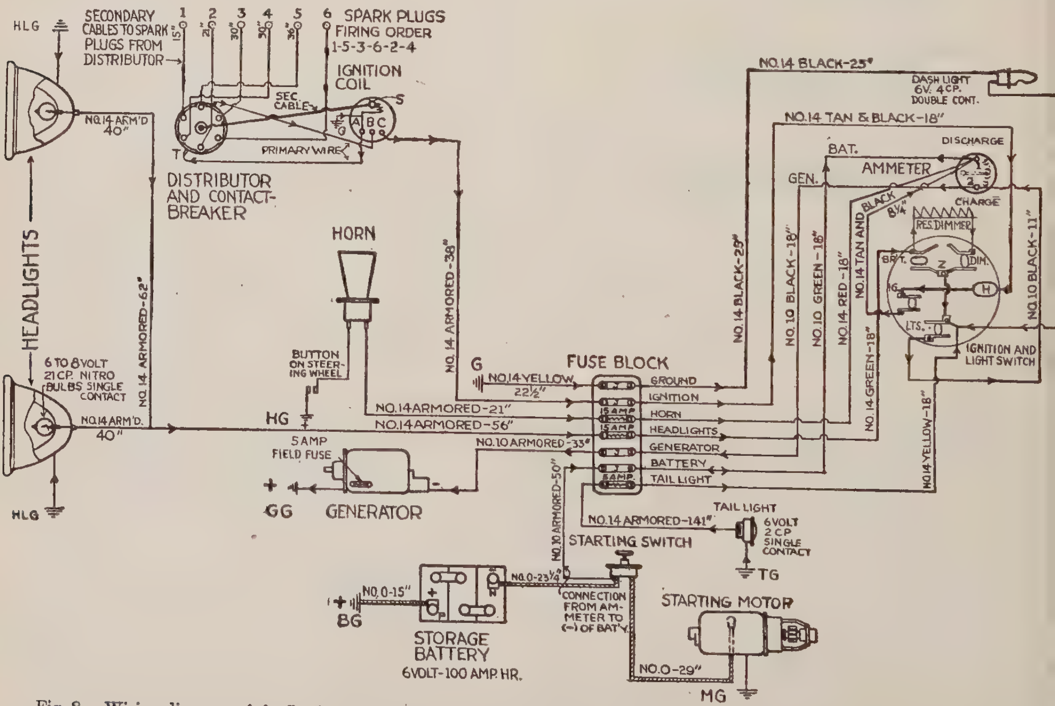


Fig. 8. Wiring diagram of the Lexington (Series "S"), showing the **size of wire used, length of wire,** size of lamp bulbs, fus block, and the various circuits. Note where armored cable is used; also how the connections are made to the ammeter, an where secondary cable is used. Note also the starting-motor cable and the size of it.

Note, too, that **No. 10 wire** is used in the **generator and battery** circuit; **No. 14** is used in **ignition and lighting** circuits, an **No. 0** in the **starting-motor** circuit.

The Connecticut ignition thermostat (see "H" on the switch) is incorporated in the ignition circuit, and is for the purpos explained under a similar principle but different arrangement, as used in the Connecticut ignition system on the Overland "4. See Index for "Connecticut ignition thermostat."

he same circuit to (1) on the ammeter, through the mmeter to (2), to jumper (J) on the fuse block, to he (−) terminal of the generator. The condenser s in the coil.

The secondary circuit is from the coil of the econdary terminal (S), through the secondary cable o the center, or rotor of the distributor, to the spark lugs, to ground, to ground (G) of the coil, to the rounded end of the secondary at (A).

Generator charging circuit: From the (+) ground f the generator, to the (+) ground of the battery, o the fuse block, through jumper (J) on the fuse lock ("jumper" means that instead of a fuse, a traight connection is made), through No. 10 size reen wire (**BAT.**), to (1) on the ammeter, through he ammeter to (2), through (**GEN.**) black wire No. 10 size), to the fuse block, through jumper (J), o the (−) terminal of the generator.

Headlight circuit: From the (+) battery ground r (+) generator ground (whichever is in service), to round of the headlights (**HGL**), through the lamp ulbs in parallel, to the fuse block, through a 15-mpere fuse, through green wire (No. 14) size, to one side of the dimmer resistance. If connections are made at (**BRT.**), then resistance is cut out. If made at "Dim," then current must flow through the resistance and bright would be "off"; then to (**Z**), to (**LTS**), to (2) on the ammeter, and through the ammeter to (1), to the (−) battery through wire (**BAT.**) (if the battery is supplying the current), or, if the generator is supplying the current, not through the ammeter but direct through wire (**GEN.**), to the (−) terminal of the generator.

The other circuits, such as those of the horn, the tail light, and the dash light, can be traced in the same manner, starting with the (+) ground of the battery, if engine is not running, or is running very slow; or at the (+) ground of the generator, if the engine is driving the generator at sufficient speed to charge the battery, at which time all current is taken from the generator. (The starting-motor current, of course, is never taken from the generator.) From the (+) of the generator, or battery, it is then necessary to **start with (+) ground of all circuits because the (+) of the battery is grounded.** For this reason the **(+) of the generator must be grounded,** and the "lead" is from (+) to all grounds, back to (−) of battery or generator.

WIRING METHODS

There are three methods for wiring a car: (1) the ingle-wire, or grounded, return system; (2) the wo-wire, or fully insulated, system; (3) the three-ire system.

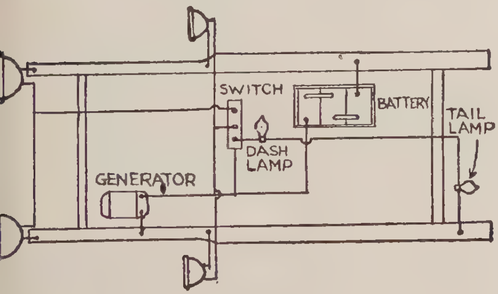


Fig. 9

The single-wire or grounded return system (Fig.): One insulated wire is insulated from the frame nd is termed the "lead" wire. The frame serves as ne return wire. However, when the (+) terminals f the generator and battery are grounded, then the ame serves as the lead. The ground connection om the battery wire or cable to the frame is usually heavy copper connection which is tightly bolted to cleaned surface with copper or brass washers on ich side. This connection, as well as all other rounded connections, must be clean and secure, so nat vibration will not jar it loose. This is the sysm in general use.

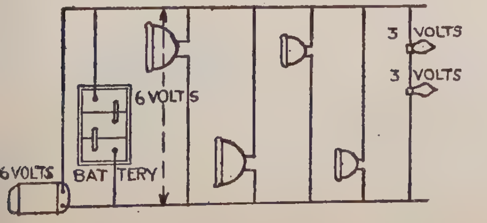


Fig. 10

The two-wire, or insulated, system (Fig. 10): In this system, both insulated wires—the lead wires and return wires—are kept away from the frame and from all metal parts of the car.

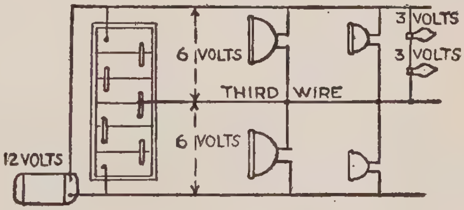


Fig. 11

The three-wire system (Fig. 11): This system consists of three wires, one being known as the **"neutral."** Note in this illustration that the storage battery is a 6-cell or 12-volt battery and the third wire divides the three cells to a circuit, making 6 volts for each side of the third wire.

It is important that the lights or load be equalized, for if three of the six cells are worked more than the other three, and both sets are charged from the same source and at the same rate, one set would get more charge than the other. When the load is properly balanced, there will be no flow of current through the neutral, which is the reason for so calling it. This system is now seldom used.

Wire Connections

The connections in electric wiring should be soldered. The unsoldered connection may work as well as a soldered connection at the time of being made, but the resistance always increases.

Soldering paste: Do not use acid when soldering electrical apparatus or wiring, as acid is an electrical conductor and destroys the insulation. It is much better to use a non-corrosive soldering paste.

Tape: Do not use friction tape on high-tension wiring or on other wiring where the grease or oil can get to it. It is much better to use linen tape and shellac. Friction tape will not insulate ignition current, neither will it hold when oily. Repairmen often burn the alcohol out of the shellac after coating with it. This causes it to harden, and makes a hard-coated insulation.

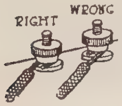


Fig. 12 Fig. 13

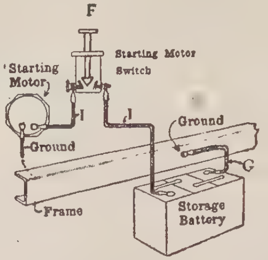


Fig. 14

When placing a wire terminal under a terminal nut, twist the wire in the direction in which the nut turns, as shown in Fig. 12.

When connecting a wire under a screw or nut, use a brass washer.

Note. When stranded wire is used on any part of a car, sometimes one strand will play loose from the others and cause a short circuit. Always twist and solder the ends of stranded wires.

Use wires with different colored insulation when wiring the car; then they can easily be traced.

Starting-Motor and Battery-Cable Connections

Short circuits: Fuses, which will melt on a dead short circuit and open the circuit, are usually provided on all parts of the electric system, except from the battery to the starting motor. The current here is too great for a fuse.

It is plain, therefore, that if the insulated cable (1, Fig. 14) should become frayed and touch the frame or any metal part of the car, a dead short circuit would result. If this were left shorted for several hours, the plates would be likely to become buckled inside of the battery and touch each other and cause an internal short circuit which could not be repaired. A battery is on practically a dead short circuit each time the engine is started, but only for a moment.

Result of Open Connections between Generator and Battery

Open circuits: If, on the other hand, the ground terminal (G) of the battery to the frame, or the wire from the battery to the generator, in fact all wires in the circuit from the generator to the battery and ground, are not in perfect contact, there will either be a resistance set up which will reduce the charge going to the battery and the discharge from the battery, or a complete open circuit.

If a complete open circuit should exist between generator and battery, especially on a constant-current-regulated generator, such as a third-brush-regulated generator, then this would have the same effect as if the battery were disconnected from the circuit. The result would be that the generator would build up a high-current value at high speeds and burn out the lights and possibly the cut-out winding, and might also damage the field windings.

How to Make Connections

Good connections from generator to battery and battery ground connection are, therefore, very important. The **battery ground connection** is not only used for the starting-motor circuit, but is used for the generator and all other circuits.

The ends of wires or cables should be "tinned" by dipping them in molten solder and then cleaned, and strong copper terminals should then be soldered thereto for attaching to the motor and to the switch. The **terminals** themselves should also be cleaned before soldering.

If the battery terminals are sulphated with a green corrosion, wash them off, as well as all surrounding parts, with carbonate of soda or some other alkali.

Clean the battery terminals inside with a round file and the terminal itself with a flat file. The acid of the battery tends to corrode the terminals, and after cleaning, a little vaseline will help to prevent this (on the lead terminals and the lugs of the battery).

The ends of wires connecting with the battery are fitted with copper terminals which are lead coated. On the cable leading from the battery to ground on the end of the cable which grounds to the frame, a heavy copper terminal is used. It is important that these lugs be properly scraped, cleaned, and soldered, and that all connections be drawn tight.

The frame, where the ground is made, should be scraped clean, and the connection should be drawn tight with a bolt.

Poor connections at battery terminals, or ground, will often result in slow cranking of the starting motor, in dim lights, and in a weak current supply in general from the battery.

Wiring Troubles

Wiring troubles are numerous if the wiring is not properly done. All connections must be soldered. Oil and grease destroy insulation. Moving parts must not touch wires. Protect wires from chafing. Avoid frayed ends. Tape all connections. Connections and terminals must be kept tight. Vibration often jars them loose.

WIRES AND ACCESSORIES FOR LIGHTS, HORN, ETC.

These wires should be protected from oil and dampness and from the frame. There are two methods, either or both of which may be used. One method is to use armored wire (Fig. 15), where the wire remains permanently in the metal armor. The other method is to use a conduit, where it is possible for the wire to be withdrawn.

Conduits (Fig. 16) provide a complete enclosed **runway for wires from which they can be withdrawn** if necessary and through which new wires can be installed. A conduit affords protection from mechanical injury, such as bruises, etc. The conduit is made of galvanized steel and is flexible. Conduit is now seldom used.

Flexible-steel armored cable is very popular. It can be purchased containing one or more wires. The wire **cannot be withdrawn.**

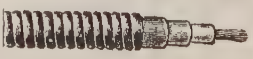


Fig. 15

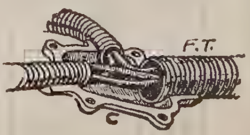


Fig. 16

Fig. 15. Armored cable.

Fig. 16. Showing wires run through metal, flexible tubing or conduit.

The coupling box (Fig. 17) provides a convenient and easily separable means for connecting together the wiring on the chassis and on the car body (seldom used).

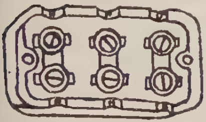


Fig. 17

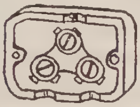


Fig. 18

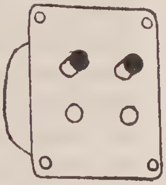


Fig. 19

Fig. 17. Coupling box.
Fig. 18. Junction box.
Fig. 19. Lighting switch.

The junction box (Fig. 18) is for use wherever a branch circuit is tapped off the main wiring. If it is used, no taping of joints is required, and proper connection is assured without soldering. It also affords a junction from which to make tests. (Now seldom used.)

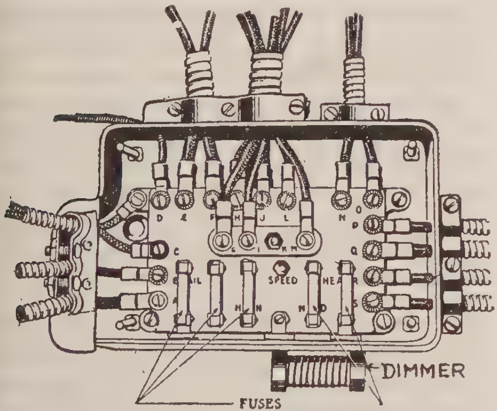


Fig. 20

A junction block, as used on the Studebaker "Big Six" car, is shown in Fig. 20. Note that the fuses are included in the junction box.

Ignition switches are made in many different forms and are usually placed on the cowl (dash) of the car, and are operated with a key. The ignition switch must be "on" when the engine is started.

Starting motor switches are usually operated by the foot. See Index under the caption, "Starting-motor switches."

Lighting switches are usually placed on the cowl (dash) of the car, and are of the **"push-botton"** type. They are usually termed "gang" switches. Fig. 19 shows a "two-gang" type.

A touring switch is sometimes provided on a car or the purpose of allowing the operator to discontinue the charge from the generator to the storage battery when the car is on a long tour, running mostly during the day.

Fuses

Fuses are used on many systems, particularly when the "grounded" or "single-wire system" is used. The purpose of a fuse is to melt and open he circuit in case of a short circuit, and thus to prevent discharge of the battery.

A fuse is never placed in the circuit between battery and starting motor, as the current consumption s too great.

Note. When a fuse "blows," it should not be replaced with a new one until the cause of its blowing (usually a short circuit or overload) is found.

Fuse wires are made in different diameters. The fuse is made of lead alloy and will melt at a given temperature.

If a lighting circuit required 10 amperes of current, then a 15-ampere fuse would be placed in the circuit. Therefore current up to 15 amperes could pass safely; but if more attempted to pass, which would naturally be the result if a short circuit existed, the fuse would melt and open the circuit.

Fuse blocks (Fig. 21) are usually placed inside of the cowl (dash), under the hood of the engine, or in the form shown in Fig. 22, which is placed on the cowl, and to which the different wires of different circuits are connected.

The illustration in Fig. 22 is the fuse box used on the Studebaker "EJ." It is placed on the cowl and contains three fuses: one for the headlights, one for the tail light, and one for the horn, and the dash lamp. It is also arranged to hold one spare fuse.

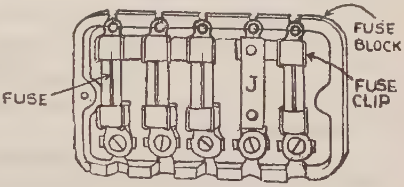


Fig. 21. Fuse block.

The fuse is placed **in series** with the circuit. If a fuse melts, or "blows," it is then an easy matter to insert another fuse, of which extras should be carried. Extra fuses are usually carried in a fuse clip on the fuse block provided for the purpose, and to which there are no wires connected.

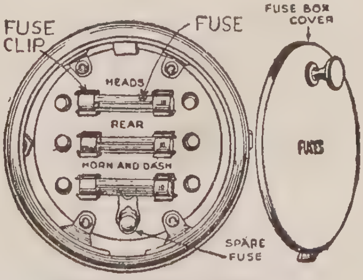
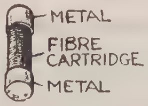
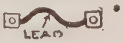
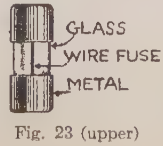


Fig. 22. Round-type fuse box.

There are three types of fuses: (1) The cartridge, or enclosed type (Fig. 23) which consists of a fiber







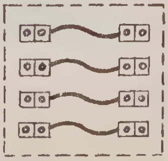


Fig. 23 (upper) Fig. 25 (upper)
Fig. 24 (lower) Fig. 25A (lower)

tube with the fuse enclosed, and which connects with the metal ends. The metal ends are then slipped into the metal fuse clips which should make good contact. With this type of fuse, when it blows, a hole is usually blown in the thin fiber shell.

(2) **The visible type** (Fig. 24) is the type most used. The fuse is enclosed in a small glass tube, and connects with metal ends which are slipped into the fuse clips.

(3) **The open type** (Fig. 25) is seldom used. The fuse block to accommodate this type is shown in Fig. 25A. A screwdriver is necessary to connect or to disconnect a fuse of this type.

Capacity of Fuses

The size of fuse to use is determined by the amount of current that is to pass through it. If the fuse is to be placed in the headlight circuit and 5½ amperes are required, then a 10-ampere fuse would be ample protection.

On an average, a fuse of about 10-ampere capacity is used in the **ignition circuit,** if one is used in this circuit at all, which is seldom.

Fuses in the **lighting circuit** are used on almost all cars, unless a circuit-breaker is used instead, as on the Delco systems. The capacity for **headlight fuses** is 15 to 20 amperes. The **tail-light** fuse is usually of a 5-ampere capacity, and the **horn circuit** of a 15-ampere capacity.

On many cars where fuse blocks are used, it will be found that, although there are fuse clips provided for fuses, a "jumper" is placed in the clips instead of fuses, in all circuits except the horn and lighting circuits.

Testing a Fuse

The enclosed type of fuse, if suspected of being blown, or **the visible type,** if connection of the fuse with the metal part is suspected of being loose, can be tested with a test light (2 c.p.), and battery, as in Fig. 26. If the fuse is blown or the connection is loose, the light will not light, as the circuit is open.

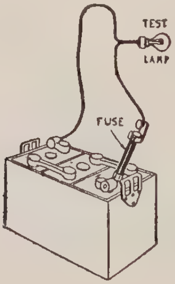


Fig. 26. Testing a fuse.

Fuse Clip Connections

The importance of good contact and clean fuse clips is very great. If the clips are corroded, or if the fuse is not making good contact in the fuse clips, resistance will be offered to the flow of current.

Fuse Between Generator and Battery

If a complete open circuit should exist betw fuse clip and fuse, and this fuse should be in se with the main charging circuit, between the gene tor and battery, this would have the same effect disconnecting the battery from the generator. A if the generator regulation was by means of a th brush, the result would be, at high speeds of generator, that the generator would build up a h value and burn out the lamps and possibly the c out voltage winding and shunt-field windings, if generator was run for a long period of time at a h speed. Thus the importance of occasionally exa ining the fuse clips to see if they are clean and they retain tight connection, must not be forgott

If a fuse should blow in the "main charging c cuit," between generator and battery, the sa result would probably occur. For this reason fuse is omitted in the main charging circuit on ma of the electric systems using a third-brush regula generator, unless there is a fuse in the "field-circu of the generator.

Shunt-Field Fuse

On almost all third-brush regulated generators fuse is placed in the "shunt-field circuit" of generator, in order to protect the generator in c an open circuit occurs in the "main charging circui

In other words, if an open circuit should occur the "main charging circuit" when the generator w running at high speeds, the generator would build a much higher output than normal. If a fuse placed in the "shunt-field circuit," then the fuse w "blow" and open the "shunt-field circuit," thus p venting the generator from reaching an abnorm value—providing the "shunt-field fuse" is of t proper capacity. If the fuse should be of a mu higher value than required, it would not blow time to prevent the generator building up, and t lights would be burned out. Hence the importan of using the correct capacity of fuse in the generat "shunt-field winding," and a fuse of a large enou capacity, or none at all, in the "main charging c cuit." As already stated, a fuse is seldom placed the main charging circuit from the generator to t battery where a third-brush regulation system used, and seldom in the ignition circuit. See Fig. page 426.

Delco Circuit-Breaker

A circuit-breaker is used on Delco electric sy tems in place of fuses. This device opens the c cuit when the current is above normal, as, f example, when a short circuit occurs. The circu breaker is not placed in the generator "ma charging circuit," however, but is usually placed series with the lighting or horn circuit. See Inde "Delco circuit-breaker."

Westinghouse Compensator

A small cylindrically wound resistance unit sometimes incorporated with the fuse block in so of the Westinghouse systems, and is termed "compensator" or "ballast-resistor." Its purpose to protect the side lights from over-voltage, wh the headlights are not lighted.

INSTRUCTION No. 38

LIGHTING A CAR: Electric Lighting; Gas Lighting; Oil Lighting

LIGHTING METHODS

There are three methods for lighting a car: By cetylene gas, by electricity, and by kerosene oil.

The gas light can be produced from carbide in a generator," or it can be stored in a "gas tank" and rried on the car.

Electric lights are supplied with electricity from a orage battery. When the storage battery runs own, it can be recharged from an outside source, or om a dynamo, run from the engine.

The old-style "carbon filament" in the electric obe consumed so much current that it was difficult obtain a storage battery of a reasonable size and eight which would supply current for any length of me. The carbon filament lamp used a filament emically treated and in a vacuum. The filament the "Tungsten Mazda" globe reduces the current nsumption, and is not liable to break with the sual motor-car vibration.

Lights on the car may be divided into those which are required by law (headlamps and rear lamps), and those which add to the convenience and comfort of the driver and his passengers. Side lamps are now seldom used, but small 5 or 6 c.p. lamps are used in the headlamps for city driving, and are often termed "dimmer lamps."

Although some of the older pleasure cars and some trucks and other slow-moving vehicles are still equipped with gas or kerosene lamps, **electricity is the standard method of car lighting** at the present time.

It is well worth knowing that any oil lamp can be quickly and inexpensively converted into an electric lamp by obtaining "adapters" from any of the accessory dealers.

Oil light and gas lights are now seldom used, but are mentioned farther on as a matter of information.

AUTOMOBILE ELECTRIC LIGHTING SYSTEMS

There are three methods of furnishing electric rrent for car lighting:

(1) By independent storage battery system.

(2) By the generator and battery system.

(3) By an independent generator system.

(1) Where an independent storage battery system used, the capacity of the battery must be great ough to run the headlamps and rear lamps for a asonable time before the battery has to be rearged.

A current consumption of approximately 7.85 nperes is required for headlamps and for rear and sh lamps, the equipment of the average car.

A 100-ampere-hour lighting battery would run ese lights for about twelve hours of steady burning. nder average conditions this would mean that the ttery would have to be recharged about once a eek. A 120 or 150-ampere-hour battery will not st much more than a 100-ampere hour and will ve longer service.

(2) Generator and battery system: The advantage this system is that it automatically keeps the batry charged, and permits more current to be used lighting without danger of running down the ttery while on the road. This is **the method now nerally used.** The generator is driven by the gine and charges the battery. The battery supes electric current for the starting motor, ignition starting, and also for lights, if the generator is t charging the battery. In such a case, current is pplied for ignition and for lights by the generator.

(3) Independent generator system: The Ford as example: The generator in this system delivers ernating current which is used for both lighting d ignition. The battery cannot be charged with ernating current, and on this account the lights n be run only when the generator is running. us the strength of the light varies with the speed the engine unless some type of regulator is talled. This system is used only on Ford cars of the model "T" type, which were not equipped with an electric generator and battery. The present Ford enclosed models are thus equipped.

Another type of magneto which, if run fast enough will light electric lamps, is the inductor type of magneto, shown in Fig. 12, page 246. The "shuttle" type of armature magneto will not light lamps.

Where Lamps Are Placed

Headlamps, of which there are two, are usually connected in parallel. The candle power varies from 15 to 21 c.p. each.

Side lamps are usually placed one on each side, and are usually connected in parallel. They are of 4 c.p. each, but are now seldom used, being placed in the headlamps as "auxiliary" or "dimmer" lamps, for use when the car is standing, or for city driving and to save current.

Spot lamp: Only one is used, usually a nitrogen lamp of 21 or 32 c.p. (not permitted to be used in several states).

Rear lamp, also called "tail lamp": Always with a red lens in the rear and a white light at the side, to illuminate the license number. It is usually 2 c.p.

The tail light and instrument lamp are often **connected in series.** If the rear lamp should burn out, the instrument lamp would not burn, and vice versa. This is an advantage, because the law requires that the rear light burn during the night. Since it is impossible to tell from the seat if the rear light should fail, this method is used. The voltage is just one-half of that of the regular lighting circuit when connected in series.

Step lamp: Two of these are sometimes placed just below the doors, and are usually 4 c.p.

Dash or instrument lamp: Placed over the instruments, such as the speedometer, ammeter, etc., and are 2 c.p.

Inspection or trouble lamp: A lamp and extension cord, carried under the seat, and, in case of need, is connected in the dash-lamp socket; usually 4 c.p.

Tonneau lamp: Placed back of front seat; 4 c.p.

Dome lamp: Placed in the ceiling of the car; 4 c.p.

Pillar lamps: Usually two of these, placed on the rear pillars, one on each side in rear of car; 4 c. p.

It is advisable to use the best grade of lamp, of as low a candle power, and with as few lights as possible, if the battery does not get sufficient charging from the generator.

Candlepower, Voltage, and Amperage of Electric Lamps

The candle power of a lamp is expressed as c.p. Although we speak of a lamp as being 21 c.p., we really refer to the spherical c.p. This means that 21 c.p. is sent out in every direction.

A reflector does not increase the brilliancy of the light from the filament. It simply takes the total amount of light which is thrown in all directions, and concentrates it in one direction (see Figs. 20 and 21, page 436). For instance, with a "spreading beam," the brilliancy is not as intense as from a "straight beam" (see page 436).

The voltage is usually that of the battery, but quite often, to save the lamp from burning out, a lamp of one or two volts higher is used. For instance, if a 6-volt lamp is used on a lighting circuit using a 6-volt battery, the light would be bright as long as the battery was fully charged. If a generator is used to charge the battery and supply current for the lights when the car is running over 10 or 15 m.p.h., then the probabilities are that the generator would develop a slightly higher voltage than the battery. The result would be that the higher voltage would increase the brilliancy of the lamps and cause them to burn out quicker than if the voltage was the same as or less than that of the lamp. For this reason lamps of a voltage of, say, 1 or 2 volts higher than the battery voltage are used.

The amperage, or quantity of current consumed, is governed by the candle power of the lamp—the c.p. averages from 2 to 32. The higher the candle power, the more voluminous is the light—if voltage or pressure is in accordance with that of the lamp—therefore the higher the c.p., the more current or amperes consumed per hour.

Watts: If you multiply the volts by the amperes the result is expressed in "watts." For instance: 6 volts multiplied by 2 amperes gives 12 watts (there are 746 watts to a horsepower).

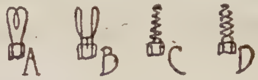
Automobile Electric Lamp Bulbs

Two types of lamps are used for car lighting: **the vacuum type,** usually known as Mazda B, and **the nitrogen-gas-filled lamp,** known as the Mazda C.

The vacuum lamp uses a "Tungsten" filament instead of a "carbon" filament. The carbon filament lamp requires more current and is now seldom used. The air is withdrawn from the bulb of a vacuum lamp, hence a vacuum.

The gas-filled lamp also uses a Tungsten filament, but the bulb is treated with nitrogen gas which increases the brilliancy by increasing the heating intensity of the filament. For this reason the "gas-filled" lamp is very sensitive to an increase of voltage and is best adapted for "constant-voltage" regulated generators.

The source of light is the fine wire at the center of the lamp bulb, known as the "filament." The current heats this wire white hot. If a bulb was designed for 6 volts, and the circuit was 12 volts, then this wire would become so white it would burn up. If designed for 12 volts and the circuit was 6 volts, the filament would be yellow and dim.



Filaments of lamps are made in different shapes: (**A**) is the type used for house lighting, and is not suitable for automobile use on account of vibration. (**B**) is a type used for rear, speedometer, side, and auxiliary lights, as the Mazda B, 62, 63, 64, 81 and 82. This lamp does not require focusing. (**C**) is a type used for headlight lamps, as Mazda B 1125, 1126. (**D**) is of a similar construction. Another type of filament is that shown in the Mazda C lamps. All bulbs for headlight lamps must be focused.

Mazda B lamps usually have this wire or "filament" made up in the form of a spiral about 3/16″ long, and ⅛″ in diameter. This gives a uniform distribution of light all around the spiral.

Mazda C lamps usually have the filament made up in the form of an inverted "V." In most types of C lamps the V is about ⅛″ high and about the same distance across the base. Some makers of type C lamps make the V about 3/16″ long and ⅛″ across the base. This form gives a much better distribution of light than the short V.

The voltage lamp to use depends upon the voltage of the system. If you do not know this, count the cells of the storage battery. Each cell gives 2 volts.

Use of the Mazda B and C Lamps

The Mazda B lamp is designed for all lights, such as rear, side, and headlights. It is made in 6 to 8-volt, and 12 to 16-volt sizes.

The Mazda C lamp is designed for headlight lamps and spot lights, and is made in 6 to 8-volt and 12 to 16-volt sizes.

The candle power of these lamps is given in tables farther on.

Where 21 c.p. or less is used in headlamps, the type B will usually give the best satisfaction, even though they take 20 per cent more current, owing to the sensitiveness of the C lamp. The spiral filament of the B lamp also gives a better distribution of light than the C with a short filament.

Where more than 21 c.p. is desired, type C must be used, but those with a long "V" are preferable.

The Mazda C lamp is brighter and gives more c.p. for the same amperage consumption, but is more sensitive to voltage variations, as previously stated.

Note. As the lamps become older, the current consumption increases. If the glass of the lamp bulb is blackened or the filament bends down, and if less than its rated c.p. is being used, it will be best to replace the lamp bulbs.

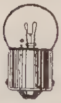
In order to tell what class of base of lamp bulb is required on a car: If the wiring of the car is a single-wire grounded system, then an "S.C." base is required. If the wiring is a two-wire system, a "D.C." base is required.

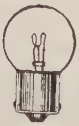
To ascertain the voltage: Count the cells of the storage battery. If there are 3 cells, a 6-volt lamp is required; if 6 cells, a 12-volt lamp is required. Each cell is counted as 2 volts.

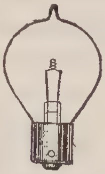
To determine the candle power to use: First determine the voltage. Then refer to the tables following. For instance, if there are three cells to the battery, then the voltage is 6 volts. Refer to the table "6-8 volts." Note that the **headlamp bulbs** are made only in 15 c.p. in class B, and in 21 c.p. in class C. Therefore one or the other must be selected. The **rear and speedometer lamps** are 2 c.p., but if the rear light and speedometer light are in "series," then a 3-volt lamp is required. The **side and auxiliary lamp** is made only in 4 c.p.

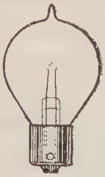
Mazda Lamps for 6 to 8 Volts

Mazda—61
G-6 Bulb


Mazda—63
G-6 Bulb


Mazda—81
G-8 Bulb


Mazda—1125
S-11 Bulb
Mazda B


Mazda—1129
S-11 Bulb
Mazda C

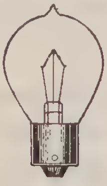
6-8 VOLTS
FOR AUTOMOBILE SERVICE

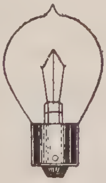
MAZDA NUMBER	BASE	VOLTS	C P.	CLASS BULB	AMPERES
MAZDA B LAMPS FOR REAR AND SPEEDOMETER LIGHTS (2 in Series, each lamp 3-4 Volts)					
61 62	S.C. D.C.	3-4	2	G- 6	.84
MAZDA B LAMPS FOR REAR AND SPEEDOMETER LIGHTS					
63 64	S.C. D.C.	6-8	2	G- 6	.47
MAZDA B LAMPS FOR SIDE AND AUXILIARY HEADLIGHTS					
81 82	S.C D.C.	6-8	4	G- 8	.80
MAZDA B LAMPS FOR HEADLIGHTS					
1125 1126	S.C. D.C.	6-8	15	S-11	2.31
MAZDA C LAMPS FOR HEADLIGHTS AND SPOTLIGHTS					
1129 1130	S.C. D C.	6-8	21	S-11	2.81

Mazda Lamps for 12 to 16 Volts

Mazda—67
G-6 Bulb

Mazda—89
G-8 Bulb


Mazda—1139
S-11 Bulb
Mazda B

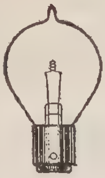

Mazda—1141
S-11 Bulb
Mazda C

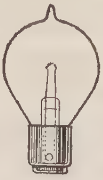
12-16 VOLTS
FOR AUTOMOBILE SERVICE

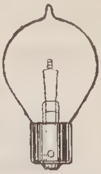
MAZDA NUMBER	BASE	VOLTS	C. P.	CLASS BULB	AMPERES
MAZDA B LAMPS † FOR REAR AND SPEEDOMETER LIGHTS					
67 68	S.C. D.C.	12-16	2	G- 6	.19
MAZDA B LAMPS FOR SIDE AND AUXILIARY HEADLIGHTS					
89 90	S.C. D.C.	12-16	4	G- 8	.36
MAZDA B LAMPS FOR HEADLIGHTS					
1139 1140	S.C. D.C.	12-16	15	S-11	1.09
MAZDA C LAMPS FOR HEADLIGHTS AND SPOTLIGHTS					
1141 1142	S.C. D.C.	12-16	21	S-11	1.16

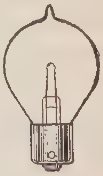
† For use two in series on 12-16 volt systems, MAZDA Nos. 63 and 64 are customarily employed.

Mazda Lamps for Ford Cars


Mazda—1126
S-11 Bulb
Mazda B


Mazda—1130
S-11 Bulb
Mazda C


Mazda—1125
S-11 Bulb
Mazda B


Mazda—1129
S-11 Bulb
Mazda C

FOR FORD CARS

MAZDA NUMBER	BASE	VOLTS	C P	CLASS BULB	AMPERES
6-8-volt lamps, to be burned two in series on magneto lighting system. To insure most satisfactory service, see that two Mazda-1126 lamps or preferably two Mazda-1130 lamps are operated in series. Fitted with double contact (D.C.) bayonet candelabra base.					
MAZDA B LAMP FOR HEADLIGHTS					
1126	D.C.	6-8	15	S-11	2.31
MAZDA C LAMP FOR HEADLIGHTS					
1130	D.C.	6-8	21	S-11	2.81
6-8 volt lamps, for cars equipped with 3-cell (lead type) storage battery-generator lighting system. Fitted with single contact (S.C.) bayonet candelabra base.					
MAZDA B LAMP FOR REAR AND AUXILIARY HEADLIGHTS					
63	S.C.	6-8	2	G- 6	.47
MAZDA B LAMP FOR HEADLIGHTS					
1125	S.C.	6-8	15	S-11	2.31
MAZDA C LAMP FOR HEADLIGHTS					
1129	S.C.	6-8	21	S-11	2.81

Note that where lamps are to be used on a Ford magneto, two lamps (No. 1130) are connected in series.

A Double-Filament Edison Mazda Headlight Lamp

The purpose of this lamp is to dispense with two lamps in the headlights, and thus to do away with the separate "dimmer" lamp. This lamp, shown in the illustration, has a double filament using a DC base. It is a gas-filled Mazda C type, built in the S11 type of bulb, having a 21 c.p. filament as well as a 4 c.p. filament. Both filaments pass through the focal area of the reflector.

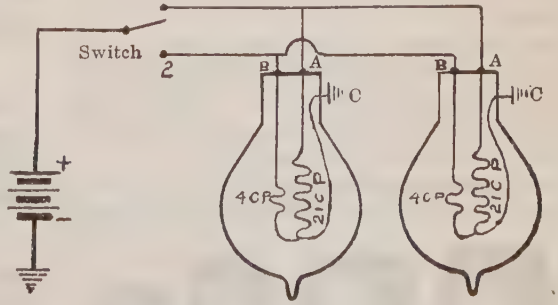


Fig. 6. Mazda No. 1158, double-filament lamp, showing the circuit (1) when the 21 c.p. filament is on and the circuit (2) when the 4 c.p. filament is on.

This type lamp is made only for 6 to 8 volts and is numbered Mazda 1158.

Two wires are used for connecting to the lamp socket from switches. (**A**) and (**B**) are terminals of the base and are insulated; (**C**) is grounded.

When the 4 c.p. filament is used, the circuit is through (**B**) insulated, and (**C**) grounded and the switch is connected on terminal 2.

When the 21 c.p. filament is used, the circuit is through (**A**) insulated and (**C**) grounded and the switch is connected on terminal 1.

Lamp Bulbs and Sizes for Motorcycles

There are only two lamp bulbs listed for motorcycles:

Class B, Mazda 63, S. C., 6–8 volts, 2 c.p., G–6.

Class C, Mazda 1129, S. C., 6–8 volts, 21 c.p., S–11.

Meaning of Abbreviations

The abbreviations used with the lamps, such as "G–6," "G–8," and "S–11," refer to the shape and size of the bulb.

For instance, "G" indicates that the bulb is round or globular; 6 means that many eighths of an inch, or 6/8″ or 3/4″ diameter. "G–8" would be a round bulb, 8/8″ (or 1″) in diameter.

Where the designation "S–11" appears, the "S" indicates "straight side," and the 11 designates the diameter in eighths of an inch, or 11/8 = 1⅜″ diameter.

Formerly all of the bulbs were round, but now only some are round, such as "G–6" and "G–8." The other bulbs are pear shaped and designated as "S." They are not really straight, but this term is used in order to distinguish them from the round bulb.

Where figures appear under the "voltage" of the lamp bulbs, as "6–8," or "12–16," this means that the lamp is intended for electric systems using a 6-volt battery, but will stand a voltage up to 8 volts. The lamp sometimes gets this—or near it—when the generator is charging the battery, as the generator voltage is slightly higher than the battery voltage.

The "12–16" lamp is for a 12-volt system, such as a Dodge, and the lamp is capable of withstanding a generator voltage as high as 16 volts.

Lamp Bases

There are four types of these: (1) double-contact bayonet candelabra; (2) single-contact bayonet candelabra; (3) candelabra screw base; (4) miniature screw base. Each of these is shown in the illustrations.

The lamp base is that part which is fitted to the end of the bulb and fits into the socket. Only two of the types mentioned above are in general use for automobile work: the "S.C.," meaning "single contact," and the "D.C.," meaning "double contact." The "S.C." is used most.

The double-contact base (D.C.) (Fig. 7) has two contacts (note the top) insulated from the metal base. These contacts are connected with the ends of the lamp filament; and when connected to the socket they make contact in the socket with the circuit. The "D.C." base and socket are used only for a "two-wire insulated" system of wiring.

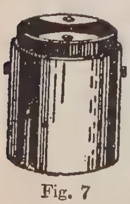


Fig. 7

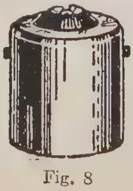


Fig. 8

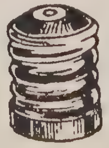


Fig. 9

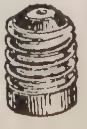


Fig. 10

The single-contact base (S.C.) (Fig. 8) has one contact in the center which is insulated from the metal base. One filament of the lamp connects with this center contact, and the other end of the filament connects with the metal base. When placed in the socket the center contact connects with an insulated terminal in the socket, which connects with the single insulated wire of the light circuit, and the rest of the socket and outside part of the base are grounded. The "S.C." base and socket are used only for the "single-wire, grounded" system of wiring.

The words "Bayonet" and "Candelabra," which appear in the tables to designate the type of base, are explained as follows:

Bayonet base: The "Candelabra" screw type base (Fig. 9) was originally used on miniature lamps, but owing to the vibration of the automobile, the lamps would loosen. A type of base was then designed as shown in Figs. 7 and 8, the single contact (Fig. 8) being used most and arranged as shown in the illustration (Fig. 11). The base (**B**) is thrust into the socket (**S**) through slot and is then given a turn or twist which locks (**T**) in place. The thrusting effect was what gave the base its name: "bayonet type." The word "candelabra" is also used with the word "bayonet," but a candelabra base is really a screw type, as shown in Fig. 9.

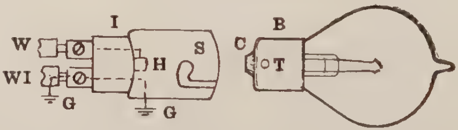


Fig. 11. (**B**) is the base, S. C. Type. The tip (**T**) locks in the opening of (**S**). Contact is made by (**C**) at (**H**), which conducts the current from (**W**) to one end of the filament, back to the grounded base, thence to ground (**G**), or to (**W1**) which is grounded. (**I**) is insulated from the socket (**S**), and (**C**) is insulated from the base (**B**).

The candelabra screw base (Fig. 9) is not used for automobile work, because of the vibration. This type is often used on trouble lamps, flash lamps, etc.

The miniature screw base shown in Fig. 10 is a smaller size, used principally for decorating purposes.

Lamps must be selected according to the type of sockets used on the car. On a single-wire grounded system, use an "S.C." base. On a double or two-wire system, use a "D.C." base.

Headlight Adjustment

The light you get on the road will depend on the candle power you get from the lamp in the reflector; on the focus or adjustment of the lamp in relation to the reflector; and on the direction in which the headlamp itself points.

Different Focusing Adjustments

Getting the lamp bulb in the proper relation to the reflector to give the best light on the road is called "focusing." All headlamps are provided with some means of moving the lamp bulb back and forth along the center line of the reflector, which line is called the axis. The four types of adjustments (Figs. 12, 13, 14 and 15) shown, should cover practically all of the headlamps used.

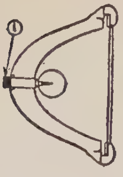


Fig. 12

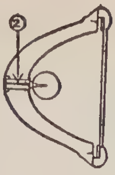


Fig. 13

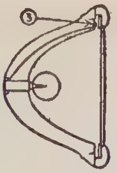


Fig. 14

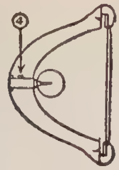


Fig. 15

Fig. 12 has an adjusting screw or knob near the center, on the rear of the headlight shell. The lamp bulb is moved forward by turning the screw or knob (1) to the left, and backward by turning it to the right.

Fig. 13. The lamp is held in place by a ratchet device (2). The lamp is moved forward or back by grasping the bulb and either turning the bulb to the right or pressing it to one side or the other to disengage the ratchet, and then pulling or pushing the lamp in its socket to the next notch in the ratchet. If the lamp does not move easily, remove the reflector and see how the ratchet works.

Fig. 14. The adjustment is made by turning the large screw (3) in the rim of the headlight front just at the edge of the reflector. By turning this screw to the right, it will move the lamp forward in the reflector. Turning it to the left moves it backward in the reflector.

Fig. 15. The lamp is held in place by a set screw (4) in back of the reflector. When the set screw is loosened, the lamp may be moved backward or forward. The set screw must be tightened securely to hold the lamp in place.

Example of Headlamp Adjustment on the Studebaker

Fig. 16 shows the type of headlamp used on the Studebaker "Light Six" car, and Fig. 17 shows that used on the Studebaker "Big Six." Observe the two methods of adjustment; also the manner in which the door or rim is removed, etc.

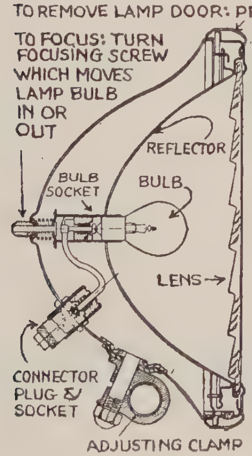

TO REMOVE LAMP DOOR: PRESS IN ON RIM & TWIST TO LEFT
TO FOCUS: TURN FOCUSING SCREW WHICH MOVES LAMP BULB IN OR OUT
REFLECTOR
BULB SOCKET
BULB
LENS
CONNECTOR PLUG & SOCKET
ADJUSTING CLAMP

Fig. 16

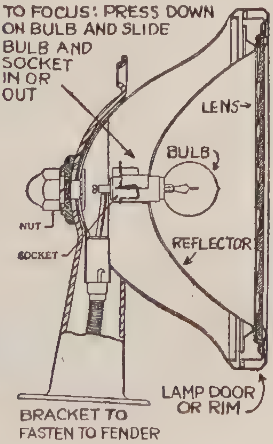

TO FOCUS: PRESS DOWN ON BULB AND SLIDE BULB AND SOCKET IN OR OUT
LENS
BULB
NUT
SOCKET
REFLECTOR
LAMP DOOR OR RIM
BRACKET TO FASTEN TO FENDER

Fig. 17

To remove the door (Fig. 16): Press in hard against the rim of the lamp, and twist in a counter-clockwise direction. The same applies to Fig. 17.

To replace burned-out bulbs: Remove the door; then remove the bulb by pressing it into the socket and twisting it one way until it is released from the catch. See Index, for lamp-bulb sizes for various cars.

If a lens breaks, and a new one has to be ordered, the name and size will usually be found moulded into the lens.

The "door" to the headlamp on various makes may be fastened on in one of several ways. There may be a hinge at the top and a screw clamp at the bottom, or the hinge may be at one side and the clamp at the other. If no hinge shows, and the "door" overlaps the shell of the headlamp, the "door" can probably be removed by pressing it in, and at the same time turning it to the left, as described above.

In some headlamps, the glass is held in place by a retaining spring, which slips in between the headlamp shell and the glass.

In other headlamps, the rim which holds the glass is held up against the shell by a band which fits over shoulders on both rim and shell, and is drawn up by a screw at the bottom of the headlamp.

Tilting Reflectors

On some makes of lamps the reflectors are arranged so that **the reflectors can be tilted.** One method is as shown in Fig. 18 (as used on the Lexington), and another method is the one used on the Cadillac (Fig. 19).

Bellows for Tilting the Reflector

The operation of the reflectors (Fig. 18) is controlled by a small three-way valve located on the instrument board, the partial vacuum created in the engine by the suction stroke of the piston being utilized to exhaust the air from the metal bellows connected to the reflectors when it is desired to illuminate the road for a long distance. To accomplish this the handle of the valve is turned to the letter (H) on the dial.

When it is desired to lower the reflectors to their tilted, or normal, position, the handle is turned to the letter (L) on the dial, which breaks the communication of the bellows with the engine and allows air to enter the bellows through a port in the valve. Communication is maintained between the inside of the headlights and the engine by ⅛″ O.D. annealed copper tubing, and between the end of the tubing and the bellows by rubber tubing, in order that the movable reflector unit may be easily removed.

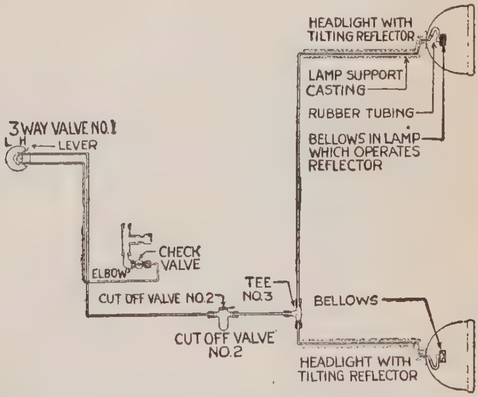


Fig. 18. **Tilting reflectors, as used on the Lexington.** The bellows has the appearance of a coil spring, and is just back of the center of the reflector. The bellows expands and pushes the reflector forward at the top, giving the focal point of the lamp a deflection of five degrees. This is what happens with the control lever at (L): When the lever is at (H), the bellows contracts by action of the engine piston and thus deflates the bellows and pulls the reflector back at the top, giving to the focal point of the lamp an elevation of five degrees.

A check valve is placed in the vacuum line between the three-way valve and engine to prevent a quick change to the tilted position when the throttle is opened quickly. **A cut-off valve** is provided to render the system inoperative from the driver's seat when necessary.

If the system should become inoperative at any time, it may be the result of a break in the line, a leaky connection, a break in the rubber tube connection to the bellows, or the three-way valve may have become dry, permitting air to leak in, destroying the vacuum. The three-way valve may be taken apart for inspection and lubrication. Care must be used in reassembling not to disarrange any of the parts. Use a small amount of commercial vaseline for lubrication.

Cadillac Mechanical Shifting Method of Tilting the Headlight

The reflectors are pivoted, in order that they may be tilted by means of a lever on the steering column connected with an arm (**A**) projecting from the bottom and connected with the reflector (**R**). The lever pulls the reflector down (as indicated by dotted lines), thus tilting the reflector (Fig. 19).

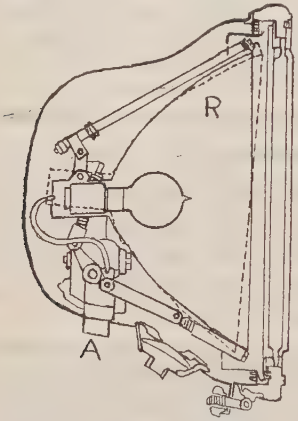


Fig. 19. Tilting reflector as used on the Cadillac.

The advantage of tilting headlights is explained as follows:

When there is a clear road ahead, the illumination of the road for a distance is desirable. Thus the reflector is so focused that the light is projected ahead for the greatest distance.

If a vehicle is approaching in an opposite direction, the reflector (**R**) can be tilted down by movement of the lever on the steering column connected to the arm (**A**), thus tilting the reflector at an angle as shown in the dotted lines. This deflects the rays below the level of vision of the occupants of the approaching car, and at the same time increases the illumination in front of the car, where it is needed most.

Reflectors: Principle of

A parabolic type of reflector, made of metal with a polished silver surface, is used in most head-lamps.

If a lamp were used without a reflector, the light which leaves the lamp filament would be thrown in every direction (Fig. 20).

When a reflector is used, the light from the lamp filament is concentrated all in one direction (Fig. 21). See also "Candle power" (page 432).

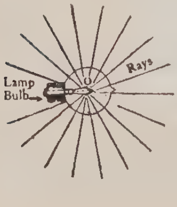


Fig. 20

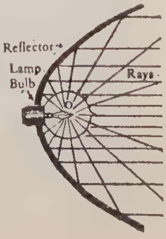


Fig. 21

A ray of light is the light which falls on any one point of the surface of the reflector, and is sent off from that point.

A beam is the total mass of light rays leaving the opening in the reflector.

One of the fundamental laws of light is, that the angle at which light leaves a surface is the same as the angle at which it strikes the surface. By referring to Figs. 22, 23, and 24, the angles which are made by the rays of light leaving the surface of the reflectors at (**H**), (**M**), and (**N**) will be seen to be the same as the angles made by the rays of light striking the reflector at the same point. The angles at which the rays strike the reflector are called **"angles of incidence,"** and those leaving the reflector are called **"angles of reflection."**

X—Focus Point O—Light Source

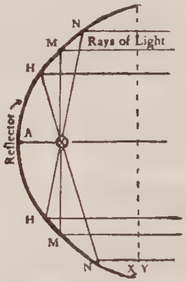


Fig. 22. Straight beam.

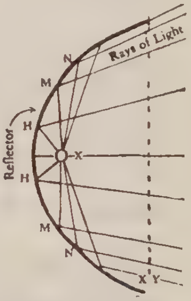


Fig. 23. Spreading beam.

The distribution of light leaving the opening of the reflector when lamp filament (**O**) is at the focal point (**X**) of the reflector is shown in Fig. 22. The rays which start from point (**X**) and strike the reflector at (**H**), (**M**), and (**N**) must be reflected parallel to each other to make the reflecting angles equal the striking angles. This gives a cylindrical or "straight beam." The beam is theoretically the same size (**XY,** Fig. 22) throughout its entire length. A **"straight beam"** gives a very narrow streak of light down the center of the road, like a spotlight; but no light is thrown to the side of the road.

The form of beam leaving the reflector when the filament (**O**) is back of the focal point (**X**). The rays spread or diverge from one another, and form a **"spreading beam,"** with its narrowest point at the opening of the reflector (**XY**). Note that the light rays which leave the headlamp at a rising angle are those which come from the upper half of the reflector.

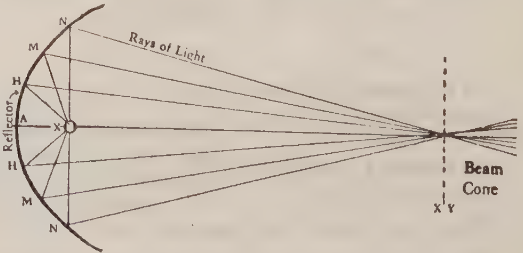


Fig. 24. Crossed beam.

The effect of bringing the filament (O) ahead of the focal point (X) is shown in Fig. 24. This forms what is termed a **"crossed beam."** Note that the light rays which leave the headlamp at a "rising angle" are those which come from the lower half of the reflector.

Anti-Glare Devices

In most states, **laws are being enforced to prevent glare.** The light which produces glare is that part which leaves the headlamp at a "rising angle" and so never hits the road, but does hit the eyes of approaching drivers or pedestrians. These rays may come from either the top or bottom of the reflector, depending upon the position of the lamp in the reflector.

Methods for Reducing Glare

(1) **By using a very low candle-power lamp, or dimming the headlamps;** using whiting, semitransparent paint, or colored glass. Low-candle-power lamps reduce the brilliancy, and colored glass or paint absorb part of the light and reduce the lighting effect desired, and are unsatisfactory.

(2) **By tilting the reflector down** enough to bring the upper edge of the beam below the average eye level (42 inches is the usual legal limit).[1] The distance along which the road will be lighted is very much shortened. If the reflector can be tilted back to normal position, as shown in Figs. 18 and 19, then the distance will be greatly increased.

(3) **By diffusing the light** by means of ground glass, office-partition glass, or by a specially designed "diffusing" lens, having its surface covered by a large number of small lenses or pyramids. With diffusing lenses there is a tendency to glare if the candle power of the lamp is sufficient to light the road, as the light is thrown in all directions.

(4) **By using "deflecting lenses"** which bend or deflect that part of the beam which leaves the headlamp at a rising angle and direct this part of the beam back to the road level. Devices of this kind have the advantage of being able to limit the glare without cutting down the distance along which the light will be thrown on the road. Some of the deflecting lenses which are constructed so as to affect all of the light leaving the headlamp make it hit the road nearer to the car than it would with clear glass, and are not desirable.

Classification of Some of the Anti-Glare Lenses [2]

In the accompanying illustration, A, B, C, and D, are **"diffusing" type lenses.** As these devices scatter the light in every direction, the adjustment of the headlamp has little effect on the road illumination. Both the light and the glare will be a little stronger if the **focus is for a straight beam.**

A

B

C

D

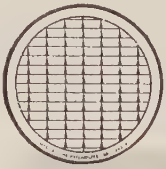
A, **Warner:** Both sides of glass covered with small lenses; adjust focus for straight beams for best lighting.

B, **Prismolite:** Front of glass covered with small pyramids except small spot near center; adjust focus for straight beam.

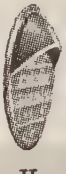
C, **Morelight:** Front of glass covered with short cylinders, arranged in circles; adjust focus for straight beam.

D, **Stewart:** Cup fitting around bulb; outside covered with small lenses; inside with ribs; adjust focus for straight beam.

F, G, H, I, shown below, are **"deflecting" type of lenses, which are intended to be used with a straight beam.** In making adjustments, adjust in accordance with directions for plain glass adjustment, page 438, except that the lamp must be moved to the point in the reflector which gives the smallest point of light on the screen or wall, instead of making the spot 3 ft. in diameter.


F

G


H

I

F, **Sun Ray:** Horizontal prisms throw light on the center of the road. Small triangular prisms throw a light along the sides of the road. Adjust for straight beam.

G, **Conaphore:** Horizontal prisms throw light on the center of the road; cylinders in the center throw a soft light along the sides of the road. Adjust for straight beam.

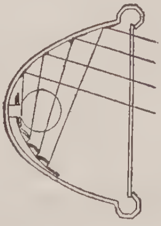
H, **Macbeth:** Horizontal prisms throw light on the center of the road, and cylinders on the inside spread the light to the side of the road. The hood at the top cuts off the light from that part of the lens. Adjust for straight beam.

I, **Holophane:** Circular prisms at bottom throw light on the road and give quite a spread. Horizontal prisms and vertical cylinders at the top throw diffused light along the sides of the road. Adjust for straight beam.

J, K, L, M, are **"deflecting" type lenses designed to be used with a spread or crossed beam,** depending on whether a part of the lens which bends the glare rays down is located at the top or bottom of the lens. The focus is adjusted to give a beam having some spread.

J

K


L

M

J, **Roadlighter:** A deflecting type of lens. Adjustment is for a spreading beam.

K, **Osgood:** Horizontal prisms on the back of the lens throw light down on the road. The cylindrical section on the center of the front of the lens is intended to add to the spread of the light. Adjust focus for spreading beam.

L, **Letts deflector:** A deflecting device. The corrugated reflector is placed below the lamp and changes the angle of the light striking the reflector so that all the rays are sent down on the road. Adjust focus for crossed rays.

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[1] The most common "glare height" regulation in regard to headlamps is that, at a point 75 feet or more ahead of the car, the concentrated beam from the headlamp shall not rise more than 42 inches above the road level, when the car is standing on a level. In the latest headlamp regulations, the height has been raised to 60 inches from the road surface, and the intensity of the light is limited to a maximum of 800 candle power above this point. [2] See page 442 for **Bausch & Lomb lens.**

M, **Fractor:** A deflecting device. The prisms on the glass cup which is placed below the lamp change the angle of the light striking the reflector, so that all of it is sent down on the road. Adjust for crossed beam.

With any of the deflecting devices it is best to make the adjustment for either spread, crossed, or straight beam, while the plain glass is still in place in the headlamp.[1]

An Ideal Light

An ideal light is one which will meet the following requirements: (1) sufficient light to illuminate the road such a distance ahead that the driver would have ample time to stop before reaching an object, and so that it would have penetrative powers in dust and fog; (2) very bright light at the edge of the road and close to the car so that the road could be clearly seen and followed in spite of glare from an approaching car; (3) full width of the road from fence to fence lighted for at least 200 feet ahead of the car.

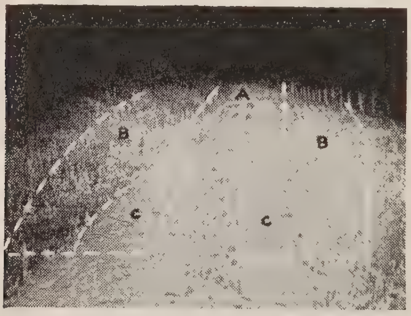
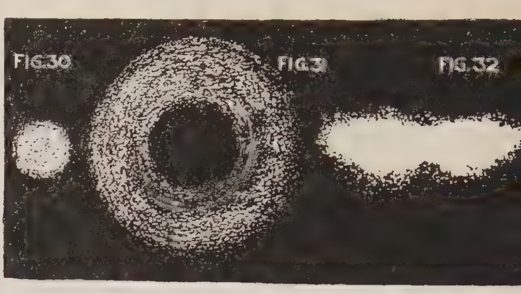


Fig. 25. One make of lens designed to meet these conditions is shown. This illustration was furnished by the manufacturers of the Roadlighter lens (J, page 437), who claim that this lens meets the ideal requirements mentioned above and have corroborated the statement with a photograph of the lens in use. Note that the prisms in the lower half of the lens (see J, page 437) concentrate the distance light, at (**A**). The diagonal prisms in the upper half of the lens bend the light, which would otherwise cause glare, to light the sides of the road from fence to fence (**BB**), and give the bright light on the edge of the road as shown at (CC).

How to Focus Headlight Lamps

In order to secure the best lighting effects, headlight or spotlight lamps should be carefully adjusted in their reflectors every time new lamps are inserted, or, better still, at regular intervals.

Focusing may easily be accomplished by standing the vehicle on level ground not less than 25 feet, and preferably 50 feet, from a flat vertical surface, such as the wall of a house, a garage, or a fence. For an automobile, two points should be marked on the wall the same distance apart and at the same, or slightly less, height above the ground as the centers of the headlamps on the car. The cover glasses of lenses should be removed from the headlamps and the beams (preferably one at a time) trained on to the marked points on the wall. The lamps should then be adjusted in the reflectors by means of the focusing devices until the smallest possible spots of light are obtained. The headlamps should then b so set that the centers of these spots coincide wit the marked points on the wall.



The appearance of the spot from **a well-focused headlamp** is shown in Fig. 30.

The spot from the same headlamp when **the bulb is either drawn too far back into the reflector or not far enough,** i.e., is behind or ahead of the focal point (either condition produces a similar effect), is shown in Fig. 31.

The same effect as shown in Fig. 30 is shown in Fig. 31, except that the glare-reducing lenses are now supposed to be placed in the lamp door. The illustration in Fig. 32 shows how the upward rays of light are turned down below the horizontal.

What actually happens to the light rays from the light source in a parabolic reflector, such as is generally used for automobile headlamps, is shown in Fig. 33.

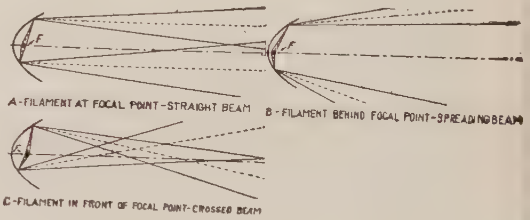

F
A-FILAMENT AT FOCAL POINT-STRAIGHT BEAM
F
B-FILAMENT BEHIND FOCAL POINT-SPREADING BEAM
F
C-FILAMENT IN FRONT OF FOCAL POINT-CROSSED BEAM

Fig. 33. Beam characteristics of parabolic reflectors with light sources in three positions.

When that source is as shown at (**A**), (Fig. 33) the lamp bulb is **at the focal point** of the reflector. When the source is in position (**B**), the lamp bulb is **behind the focal point.** When the source is in position (C), the lamp bulb is **ahead of the focal point.**

Position (A) is the correct position for the lamp filament, and produces the smallest spot of light, or the most highly concentrated beam, as in Fig. 30.

When focusing headlamps with plain lenses, adjust to get the result shown in Fig. 30.

Height of Light on the Road

With the lamps in focus, the centers of these spots of light should be at the same height as the centers of the headlights themselves.

This adjustment can be made, by loosening the clamp bolts which fasten the lamps to the brackets, and twisting the lamps so that the rays are thrown straight ahead and at correct height. **The brightest part of the light should strike the road about 150 feet ahead of the car.**

On some cars, where brackets are provided for the headlamps, the brackets can be bent with a large monkey wrench.

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[1] Addresses of some of the lens manufacturers: The Roadlighter lens is manufactured by C. A. Shaler Co., Waupun, Wis.; other manufacturers are: The Warner Lens Co., 914 Mich. Ave., Chicago; Macbeth, by Macbeth-Evans Glass Co., Pittsburg, Pa.; Legalite, by The Legalite, Corp'n., Boston, Mass.; Sun Ray, by Prismolite Co., Columbus, Ohio; Conaphore, by Edw. A. Cassidy Co., Madison Ave. and 40th St., New York; Clear Light Lens by Woodworth Mfg. Corp'n, Niagara Falls, N.Y.

Focal Adjustment for Different Lenses

There are three general types of anti-glare or glare-reducing lenses:

(1) The **diffusing type,** as A, B, C, and D, page 437, which requires a focal adjustment for a "straight beam," or where the lamp filament is at the focal point, as shown in Fig. 22, page 436.

(2) The **deflecting type** of lenses which require a focal adjustment for a **"straight beam,"** the same as the diffusing type, are F, G, H, and I, page 437.

(3) The **deflecting type** of lenses which require a focal adjustment for a **"crossed beam,"** as in Fig. 24, page 436, where the filament is ahead of focal point, are J, K, L, and M, page 437.

Therefore, when fitting lenses of either of these types, it is necessary to adjust the focal point accordingly, after first making the adjustments with the lenses removed, as shown in Figs. 30 and 31.

When **a "diffusing" type** of lens is used it makes no difference whether you have a crossed beam, a spreading beam, or a straight beam, except that where a straight beam is used there will be less diffusion, and consequently a stronger light ahead of the car.

When **a "deflecting" type** of lens is used it is absolutely necessary to know whether it is intended for use with a spreading, a crossed, or a straight beam, before the focus can be made to insure satisfactory results. Therefore the manufacturer's instructions should be followed carefully.

If that part of the deflecting lens which is designed to bend the "glare rays" down towards the road is located in the upper half of the lens, a "spreading beam" must be used; if located on the lower half, a "crossed beam" must be used.

If the device is made of prisms having a uniform angle on both upper and lower halves of the device, a "straight beam" must be used.

Checking Lamp Adjustment

To find out whether the lamp is set for a "spread" or a "crossed beam" pass a screen, such as a piece of oard or paper, down in front of the headlamp. If the shadow caused by the screen moves up as the screen moves down, the filament of the lamp is in front of the focal point (Fig. 34), and you have a "crossed beam." If the shadow moves down with the screen, the lamp is set for a "spreading beam."

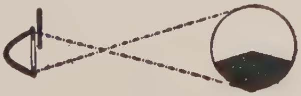

Fig. 34

Another method of testing whether the light is a crossed beam or a spreading beam: Let the light rom the headlight shine on a wall or screen 10 or 15 feet ahead of the lamp. Then move the lamp ulb back in the reflector.

If the spot on the wall grows **larger** as the lamp ulb is moved toward the back of the reflector, the amp is adjusted for a **spreading beam** and the filament is **back** of the focal point.

If the spot on the wall grows **smaller** as the lamp s moved back towards the reflector, the adjustment s for a **crossed beam,** and the filament is **ahead** of he focal point.

If the filament is moved from as far back in the reflector as it will go, to a point as far ahead as it will go, you will find that the spot of light will first grow smaller and then grow larger, as the filament passes the focal point. The point where the spot is **smallest** is the point where the filament is practically at the focal point (**X**), and the adjustment is for a **straight beam.**

These tests are, of course, made with plain lenses.

To Clean Reflector

Do not forget that dust or dirt on the reflector or on the glass lens may cut down the light on the road by more than half. The reflectors of head and side lamps are plated with pure silver.

To clean reflector, use a very soft, clean cloth, or powdered dry rouge and a chamois skin, without using pressure and rub in a circular motion. Never rub a reflector with a cloth or chamois skin which is covered with dust or grit. It will scratch the reflector and ruin it for service.

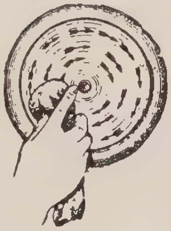

Fig. 35

If a reflector becomes tarnished or scratched, take it to a silver plater and have it buffed. It cannot be properly polished in any other way. An improvement can be made, however, where reflectors are tarnished, by moistening the rouge with alcohol and applying with a soft chamois. Do not use the chamois for any other purpose.

To Clean the Glass Lens

Absorbent cotton, dipped in alcohol and lightly rubbed in a circular motion over the surface, will be found efficient.

Dimming Headlights

There are four methods for reducing the brilliancy of headlights, which is required by law in most cities.

One method is to use resistance wire which is in series with the circuit, as shown in the Lexington (Fig. 8, page 426). See also Fig. 14 of Hudson, page 390.

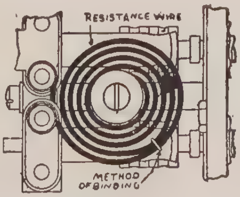

Fig. 36

To vary the intensity of the headlights when the dimmer is in circuit (Delco Hudson system) is merely a matter of shortening the path of the flow of current (the dimmer "resistance" wire, Fig. 36), which can be done by tying one coil together. This will make considerable difference.

To do this, it is necessary to **remove the switch.** Remove the four bolts passing through the housing at the back of the switch. The housing will then come apart. Remove No. 1 wire which connects with the generator, before dismantling the switch, otherwise a short circuit will result.

Another method (seldom used) is to have the switch connections so arranged that the two headlights which are always connected in parallel will be connected in series, thus reducing the voltage of each lamp one-half. For instance, if the two lamps are connected in parallel on a 6-volt circuit, each lamp would get 6 volts. If connected in series, each lamp would get 3 volts, thus dimming the lamps.

Placing auxiliary lamps of about 5 or 6 c.p. in the headlamps is the method in general use.

A double filament lamp is another method, as explained on page 433.

Frosting Compound

Q: Will you suggest a quick method for dimming headlights?

Ans.: Five cents' worth of epsom salts dissolved in a teacup full of water provides the neatest and most efficient headlight dimmer for automobiles, so far proposed. The solution is used on the inside of the headlight glass, where it is allowed to evaporate.—*Scientific American.*

A "Spot-Light"

The spot-light is a type of lamp which can be placed on the wind-shield, and turned in any direction by hand.

Where a great deal of night driving is done, or where a cross-country trip is made, a spot-light is of great convenience. It is fastened close to the driver's hand, and can be directed at any spot desired.

Adjustment is for a **"straight-beam,"** with the filament exactly at focus point.

Spot-lights are prohibited in some states, and in others the law requires that the light be thrown on the ground, not more than 60, 75, or 100 feet ahead of the car, and it must not be directed in the faces of persons approaching.

Electric bulbs used with spot-lights are usually of the nitrogen type, 20 or 32 c.p.

GAS LIGHTING (ACETYLENE)

Gas lighting is now seldom used, but it is explained here for the benefit of the reader. There are two methods of supplying the acetylene gas to the gas burners. One method is by means of a carbide gas generator, and the other by means of a tank containing compressed acetylene gas. The method whereby the gas is supplied to the gas jet by a gas generator is shown in Fig. 37.

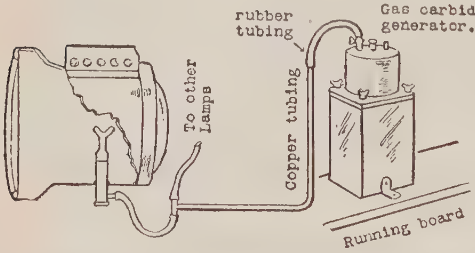

Fig. 37. **Showing how small 1/8" copper tubing and rubber tubing connects from generator to lamps.** Note that the rubber tubing connected from the copper tubing to the lamp drops in a curve. This places the rubber tubing at the lowest point. The gas condenses and turns to water, and the water clogs the pipes and gas tips. If this rubber tubing is disconnected occasionally, the condensed water will drain out.

It is always necessary that the line or leads from the gas generator to the lamps be on as much of an incline as possible. In fact, a draincock could be placed at the lowest point to advantage. The pipes to each lamp should be independent if possible.

There are two types of gas or carbide generators: the "drip" type, and the "automatic" type.

With the "drip" principle of generation, the water is usually arranged to drip directly on the carbide, and the amount of gas formed is regulated by a tap which allows more or less water to come in contact with carbide (Fig. 38).

A modification of this system allows the water to drip down a perforated metal tube, surrounded with carbide, and thus the water gradually soaks through the carbide.

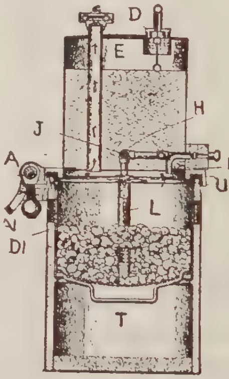

Fig. 38

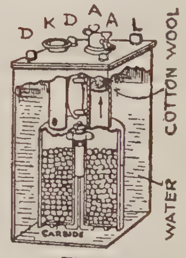

Fig. 39

Fig. 38. **Explanation of the "drip" type of carbide generator:** The tank (E) being filled with water at (D), the water saturates the cotton wick (H) in the tube (J) and the valve (F) being turned on, it drops into the screen tube (L), passing out of the holes at the bottom. As it comes in contact with the carbide, it forms gas which passes out at the top of the generator through pipe. The unused carbide held in the cage is separated by the screen in the bottom, and the dust or used carbide falls to the bottom (T) perfectly dry. Consequently the charge is always fresh while it lasts and is ready to light or extinguish. Cleaning simply means emptying the dry dust at the bottom and refilling the cage with carbide, and the tank with water. To shut off the light turn the valve (F) off. (F) being a two-way valve on the side (not lettered), the gas then contained in the generator passes out of the two-way valve into the air, thus insuring perfect safety.

Fig. 39. **The automatic type of generator:** In some respects this is simpler and gives a better regulation of the gas, but it does not seem to be always reliable.

The operation is as follows: The carbide is contained in a bell or chamber with perforated sides and bottom, to admit water freely. This bell has a suitable outlet for the gas. It is supported inside an outer vessel or tank to hold the water. Immediately the water comes in contact with the carbide, gas is generated and, if the supply tap (A) is open, this gas will pass on to the lamps. Should the tap be closed, the pressure exerted by the gas then acts inside the bell, and drives the water away from the carbide.

Should the generation of gas still continue, it will force its way through the water and escape into the atmosphere, through a small vent hole (L), so that no dangerous pressure can develop within the generator.

It will be seen that an automatic regulation of the gas is thereby obtained, because immmediately that more is being generated than can be used, the water is driven away from the carbide, but as soon as there is a demand for more gas the pressure inside the bell falls and water re-enters.

The gas outlet pipe and cotton wool or horsehair filter, whence the gas reaches the top, or to which the tubes are connected to the lamps is shown at (**AA**).

A gas bag is provided on the gas outlet pipe inside the generator to steady the pressure.

The carbide container lifts out of the tank by unscrewing the nuts (**DD**).

The tank is filled from the aperture (**K**), in the plug of which is a small vent acting as a safety valve. In this, as in other forms, the gas can be turned on and off any number of times till the carbide is all used up.

Gas Burners—Also Called Gas Tips

The gas burner is made up in various styles, and consumes from .25 to 1.5 cubic feet of gas per hour. By referring to Figs. 40 and 41, the reader will observe the construction.

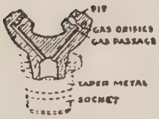

Fig. 40

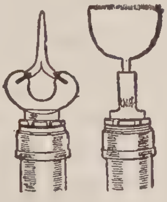

Fig. 41

Fig. 42

Fig. 40. Interior of a gas tip or acetylene burner. Tips are generally made of lava. Two small holes are in each end, only one of these being discernible to the eye. The hole, however, which becomes clogged is the small hole inside the large one.

Fig. 41. Showing end and side view of the flame when burner is in good order.

Fig. 42. Showing how to clean a gas tip.

If acetylene gas was used with an ordinary jet, it would have a yellow tint, but the oxygen drawn into the tip through the large hole raises the temperature of the flame to a point where a white blaze is obtained. It is therefore necessary that the smaller hole in the burner be kept clean.

If the flame is yellow and dim, the lack of oxygen is probably the cause, or the pipe line needs blowing out, or the generator needs cleaning.

If the independent generator is used, it is important that all parts be perfectly clean and fresh carbide be added daily, using whatever quantity is required.

The average gas tip consumes one-half foot of gas per hour. Gas tips are made in standard sizes as follows: ¼ foot; ½ foot; ¾ foot, and 1 foot.

Lighting the Gas

The usual method for lighting the gas is to turn on the gas at the generator or tank, and to light the gas at the burners with a match.

Another method is to turn on and light the gas from the seat. This is accomplished by a valve and electric spark (Fig. 43).

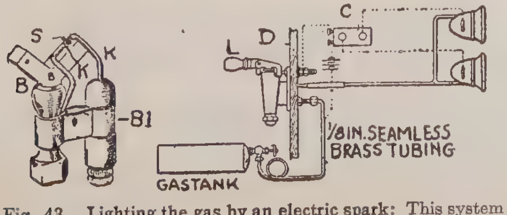

Fig. 43. Lighting the gas by an electric spark: This system consists of a special valve and switch placed on the dash-board (D), a high-tension coil (C), and a special gas lighting attachment shown in the cut.

The connections are as follows: The gas tank is piped to the valve and connected to a union under it. After gas passes through the valve it is then carried to the lamps. A wire runs from switch to coil and from there through primary winding to battery; through battery to ground.

An attachment (**B1**) is placed on each gas tip to be lighted. When lever (**L**) is pressed down, this opens the gas and also makes a temporary electric contact, and a spark jumps across points (**S**) and lights the gas. An ignition battery or dry cells will do this work.

Non-Freezing Solution for Gas Generators

Use plain alcohol in the proportion here given. Alcohol is a fuel, but not explosive. It will, therefore, probably give a slightly stronger gas than water, and for this reason less will be required. Do not use glycerine, as this is an explosive.

Percentage of alcohol to water: At 18 degrees, 10 per cent; at 5 degrees, 20 per cent; at −2 degrees, 25 per cent; at −9 degrees, 30 per cent; at −15 degrees, 35 per cent; at −24 degrees, 40 per cent.

Note: The − in front of the figures are minus signs, meaning below zero.

Carbide—Used in the Generators

The chemical formula for Acetylene is C_2H_2 (i.e., a compound of carbon and hydrogen). It has a characteristic pungent odor—which at once gives evidence of any leakage—and is a poison if inhaled in any quantity.

Approximately one pound of good quality calcium carbide will generate six cubic feet of acetylene gas. It can readily be liquified or compressed, but in this state it is highly explosive, and its use finds no favor in this country. What is known as dissolved acetylene, however, is safe.

The gas in a moist or impure state attacks copper or brass, forming acetylene of copper, which is exceedingly explosive; so much so that it will go off by slight friction or a blow. This accounts for the small explosions that are sometimes experienced when cleaning a generator.

The Pressure-Gas (Acetylene) Storage Tank

This tank is used instead of a gas generator, and is charged at the factory. When the tank is exhausted it is taken to the local agent and exchanged for a fully charged tank.

The gas used in the tank is acetylene gas, made from carbide—the same kind of gas used in a generator. Fig. 44 illustrates the Prestolite gas tank. The amount of gas in the tank is indicated by the pressure gauge. In this way the motorist can tell the quantity of gas in the tank. A key opens the valve which allows only a low pressure of gas to feed the lamps.

The piping of the gas from the gas tank to the lamps is just the same as that used with an independent generator.

The Prestolite gas tank is made in three styles: Style E, which weighs 23 lbs.; style B, 30 lbs., and style A, 50 lbs.

The pressure inside the tank (E) is based on a pressure of 15 atmospheres, or about 50 cubic feet of gas, which will supply gas for two ½-foot burners for 50 hours.

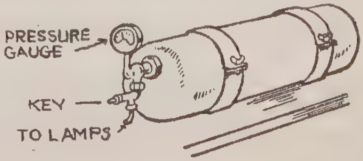

Fig. 44. The pressure-gas storage tank is usually placed on the running board of the car.

The tank should be placed on the car in such a vay that it can be easily removed. The running ooard is a convenient place. Always place the ank top side up.

Prestolite Gas Tank Pointers

Prestolite gauges, how to read them: Several tyles of gauges are used. Some register in atmosoheres, some in pounds and some in both (see Figs. 5, 46, 47). If you wish to determine the number of pounds of pressure in your tank, reading from a auge showing only atmospheric pressure, multiply he number of atmospheres shown by 14.7, which is he number of pounds to which one atmosphere is qual. The result will give you the number of oounds of pressure in your tank. All atmosphere auges are marked "ATM." **An atmosphere equals 4.7 lbs. at sea-level.**

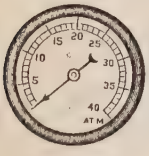

Fig. 45

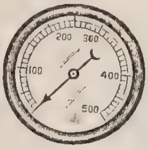

Fig. 46

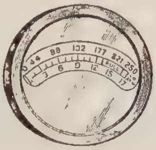

Fig. 47

Fig. 45. Gauge reading in atmospheres.

Fig. 46. Gauge reading in pounds.

Fig. 47. Combination gauge reading in pounds and atmosheres.

Prestolite tanks are charged to a pressure of 225 ounds (equal to approximately fifteen atmospheres) 65° Fahrenheit. If the temperature of a tank be creased 10° to 20° F., the pressure will be raised to 50 pounds. If the temperature be lowered, e pressure will be reduced in about the same ratio. is accounts for the rapid fall in the gauge pressure en a tank is taken from a warm garage into the ld air of the street. Change in temperature does t affect either the quantity or the quality of the s. Consequently, when the outside temperature is 65° F., a properly filled Prestolite tank will show a pressure of about 15 ATM (atmospheres) when using the atmospheric type of gauge, and 225 pounds when using the gauge reading in pounds, while the gauge showing both pounds and atmospheres will indicate a pressure of 221 pounds, or 15 ATM, with corresponding variations according to the outside settled temperature, despite the fact that the first two mentioned gauges show a capacity of 40 ATM and 500 pounds, respectively.

Where to look for leaks: Rub soap-suds along the pipe lines and over all joints and connections. Do not use a match any more readily than you would use one to hunt for a gas leak in your cellar.

The following may be the source of a leak: (1) union where attached to tank; (2) rubber hose connecting union with brass piping of car; (3) joints where rubber hose connects with union and with piping of car; (4) joints, T's, or crosses where piping branches; (5) where rubber hose connects piping with lamps; (6) part of lamp to which burners are attached; (7) any point on piping where there is a liability of chafing.

Sizes and capacities of Prestolite tanks: "A"—22 inches long, 7¼ inches in diameter; contains 70 cubic feet of gas.

Using two ½-ft. burners, 70 hours lighting

Using two ⅝-ft. burners, 56 hours lighting

Using two ¾-ft. burners, 46 hours lighting

"B"—20 inches long, 6 inches in diameter; contains 40 cubic feet of gas.

Using two ½-ft. burners, 40 hours lighting

Using two ⅝-ft. burners, 32 hours lighting

Using two ¾-ft. burners, 26 hours lighting

"E"—16 inches long, 6 inches in diameter; contains 30 cubic feet of gas.

Using two ¼-ft. burners, 60 hours lighting

Using two ½-ft. burners, 30 hours lighting

Oil Lighting

Inasmuch as electricity for lighting is now the adopted standard, and is almost universally used, it is hardly worth while to deal with the kerosene oil lamp. The oil lamp, when used in place of electric lights, is generally placed as a tail or rear lamp, to illuminate the license number and as required by law for protection of the fire department.

The brilliancy of oil lights can be improved by using a hard wick and placing cotton in the bowl of lamp. Then use gasoline or half gasoline and light cylinder oil instead of kerosene.

BAUSCH & LOMB LENS FOR AUTOMOBILE ELECTRIC LAMPS

The diagrams (Figs. 1 and 2) illustrate the path of light from mp fitted with the Bausch & Lomb lens.

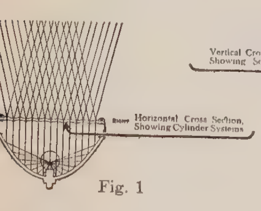

Fig. 1

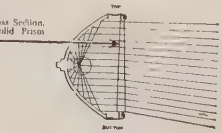

Fig. 2

he illustration in Fig. 1 shows a horizontal cross-section how the vertical cylinders (placed in front and rear of lens) w or spread rays outward sufficiently to illuminate a lateral of about 50 feet at a distance of 100 feet.

ote: The word **"cylinders"** used above refers to the flutings h are in both the front and back of the lens. The whole is in reality a **"prism,"** and in this example it is somewhat ker at the bottom than it is at the top.

e illustration in Fig. 2 shows a single or solid vertical n which deflects the light downward, or below the level ribed by law.

order to secure maximum satisfaction from these lenses necessary to adjust them properly, and this is explained llows:

e adjustment of a lamp consists in moving the lamp bulb ard or backward (see pages 435, 436). Some lamps have nal adjustments whereby the adjustment can be made the lens in place, and others where the lamp door must be ed. Adjustment should be made each time the lamp are changed.

r adjustment with the lens in the lamp, have the light on a 25 or 50 feet away. Cover or disconnect the other light. Cut out a circular piece of light-weight cardboard as in Fig. 3, with holes in it ⅞" in diameter and 4⅛" from center to center of holes. Hold it in front of the lamp so that the centers of the two holes in the card lie in a vertical line as shown.

If the bulb is **properly** set (focused or adjusted), the light on the wall will appear as one solid band, as shown in Fig. 4.

If the lamp bulb is too far away or too close from the reflector, two bands will appear, and the lamp bulb should be moved forward or backward until a single band is obtained as shown in Fig. 4.

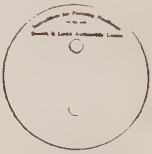

Fig. 3

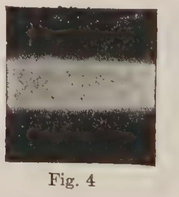

Fig. 4

Fig. 5

For adjustment with lamp doors open, which is necessary when the adjustment is inside of the lamp, the same procedure is followed. If the lamp bulb is properly focused with the reflector, a solid spot or patch of light will appear, as shown in Fig. 5.

If the lamp bulb is not properly focused, two images or spots will appear, and adjustment of the bulb should be made until only a single patch of light appears, as in Fig. 5. This adjustment is for a straight beam.

Next, place the lens in place in the door and then close it, and see if the adjustment is now as in Fig. 4.

The tilting of the lamps should be made in accordance with local requirements.

(Manufacturers are Bausch & Lomb Optical Co., Rochester, N.Y.)

INSTRUCTION No. 39

SIGNAL ALARMS; SPEEDOMETERS

SIGNAL ALARMS

There are a variety of devices properly designated as signal alarms, including: bells, bulb horns, electric horns, exhaust whistles, compression whistles, etc.

In the early days the **mechanical electric bell,** operated by the foot, was the applied method for warning the pedestrian—although possibly this was not necessary, as the cars in those days made sufficient noise to give warning a block ahead.

Then came the **bulb horn,** but the old-style bulb horn has about seen its day. It is seldom used, because of its difficult method of bulb operation and because of a tendency to get out of adjustment at the reed.

The compression whistle is the type shown in Fig. 1. It is desirable for use where there is no battery, or where the battery is not of sufficient size to operate an electric horn, or where it is desired to save battery current. It is screwed into the cylinder instead of into the relief cock. The pressure is obtained from the compression in the cylinder.

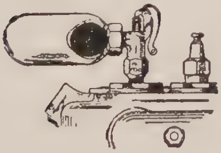

Fig. 1

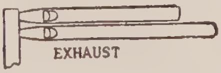

Fig. 2

The exhaust horn or whistle (Fig. 2) was used extensively at one time, but is now seldom used. It is connected to the exhaust pipe by means of a valve which is opened and closed by a foot pedal connection, which when depressed admits the exhaust gases to the horn. See Index, for "Fitting an exhaust horn."

The hand-operated horn (Figs. 3, and 3A) is not altogether desirable because it is operated by hand at an inconvenient place. It is usually placed too near the driver, whereas it ought to be nearer the front of the car.

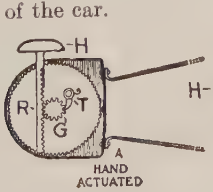

Fig. 3

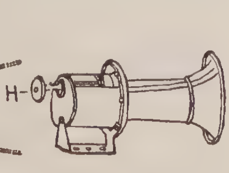

Fig. 3A

Fig. 3. Klaxon type 3, hand-actuated horn. Klaxon S-3 type is similar, except that it has a vertical push rack.

The hand-actuated horn is operated by pressing on the knob (**H**) (Fig. 3) connected with a toothed rod (**R**), thus actuating gear (**G**). This type of horn is used extensively on motor trucks.

Horn brackets for automobile use, as shown in Fig. 3B, are arranged so that the horn can be mounted at different angles. (**M**) and (83) are for motor-boat use. American Electric Co., Chicago, supplies the brackets.

Handles for hand-actuated horns (Fig. 3C) can be had o some of the horn manufacturers. They are suitable for long continued blasts when used on boats.

Fig. 3B

Fig. 3C

The Electric Horn

The electric horn is the most popular type, and i classified under two types of general construction (1) vibrating type; (2) motor type.

The Vibrating Type of Electric Horn

The vibrating type of electric horn produces sound resulting from the action of a vibrating arma ture (**B**) (Fig. 4) magnetically operated by th magnet cores (**R**). The vibrations are transmitte through rod (**A**) to a diaphragm (**D**), thus producin a sound which is greatly magnified by having a hor attached. This device looks very much like th shown in Fig. 3**A**, except that it is operated electr cally instead of by hand.

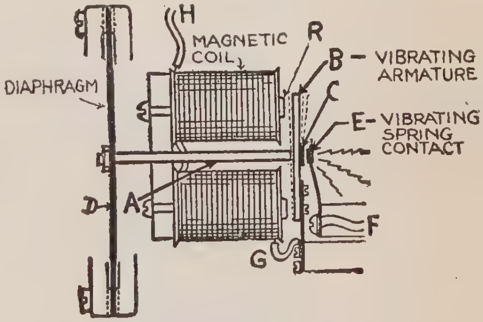

Fig. 4. Vibrating type of electric horn.

The electric circuit is to (**F**), from (+) of the battery, (generator), through the blade, through platinum iridium poi (**E** and **C**), through armature (**B**), to lower connection (**G**) the lower magnet coil, through the upper coil, to (**H**), to t push-button, to the (–) connection of the battery. Wh the push-button is depressed, the circuit is closed, and armatu (**B**) is drawn to coil (**R**), striking against rod (**A**). The mome this occurs, the circuit is opened and armature (**B**) is releas thus contact is made again at the points (**E** and **C**), and t armature vibrates back and forth as long as the push-butt closes the circuit. The action is similar to that of a vibrati type of ignition coil or electric bell.

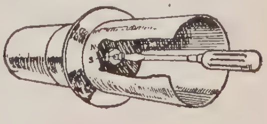

Fig. 4B

Adjustment is made by adjusting the rod (**A**) (Fig. 4**B**) relation to (**B**), to obtain a greater or less number of vibratio which increases or decreases the sound transmitted throu diaphragm (**D**).

Points (**EC**) should be of iridium platinum, otherwise th will wear down and stick. The amperage consumed is fr 4 to 6 amperes.

On some of the electric horns (Fig. 4B) this adjustment is made with a screwdriver by loosening locknut (N) and screwing adjusting screw (S) in or out while current is passing through the horn circuit, until the sound is as desired.

The Motor Type of Electric Horn

The motor type of electric horn also produces a sound transmitted through a diaphragm, but in a manner different from that of the vibrating type.

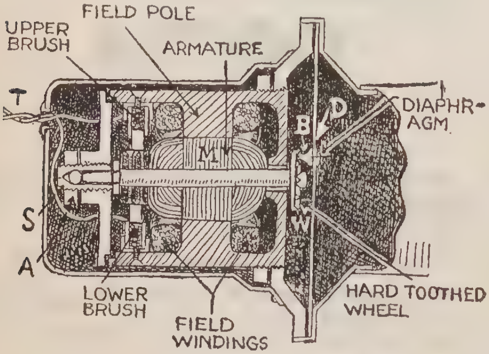

Fig. 5. Motor type of electric horn.

Construction: An electric motor (M) (Fig. 5) of small size is enclosed in one end of the horn. On the right end of the armature shaft a case-hardened steel-toothed wheel (W) operates against a case-hardened steel button (B) securely attached to the metal diaphragm (D) (see also Fig. 6). The sound produced by the wheel (W) operating against (B) is transmitted through the diaphragm (D) and greatly magnified through the horn which encloses the diaphragm.

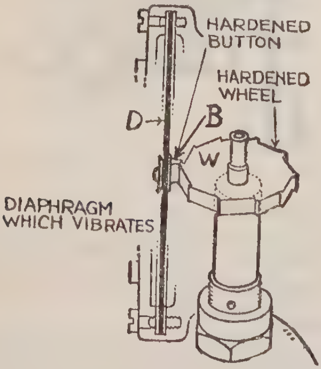

Fig. 6. Explaining how the wheel (W) actuates (B) on the diaphragm.

The intensity of this sound can be increased or decreased by moving the armature shaft so that (W) will make closer contact with (B) to increase the ound, or so that they will back away from each other, to reduce the sound.

This adjustment is made by loosening the lock-ut (A) and screwing the adjusting screw (S) in or ut, which moves the armature, as explained above. Do not adjust too tight at (B) and (W).

The motor is a series-wound motor. Note the eld-windings (shown in section), also the armature nd brushes and the commutator on which the rushes rest.

The circuit is from (+) of the battery (or generator) to one end of the field-winding, through the two field-windings to one of the brushes, through the armature, out the other brush, through push-button (P) (Fig. 7), to (−) of the battery or generator.

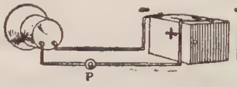

Fig. 7

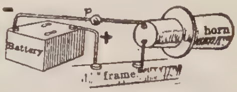

Fig. 7A

If the circuit is a "two-wire system," see Fig. 6; if a "single-wire grounded-return system," the frame is used as a ground or return, as shown in Fig. 7A.

Fitting an Electric Horn to Car

When fitting the electric horn to a car, the horn should be placed on the opposite side from the driver and as far away in front of the car as possible. The reason for this is that the noise is then away from the occupants of the car, and the signal is placed where it is most effective, usually under the hood, to the front. Being under the hood, it is protected from water when a car is being washed, and also from rain.

Connections for wiring are shown in Figs. 7 and 7A.

Klaxon Electric Motor Horn

The Klaxon is used extensively on various makes of leading cars, and its principle of construction is that explained in Figs. 5 and 6. Several different types of Klaxon horns are manufactured. Some of the leading types for automobile use are shown in Figs. 8, 9, 10, and 11.

Klaxon horns are made for **various voltages.** If the battery is a 6-volt battery, the voltage of the horn should be 6 to 8 volts. Dry cells can be used if necessary, about 6 to 8 dry cells being required.

The amperage, or current consumption, is fixed for each size of Klaxon horn, as stated under the illustrations.

To Adjust the Klaxon Horn[1]

To adjust Klaxon 20L (Fig. 8): Loosen the locknut (A), and start the current by pressing the push-button. While it is sounding, twist the motor case until no sound is heard except the buzzing of the motor. Continue twisting, in either direction, until the note is loud and clear. When the note is as desired, tighten the locknut.

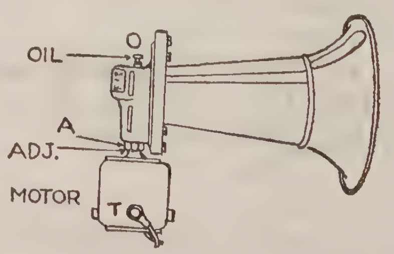

Fig. 8. Klaxon 20-L uses 7 amperes. It is a large, deep-toned horn.

To adjust the Klaxon 12-L and Klaxon-6 (Figs. 9 and 10): Loosen the screws and remove cover. You will find a locknut (A) (Fig. 5). While the motor is running adjust screw (S) until the note is

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[1] Write the Klaxon Co., Newark, N.J., for instruction pamphlet on adjusting and caring for the Klaxon.

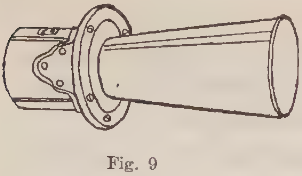


Fig. 9

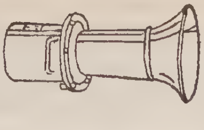


Fig. 10

Fig. 9. Klaxon 12L uses 8 amperes. A medium-sized and popular type; also a deep-toned horn.

Fig. 10. Klaxon-6 uses 5 amperes; the Klaxette, not shown, uses 3 amperes.

as desired. This action forces the armature shaft with its wheel (W) against the button (B). Replace cover and tighten screws.

Care of Electric Horns

To lubricate: Clean and lubricate the commutator once a month, as follows: With a dry cloth wipe the commutator clean. Apply a little vaseline with a clean cloth. Use thin oil in winter. Apply this to the commutator. The slightest film is all that is necessary. Every three or four months a little vaseline should be applied to the toothed wheel (W). Oil the shaft bearing once a month.

On the Klaxon 20-L, oil once a week through oil hole (O) (Fig. 8). Give two drops of "3 in 1" oil.

The tone of the horn is dependent upon the speed at which the motor can revolve, and also on the adjustment, and the speed is influenced by the care and attention given the horn.

The armature should always turn easily when made to revolve by the fingers.

Testing Electric Motor Horns

If, in testing the horn, it is found that the current or amperage consumption is greater than the fixed amount, this is probably due to dry or dirty bearings or commutator and brushes, caused by the instrument not receiving the proper lubrication.

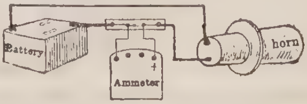


Fig. 11

The electric horn can be tested by placing an ammeter with the 30-ampere shunt (see Index for "Ammeters") in the circuit (Fig. 11). Then adjust to take the least possible current. The average horn draws from 3 to 8 amperes, depending on its size. The ammeter can also be used to test the horn for short circuit or open circuits, just the same as a generator or starting motor armature and field-windings are tested, as explained under these subjects.

SPEEDOMETERS AND ODOMETERS

Necessity of a speedometer: A speedometer is necessary in testing a car, to learn its speed capabilities under various conditions: in order to time trips over various distances, or to avoid violation of the speed limit laws, the penalty for which is arrest and fine.

Purpose of a speedometer: The speedometer for automobiles is an instrument for measuring and indicating—**in miles per hour—the exact speed at which a car is being driven.** The number of miles per hour shown at the dial of the speedometer is the actual speed at which the car is traveling at the instant of indication. For this reason the numbers shown constantly change as the car is driven faster or slower.

Necessity of an odometer: The odometer is usually embodied in the same case with the speedometer. It is necessary in auditing the cost of operating and maintaining a car. It enables the owner to tell how much gasoline is used per mile; how much his tire expense per mile amounts to; how much mileage he gets out of his car. Thus it enables the owner to make comparison of the cost of operating and maintaining his car, with the cost of operating and maintaining a car of another make. The recording and resetting features of the trip-register part of the odometer are a necessity in following a guide book when touring.

Purpose of an odometer: The odometer (combined with the speedometer) is an instrument for measuring and **recording—in miles and tenths of miles—the distance a car travels** in making a trip. It also records the entire or total distance traveled during an entire season.

Speedometer Principles

The magnetic principle (Fig. 1), as employed in Stewart-Warner and American Ever-Ready instruments, utilizes a revolving magnet positively driven from the car wheel or other part. The magnet exerts its influence on a metal part which is separated from it by an air gap, which in turn is connected with the indicating mechanism. The metal part is generally aluminum, as the inertia of the part must be kept as low as possible to make the speedometer quickly sensible to speed changes. A feature of the magnetic design is that the travel of the dial bears a direct ratio to the speed of travel of the magnet, and in order to compensate for changes in the drag, due to temperature differences, a compensating unit is fitted.

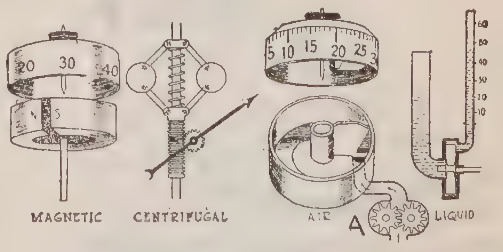


Fig. 1 Fig. 2 Fig. 3 Fig. 4

The four principles of speedometer operation: magnetic, in which a revolving magnet exerts its drag on the dial; centrifugal, in which revolving weights supply the energy due to centrifugal force; air, in which a current of air flows against a vane carrying the dial, and liquid, in which a column of liquid is lifted a height proportional to the speed of the pump drive.

Centrifugal control (Fig. 2), as utilized in speedometers, is very much the same as that on a fly-ball engine governor. Standard, Johns-Manville, Sears-Cross, Corbin-Brown, Hoffeker and Garford use this principle. Weights are mounted on the revolving shaft by bell crank levers which allow them to travel farther from the axis of the shaft as the speed of the drive increases. The centrifugal force of the weights increases as the square of the velocity of the shaft, meaning that at four times the speed the force doubles.

This tendency of the weights to fly from the axial center of the shaft under the influence of centrifugal force furnishes the basis of the indicating needle movement. An ingenious feature in centrifugal design is that although the movement of the weights would naturally vary as the square of the speed, the levers or cams governing the movement are so calculated that calibrations on the dial are uniform, or nearly so. Another feature which is carefully watched is the balance of the weights. The governors are made very sensitive, so that even at low speeds the correct rate of travel may be indicated.

The air principle (Fig. 3) is an instrument which calibrates an air current and translates the result into miles per hour. The air circulator (**A**) consists of two intermeshing aluminum gears housed in a chamber in which there are two openings, one from the outside and away from which the gears rotate, the other opening conducting the air into the speed dial chamber where the air is directed against a ight vane attached to the inside of the speed dial.

The speed dial is an inverted aluminum cup (**C**) mounted on a pivot set in jeweled bearings. The amount of air directed against the vane in the speed dial is governed by the speed at which the air circulator (**A**) is driven by the flexible shaft. The speed dial, when the car is at rest, is held at zero by the action of a nickeled steel hairspring.

The liquid or hydraulic principle (Fig. 4): One nstrument, the Veeder, which employs the hydraulic system, uses a centrifugal pump which is connected with the drive and which lifts a liquid to a height proportionate to the speed of the drive. The tube n which the colored liquid is lifted is calibrated to egister speed. See illustration. (*Motor Age.*)

Speedometer Drive Methods

Front wheel drive: The speedometer can be driven from the front wheel (Fig. 5), or off the propeller or transmission shaft, as in Fig. 6. The usual plan is to drive with gears.

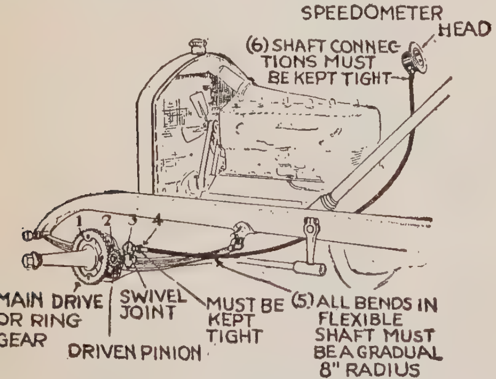

SPEEDOMETER HEAD
(6) SHAFT CONNECTIONS MUST BE KEPT TIGHT
1
2
3
4
MAIN DRIVE OR RING GEAR
SWIVEL JOINT
MUST BE KEPT TIGHT
(5) ALL BENDS IN FLEXIBLE SHAFT MUST BE A GRADUAL 8" RADIUS
DRIVEN PINION

Fig. 5. Drive from front wheel.

Transmission drive: Instead of placing the speedmeter drive on the front wheel, which has been he standard former method, it is now quite often placed just in the rear of the transmission, on the transmission main shaft. Fig. 6 shows how the driving gear is attached to the front of the forward universal joint. The swivel joint and gear section are clearly depicted. Other manufacturers are now adopting a set of gears inside of the transmission case, to drive the speedometer shaft.

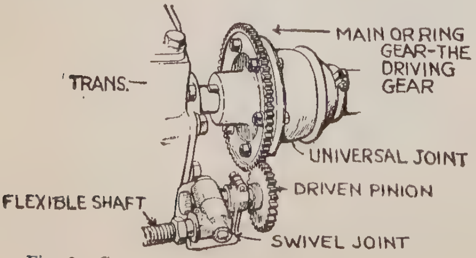


Fig. 6. Stewart speedometer, propeller-shaft drive.

The speedometer flexible shaft is shown in Fig. 7.

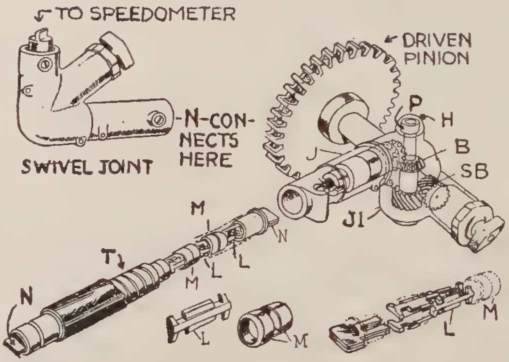


Fig. 7. The speedometer flexible shaft (Waltham, as an example) is made up of a series of links (**L**), which are held in position by a series of steel collars (**M**). The links (**L**) are covered with flexible tubing (**T**). The illustration shows the flexible shaft together with other fittings, including swivel and angle joints.

Ratio of Gearing

The ratio of gears for a speedometer when driven from front wheels is found by doubling the diameter of the tire. This gives the number of teeth necessary in the large **driving or road wheel gear.** For example, a 30 x 4 tire would require a 60-tooth gear, etc. **Driven** pinions (small) on all Stewart-Warner speedometers, for front axle drive, have the same number of teeth, viz., 16, and drive through a 2½ to 1 swivel-joint reduction.

The gear reduction in the swivel joint is mounted close to the driven pinion, as shown in Figs. 5 and 7. When installed on the left-hand wheel, a swivel joint is used which reverses the direction of rotation.

Calibration: The Stewart-Warner speedometer flexible shaft travels 1,009 revolutions per minute when the car is traveling 60 miles per hour.

On all Stewart speedometers the space between the main gear (1, Fig. 5) and the pinion gear (2), should be 1/16″. Also note that the main gear should have twice the number of teeth that there are inches in the diameter of the tire.

Speedometer Care and Troubles

The following matter refers to the Stewart speedometer, the instructions and illustrations being taken from the Studebaker instruction book.

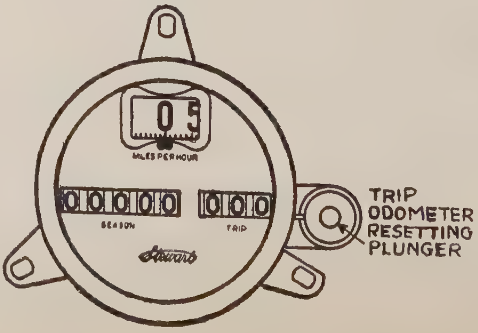


Fig. 8. Front view of speedometer.

Resetting odometer: Pull out the trip odometer, resetting the plunger (Fig. 8), after which turn to right or left as much as necessary to show the figures you desire to have appear. After resetting the odometer, do not fail to push the resetting plunger in as far as possible, or else the trip odometer will not register. The speedometer is a very delicately adjusted instrument, and must be handled carefully to insure continued satisfactory service.

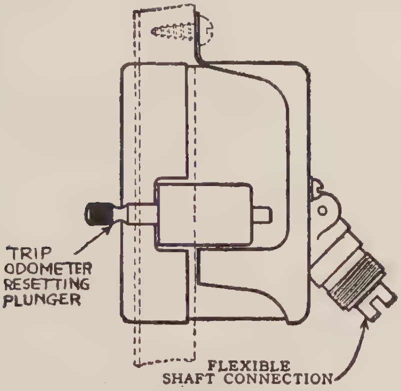


Fig. 9. Side view of speedometer.

Lubrication: Do not attempt to lubricate the speedometer head under any circumstances. Parts that required lubrication were attended to when it was assembled, and will last for the life-time of the instrument.

Speedometer Troubles

If the speedometer is not operating satisfactorily, look over the installation and see if it is in accordance with the following instructions:

Flexible shaft connection: Make sure that the clutch in the flexible shaft enters the slot in the neck of the speedometer (shown in Fig. 9, "Flexible Shaft Connection"). The sliding bar on the other end of the flexible shaft enters the slot in the driving shaft at transmission.

Speedometer Adjustments

Dial vibration results in failure to indicate speed and mileage. **Noisy instruments** are caused by any of the following:

1. Loose union connection between speedometer and flexible shaft connection.
2. Loose union connection between driving shaft at transmission and flexible shaft. (These unions on flexible shaft should always be kept as tight as possible.)
3. The flexible shaft may be bent at a sharp angle. This condition causes the shaft at times to bind, making the dial unsteady.
4. The worm gear and pinion at the drive end may be either meshed in part only or entirely out of mesh, due to speedometer pinion gear sleeve at the rear of the transmission being loose. The shaft should be shoved in the housing as far as possible, and the nut tightened.
5. The flexible shaft may not be well lubricated, which causes erratic shaft movement and unsteady indication. The manufacturer has a special grease for this purpose.
6. The chain in the flexible shaft may have broken. If so, it can be quickly repaired by replacing the broken link. **If the chain breaks,** unscrew both shaft connections and remove the chain from the outer casing. Then repair the break by hooking into place a new link—a very simple operation—replace the chain, and screw both shaft ends into place. Extra links may be obtained from Stewart-Warner Corporation branches or service stations at a nominal cost.

When speedometer pointers vibrate, look for loose unions, connection, flexible shaft bent too sharp, lack of lubrication, gears not properly meshing.

Failure to indicate speed: Look for the same causes as above; also for a broken link in the shaft.

Noise may be due to lack of lubrication or any of the causes described above.

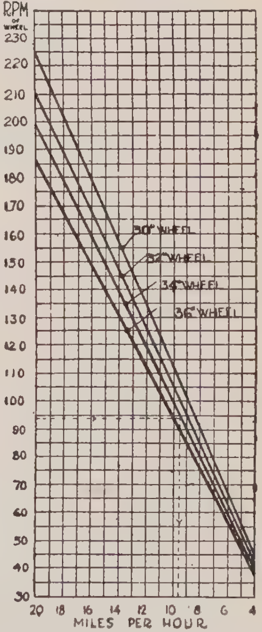
Checking a Speedometer

A simple test worked out by Mr. S. T. Williams of the *Motor World* is shown in the table below, and is as follows:

When the drive is from the front wheel, jack up the wheel. A chalk mark is then placed on the rim of the wheel, and the wheel is turned as fast as possible.

At a signal, one person reads the speedometer, and another counts the revolutions for one minute, as timed by a stop watch, or the second hand of a watch. The number of revolutions of the wheel, and the speedometer reading at the start and finish are noted. (By adding the two speedometer readings, and dividing them by two, the average speed as recorded by the speedometer is determined.)

Fig. 10



The actual speed may be obtained from the chart in Fig. 10. Supposing the revolutions in the minute to have been 94, a horizontal line is followed until it meets the slanting line representing the diameter at the front wheel, assume it to be 34". Dropping down vertically, the speed is seen to be 9.6 miles per hour—which should correspond to the speedometer readings. If carefully made, this test is quite accurate, and requires little time.

INSTRUCTION No. 40

ELECTRIC PARTS OF A CAR: Preliminary Instructions for Locating Troubles of the Electric System

DIVIDING THE ELECTRIC SYSTEM INTO PARTS AND TROUBLES THAT COULD OCCUR IN EACH PART

Before it is possible to diagnose properly or to test for any trouble in the electric system of a car, it is first necessary to know the fundamental principles underlying all the parts, their location, and the relation of one part to another.

The fundamental principles of all parts of the electric system have been dealt with in preceding instructions. We shall now deal with the division of the parts, the troubles that are likely to occur in each part, together with the effect that these may have on some other part, and also with the devices, instruments, and tools necessary to locate troubles and to remedy them.

Electric troubles may be in the external parts, or in the internal parts. If trouble occurs in the ignition system, then the point to begin at would be the source of electric supply of the ignition system, tracing through the **external** parts of this system. Then if the trouble is not located, the test should extend to the **internal** parts, such as the winding of the ignition coil, the condenser, etc. The same procedure would apply to the starting motor, the generator, the battery, the cut-out, etc.

Hence the necessity of dividing the electric system into component parts and testing the circuits of each part, and at the same time considering the relation of that part to some other part. In other words, intelligently to diagnose electric troubles requires a knowledge of the fundamental principles of all the parts and their relation to each other. The importance of separating the parts, in order definitely to be able to locate the trouble is the point to consider in this instruction.

If we separate the electric system of a car into its main external parts, we have:

1. The storage battery.
2. The generator.
3. The starting motor.
4. The wiring system.
5. Dash ammeter.

(1) Storage Battery

If we take the storage battery and divide it into its component and internal parts, we have:

(a) The storage battery plates.
(b) The storage battery separators.
(c) The storage battery jars.
(d) The storage battery electrolyte.
(e) The storage battery connectors and lugs.
(f) The storage battery ground connection.
(g) The storage battery terminals.

Any of the parts of a storage battery mentioned above could cause trouble, such as plates being internally short-circuited, separators becoming rotted, jars leaking, electrolyte falling below the level of the plates, connectors or lugs not being burned properly and thus making poor contact or open circuits, ground connection loose, and making poor contact or open circuits, and terminals also.

The construction, care, troubles, tests, and repairs of storage batteries are treated under the storage battery subject.

(2) Generator

If we take the generator and divide it into its component and internal parts, we have:

(a) The field poles and frame.
(b) The shunt-field windings.
(c) The regulation of the shunt-field winding circuit.
(d) The armature
(e) The commutator.
(f) The brushes.
(g) The cut-out.

Any of the parts mentioned, if defective, would interfere with the proper operation of the generator, for instance:

(a) **The field poles,** if loose where they are held to the frame by screws, would probably result in damage to the armature. The proper clearance between the ends of the field poles and the armature is a point to consider.

(b) **Field windings,** if grounded with the field pole, or if one coil is grounded with another, or if short-circuited, would either carry no current at all, or, at best, a weak current.

(c) **The regulation system,** such as the electromagnetic "voltage regulator," or the "current regulator," may not be properly adjusted. These regulators are usually connected with the shunt-field winding of the generator, and if not properly adjusted, they would permit too high or too low an output of the generator.

Furthermore, the regulator windings may be open-circuited or short-circuited, thus necessitating a test of the windings. Or the points of the regulator may be burned together and fail to open, or the resistance, usually connected with the points, may be burned out.

If the regulation is of the "third-brush" type, the brush may not be seating properly, or the brush may be worn too short, or there may be poor connection of the brush with the wire connecting with it, or an improperly adjusted brush.

All or any one of these troubles in the regulation system would prevent the shunt-field winding from building up lines-of-force properly and would thus affect the output of the generator.

(d) **The armature** troubles are principally either in a short-circuited or in a grounded armature coil; that is, one wire may be shorted to another wire internally of the armature, or one wire may be grounded with the core of the armature, or there may be open circuits, where the wire is broken, or loose at the commutator.

(e) **The commutator** gives more trouble than any other part of the generator. Eighty per cent of the generator troubles are indicated by the condition of the commutator.

A commutator blackened over its entire surface indicates too much grease and carbon dust. Rough commutators require turning down in a lathe or being sanded. Mica insulation, which is placed between each commutator segment, will protrude in time, as the copper, being soft, wears. As a consequence, the mica protrudes and prevents the brushes from making good contact, thus causing arcing at the brushes which, in turning, burns the commutator. There are other causes of commutator troubles, such as loose segments, loose wires to segments, etc., all of which will be taken up farther on. Oil should never be placed on a commutator.

(f) **The brushes** are a source of trouble, principally when they fail to make good contact, when there is improper spring pressure, when the brushes are stuck in the brush-holder or are worn short, when the brush-holder is loose or when there are loose connections. All these affect the operation of a generator. When new brushes are fitted, it is important that they be seated to the curvature of the armature (explained farther on).

(g) **The cut-out** has two windings: a "voltage winding" and a "series winding." The voltage fine wire winding connects **across** the main circuit of the generator. In some instances the cut-out points burn together and permit the current to flow back through this fine wire winding, which burns it out.

The cut-out series winding is connected **in series** with the charging circuit from the generator to the battery, and is a larger wire. It seldom burns out, but may become short-circuited, or open-circuited. The windings can be tested for open circuits, short circuits, and grounds, just the same as the generator field-windings, the armature coil windings, and the regulator windings; explained farther on.

The cut-out points sometimes stick together, thus permitting the battery to discharge back through the generator, which is usually indicated in the ammeter on the "discharge" side. This necessitates cleaning and adjusting points.

(3) Starting Motor

If we take the starting motor and divide it into its component and internal parts, we have:

(a) The field poles and frame.
(b) The field windings: straight "series" or "series parallel."
(c) The armature.
(d) The commutator.
(e) The brushes.
(f) The bearings.
(g) The starting switch.
(h) The ground connections.

(a) **Field pole troubles** are not common, but it is well occasionally to tighten the screws holding field poles to the frame, with a screwdriver.

(b) **The field windings,** like the generator field-windings, can be tested for open circuits, short circuits, or grounds, explained farther on.

(c) **The armature** troubles of a starting motor are usually due to the bearings giving way and permitting the armature to strike the pole pieces, thus injuring the armature windings.

The armature windings can be tested for open circuits, short circuits, and grounds, in the same manner as a generator armature, as will be explained farther on.

The armature shaft is sometimes bent or twisted, because of the back firing of the engine and hard strains. How to test and straighten this is explained farther on.

(d) **The commutator** on starting motor is subjected to a great amount of current passing through it. Thus if it is roughened, it should be turned down in a lathe. It is seldom that the mica protrudes, as in a generator commutator, because the starting motor is not used as much as the generator. Loose wires from the armature coils to the commutator segments sometimes come loose and require soldering.

(e) **Brush troubles** on a starting motor are usually due to poor contact on commutator, or to loose brush-holders. Brushes should seat properly.

(f) **Bearings** of a starting motor are usually plain bronze bearings which may become worn from the lack of oil and long service. Thus when a heavy charge of current (150 to 300 amperes) passes through the armature and the field-windings, as the armature revolves, it is forcibly drawn to the pole pieces, since the air-gap or clearance is very slight, with the result that the armature strikes the pole pieces and damages them. This usually necessitates a new armature and end-plates with new bearings.

(g) **Starting switch** troubles usually result from poor connections, loose parts, or burned contacts.

(h) **The ground connection** from battery to frame, which is a part of the starting circuit, should occasionally be examined. If not properly made when first installed, the connections will corrode and cut down the current supply, not only to the starting motor, but to all of the other circuits. Vibration often causes this contact to become loose.

(4) Wiring System

If we take the wiring system and divide it into its various circuits, we have:

(a) The starting-motor circuit.
(b) The generator charging circuit.
(c) The ignition circuit.
(d) The lighting circuit.
(e) The horn circuit.
(f) The ground connections.

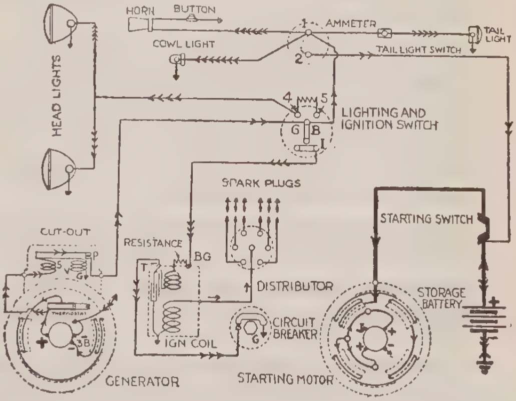


Fig. 1. Diagram of a Remy electric system as an example. The object of this diagram and the explanations is to point out where to start when tracing different circuits in order to locate troubles intelligently. Note the arrow points.

Single arrow: starting-motor circuit.
Two arrows: generator charging circuit.
Three arrows: ignition circuit (primary).
Four arrows: headlight circuit.
Five arrows: tail-light circuit
Six arrows: horn circuit.
Seven arrows: cowl-light circuit.
Single arrow to the side of wires: secondary ignition circuit.

Where to Start Tracing When Trouble Occurs

(*a*) **The starting-motor circuit:** The circuit in this example would start from (+) of the battery, thence to the starting switch, to the motor, to ground, to (−) ground of the battery, as shown by single arrows on the wires.

If the (+) terminal of the battery is grounded, then the starting of the circuit would be at the grounded (+) terminal of the battery, to the (+) grounded brushes of the starting motor.

The parts included, therefore, in the starting-motor circuit are the battery, the heavy wire, the starting switch, the motor field-windings, the brushes, the commutator, the armature, the ground connection of the motor, and the ground connection of the battery.

(*b*) **The generator charging circuit:** The point at which to start in the example (Fig. 1) is with the (+) brush of the generator, to the cut-out series winding, through the closed cut-out points, to the ammeter, as shown by two arrows on the wires.

If the (+) brushes are grounded, then the (+) terminal of the battery would also be grounded, and the start would be from the (+) grounded brushes, to the (+) grounded battery terminal, thence to the starting switch, where the main charging wire usually connects, to the ammeter.

Thus the parts of the generator main charging circuit include the generator armature, the brushes, the cut-out, the ammeter, the connection to one side of the starting switch, the battery, and the battery ground connection.

Troubles which are common in this circuit are open circuits, grounds, short circuits, and poor connections; and the poor connections would include poor brush contact, loose terminals, and loose or corroded battery terminals and ground connections. It is very important that the third brush of a third-brush-regulated generator be properly seated.

(*c*) **The ignition circuit** takes its current from the battery, at switch connection (B), when the engine is first started, or when it is running slow. When the engine is speeded up, the generator generates sufficient voltage to charge the battery, and the current for ignition is then **taken from the generator** at switch connection (G).

In the example shown in the illustration (Fig. 1) the (−) terminals are grounded; therefore the start for the ignition circuit is at the (+) terminal of the battery or at the (+) terminal of the generator, to the switch at (B) or (G), to (I), to the resistance unit on the coil, through the primary winding, to (T), to the contact-breaker, to ground (G), to the (−) ground of the battery or generator.

If the (+) terminal of the battery and generator are grounded, then the start would be from (+) of the battery or generator to the grounded terminal of the contact-breaker.

The ignition circuit is divided into two circuits, the **primary** low-tension circuit and the **secondary** high-tension circuit.

The primary or low-tension circuit includes the ignition switch, the ignition resistance unit, the primary winding and the contact-breaker, and also the condenser, which is always placed across the contact-breaker points.

The condenser is sometimes placed in the coil, and sometimes on or in the contact-breaker housing, but in every instance it connects **across** the contact-breaker points.

The resistance unit is sometimes placed on the coil and sometimes on the contact-breaker housing, and is always **in series** with the primary circuit.

The secondary circuit is an independent circu termed the "high-tension" circuit. It starts wi the secondary winding in the coil, through a ve heavy terminal, thence to the center of the distrib tor, to the rotor, thence to the segments or poin where it is distributed to the spark plugs in th regular firing order, thence to ground, to t grounded terminal of the secondary.

The parts therefore include the secondary win ing, the distributor, and the spark plugs.

The primary ignition circuit usually takes its cu rent supply from the switch (if (−) terminal grounded). Note in the diagram that the connectic to the switch is from the ammeter. If the batter supplies the current, then the current must pa through the ammeter on the "discharge" sid whereas, if the generator supplies the current, it taken direct at switch terminal (G), and thus do not pass through the ammeter.

Troubles which are common with the ignitio circuit are: open circuits, grounds, short circuits poor connections, both externally and internally c the coil, also burned-out resistance units, loose condenser connections, defective or short-circuite condensers, incorrect adjustment of contact-breake points, burned or pitted points, incorrect timing o opening of points of contact-breaker, defective distributor, incorrect spark-plug gap, leaky spark plugs fouled spark plugs.

(*d*) **The lighting circuit includes** the headligh circuit, the dimmer or auxiliary light circuit, th tail-light circuit, the cowl board or instrument ligh circuit, and, in a closed car, there will probably be dome light and tonneau light. In this example dimmer resistance is thrown in series with the headlights to dim the headlights. If switch connection i made at (5) (Fig. 1), the dimmer resistance is in serie with headlights. If connection is made at (4), th dimmer is not in circuit, and headlights are bright

The lighting circuit starts at the ammeter (1), to switch (B), if the battery supplies the current, and from the switch at (G) if the generator supplies the current; that is, on the assumption that the (−) terminal of the battery and generator are grounded, which they are in the example shown on page 449.

If the (+) terminals are grounded, then the circuit would start from the (+) ground of the battery and generator to ground of the lamps.

If current for lights is taken from the battery, the current in the example (Fig. 1) (and on many other systems) must pass through the ammeter (2) to (1), and thus it shows "discharge."

If current is being taken from the generator for lights, it is taken from (G) on the switch for the headlights, and one side of the ammeter (1) for the other lights, but does not usually pass through the ammeter.

The current passes through ammeter, however, from (1) to (2) (or in the opposite direction to that in which it passed when the battery was discharging). When the generator is charging the battery the needle will show "charge."

If the (+) of the battery and generator are grounded, then the start would be from this ground to the ground of all light circuits, as shown in Fig. 8, page 426.

Either a **fuse** (page 426, Fig. 8), or a **circuit-breaker** (see Delco system, Fig. 15, page 392) is always placed in the lighting circuit. A fuse or circuit-breaker is seldom in any of the other circuits except the horn, which always has a fuse or circuit-breaker in series with the circuit.

Troubles which are common in the lighting ciruits are open circuits, grounds, short circuits, poor onnections, burned-out bulbs, and blown fuses.

If all of the lights fail to burn, the indications are blown fuse. Therefore the first place to look is at ne fuse; if the fuse is not blown, then an open ciruit exists.

If only one of the lights fails to burn, the indicaons are that the bulb is burned out or an open ciruit exists on that line.

If the ammeter shows "discharge" with all witches off, then the indications are a "ground." f the discharge is heavy, a short circuit in the wiring xists at some point, and the fuse should "blow" if nere is one in the circuit.

When troubles of this nature occur, the trouble hould be located before a new fuse is installed.

(*e*) **The horn circuit** is usually taken from the mmeter (1), in the same manner as described under he subject of lights. A push-button is usually laced in the top of the steering column. A fuse is lways connected in the horn circuit, or else in the ircuit-breaker circuit, as on Delco systems.

Troubles of the horn circuit are open circuits, rounds, short circuits, push-button defects, and lso troubles internally of the horn. See Index for "Electric horns."

(*f*) **Grounded connections:** By referring to 'ig. 1, and to Fig. 8, page 426, and to all other viring diagrams of the single-wire, ground-return ystems, it is to be observed that the grounded onnection of the battery not only serves for the enerator charging circuit, but is also a return path r lead for all circuits. Hence the importance of eeing that this and all ground connections are tight.

(5) The Dash Ammeter

The dash ammeter might more properly be termed he cowl ammeter, as it is placed on the cowl or nstrument board of the car.

The purpose of this instrument is to indicate the mount of current passing from the generator to the attery, and indicates on the "charge" side of the ero (0) of the ammeter.

When current is being taken from the battery for ights and ignition (not for the starting motor), the urrent is from (2) to (1), and the needle of the mmeter indicates on the "discharge" side (see also age 334). Thus it is clear that if the ammeter hows "discharge" when it should show "charge," r if it shows "discharge" when all switches are off, t indicates something is wrong. This subject is reated on pages 471 and 472.

On some cars, for instance the Franklin, an indiator is used instead of an ammeter. This device ndicates when the battery is "discharging" or being "charged." Unlike the ammeter in one respect, lthough it serves the same purpose, it can be placed n the circuit of the battery to the starting motor. Owing to its construction, it will show "charge" or "discharge" on 2 amperes of current, yet it is capable of withstanding 300 amperes and any voltage. The ammeter, however, is universally used.

If the ammeter should be connected wrong, or if the battery is connected wrong, the ammeter needle will read in the opposite direction.

The point to note is this: Usually the ammeter is the point from where the ignition, lighting circuits, and horn derive their source of electric supply for either the battery or generator, and that the current runs thence to the switch.

Summary

The various parts and circuits of the electric system have now been fully dissected. The reader should bear in mind that the only successful method of diagnosing electric trouble is to locate the circuit or the part the trouble is in, and to eliminate one possible cause after another, until the probable cause is arrived at. We could fill this book with an enumeration of possible troubles, their cause and remedy, but the simplest method is to learn the fundamental principles of each part, the circuits, and the relation of one circuit and part to another, and then to THINK—and to use intelligent thought before deciding, or even starting to locate a trouble.

When making tests, first determine which one of the parts or circuits the trouble is in, and then test that part from the beginning to the end.

For instance, **if the generator fails to show "charge" on the ammeter,** start at the (+) of the generator, then the fuse (field fuse), then the cut-out, then the circuit. If the fuse is blown, there must be a short circuit. Find the cause.

If lights fail to burn, first examine the lamp-bulb to see if it is burned out; if not, then the lamp-socket, then the fuse; then start at the switch, and then test the wiring. If the fuse is blown, find the cause.

Points to Remember

Remember this same principle applies to a two-wire system.

Remember that when a fuse-block is used in a circuit, the fuses are merely cut into each circuit, which will melt and open the circuit if a wire or part becomes short-circuited. The cause of the "blowing" should always be learned.

Remember that a fuse is never used in the starting-motor circuit, but a fuse is used in the field-circuit in nearly all third-brush regulated generators. If the fuse is blown, the generator will not generate current. Also remember that the ammeter is never connected into the starter circuit unless it is connected with a "shunt."

Remember that the cut-out is often placed integrally with the generator. For instance, on the illustration, page 364, the cut-out is in the generator housing and is connected internally with the generator.

Remember that the regulation of the output of a third-brush generator does not have a separate mechanism to regulate the current, and that it is important that the third-brush, as well as all other brushes, should be properly seated to the commutator.

Remember that a generator which has a voltage regulation system does have a mechanism called a "voltage regulator," which controls the output.

Remember that a Wiring Diagram Book will tell you just what kind of a regulation system a generator has, and will also show the external and internal circuits.

OPEN CIRCUITS, POOR CONNECTIONS, GROUNDS, AND SHORT CIRCUITS

Throughout the preceding instructions, frequent eference is made to the subjects in this heading. Ve shall now analyze the meaning of these and their elation. In fact, practically all of electric troubles re due to open circuits, poor connections, grounds, r short circuits in some part of the electric system.

Open Circuits

Open circuits, as the name indicates, is a point where any part of a circuit is opened. It is an incomplete circuit, and thus it does not offer a passage for the current.

Low-tension (voltage) **direct current** is used in all circuits of the automobile, except in the secondary ignition circuit, which is an independent circuit of a high tension. The secondary circuit, however, is dependent upon the low-tension primary circuit for its existence.

In order that electricity may flow, it must have a complete circuit to flow in, even though it is not a copper path all the way. For instance, the steel frame of the car can be, and is, used for a part of the path.

Electricity starts at the positive or (+) terminal of the generator or battery, and returns to the negative or (−) terminal.

Thus if the circuit or path is open, the low-tension current cannot pass or jump across a gap, and this is termed an "open circuit."

Causes of open-circuits may be said to be loose connections or blown fuses, broken wires, or the fact that brushes on the generator or motor do not make contact; also open circuits may occur at the commutator where the armature coils are soldered to the commutator segments, or possibly on the armature coils themselves, or in the field windings, or in loose or poor connections at the battery or ground wire.

Indications of open circuits are: Lamps failing to light, ammeter failing to indicate "charge" or "discharge," the starting motor failing to start, absence of spark at the spark-plug points. In fact, an open circuit could exist in any one of the circuits, but seldom in all circuits at one time; hence the importance of knowing the different circuits and their relation one to the other.

There are several methods of testing for open circuits, all of which will be explained farther on. A few pointers are given below.

If any one lamp fails to light, it indicates an open circuit in that line. "Blown" fuses, a broken lamp filament, or a broken lamp wire may be responsible.

If all lamps fail to light when the engine and dynamo are speeded up, the open circuit is most likely located between the battery and the dynamo, or between the dynamo and the lighting switch.

The "blowing" or melting of a fuse opens the circuit and disconnects from the system the short-circuited wire which caused the fuse to blow. Therefore the cause should be located, before replacing a fuse.

An open circuit that often occurs, and that is difficult to find, is a broken wire inside of the insulation of the lighting wiring. The easiest way to find the break is first to determine which one of the wires is open and then temporarily to run another wire in its place and note if it remedies the trouble.

Testing current flow: Whether or not current is flowing in a given circuit may be determined by removing one of the wires forming the circuit, and then touching it to its terminal. If a spark occurs, current is passing through the line.

Loose and Poor Connections

It is also well to notice the close relation of open circuits and loose connections. If connections are poorly made, but not completely loosened from the terminal, then there will very likely be an "intermittent open circuit," that is, the circuit will be complete at times, and at times open.

Grounds

There are two kinds of grounds: one which is **intended** to ground the circuit, as from the battery to the frame of the car, and one which is **not intended** to ground, but does so for various reasons. It is with this latter ground that we shall deal here.

In speaking of an intended ground, bear in mind that it has no connection whatever with the ground or earth. It is merely a term used to indicate that a part of the circuit is connected to some metal part of the car, thus saving the necessity of using two wires for a circuit.

Wires that are grounded, but not intended to be grounded, can be the result of numerous causes. For instance, if the insulation on one or more of the armature coils is in such a condition that there is a leak of current through the insulation to the metal core of the armature, it would be termed "grounded."

Or if two wires are oil-soaked and close together, and if they leak current from one to the other, the circuit may not be completely short-circuited, but it will be "grounded," and thus reduced in value, owing to the leak, which results in a weak current supply.

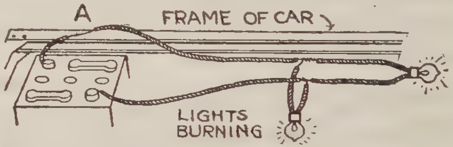


Fig. 2. A ground.

Another example of a ground is shown in Fig. 2, where a two-wire system from a battery is shown connected to two lights. If the wire was grounded to the frame at (**A**), the current could still flow to the lamps. **Therefore, a "ground" might be termed an electrical "leak."**

Short Circuits

A short circuit means that **two conductors** of current are in **metallic contact** when they **should not be.**

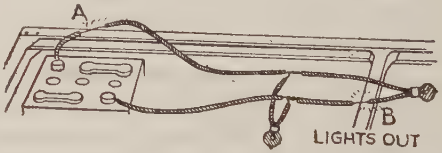


Fig. 3. A short circuit with wires which are supposed to be insulated from the frame.

For example, on a two-wire system, as in Fig. 3, if one wire was "grounded" to the frame of the car, as at (**A**), and the other wire of the circuit was grounded at (**B**), a "dead short circuit" would be the result, and the lights would not burn at all. The path of the current from the battery would be **shortened,** and as electricity takes the path of least resistance, it would flow freely through the frame of the car instead of through the lamps, which are of higher resistance. The result would be that the battery would discharge at a very high rate. In fact, the effect in this instance would be the same as connecting a wire across the terminals of the battery, and unless the wire was of very large size, it would get very hot, or burn into and thus damage battery internally. For this reason fuses or circuit-breakers are used in some of the circuits such as the lighting and horn circuits, which are longer and are more exposed, and nearer to the frame, to dampness, etc.

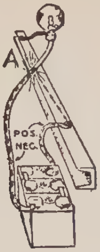


Fig. 4. A short circuit where one wire is insulated and the other grounded.

An example of a short circuit on a single wire or grounded return system of wiring is shown in Fig. 4. Under these conditions we should have the same result as in Fig. 3.

Note, for instance, that the circuit (when not short-circuited) is from the positive terminal of the battery, to the grounded connection to the frame, to the grounded connection at the end of the frame (which is intended), through the lamp, to the negative terminal of the battery.

Suppose the wire, as shown, becomes short-circuited or in contact with the frame at (**A**): the result is that the path is shortened and the current would flow from the positive terminal of the battery, through the ground connection, to the frame, through the wire in contact with the frame at (**A**), to the negative of the battery. Thus the current is short-circuited and would not pass through the lamp, since the easier path is through the wire where it makes contact with the frame. The effect on the battery would be the same as placing a wire directly across the battery terminals, which would be termed a "dead short circuit" across the battery terminals.

Indications of Grounds

If there is an ammeter on the car, it will show a "discharge" with all switches off. The needle should stand at "0" when all switches are "off."

Lamps when turned on will burn dimly, in case of a ground.

Testing for a ground is made by several different methods, but if the ammeter shows "discharge" with the switches "off," then it is a matter of finding which wire is grounded. This will be explained farther on.

If there is no ammeter on the car, and a ground is suspected, then turn all switches "off" and disconnect the wire at the terminal of the battery (as in Fig. 5), and strike the terminal in quick succession. If a spark occurs, even though very slight, it indicates a "ground." Grounds will cause the battery to discharge. The rate of discharge will depend upon the intensity of the ground.

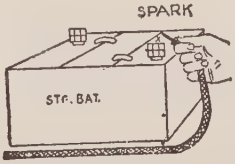


Fig. 5. One method of testing for a ground.

Indications of Short Circuits

If there is an ammeter on the car, the needle will probably go to the limit of the scale on the "discharge" side.

Fuses will blow repeatedly.

If a short circuit exists in the starting-motor circuit, it will probably be indicated by the wires getting very hot, and the smell of burned insulation can be noticed. In fact, a "dead short circuit" would cause the insulation to burn and smoke. This would seriously injure the battery internally if permitted to continue for a long period of time.

As previously stated, grounds, short circuits, and open circuits may exist in any part of the circuit, even to the armature and field-windings. The indications and appropriate tests will be taken up in their respective order farther on.

Before taking up the subjects of electrical tests and tools and devices to test with, a Digest of Troubles will be given in the next instruction, which is to be used as a reference.

INSTRUCTION No. 41

DIGEST OF TROUBLES: Electrical Troubles; Engine Troubles; Miscellaneous Troubles

MAKING A DIAGNOSIS

Diagnosing automobile troubles requires thought and reasoning. If a person understands the principle and construction of the various parts of a car and one of the hundreds of possible troubles occurs, then simply reason it out; ask yourself what the trouble is, what could cause that trouble, and why the trouble is there. Find out if it is ignition, carburetion, cooling, or just what the trouble is, and then figure it out the best you can before proceeding.

It is of little use to turn the engine over and over by the starting handle or by means of the engine starter, in an effort to get it going. If the engine will not start with a few turns, the chances are that there is something radically out of order, requiring intelligent attention. With the carburetor giving a correct mixture, the ignition system affording a hot and effective spark, and everything else apparently all right, it should be as easy to secure an explosion on the second stroke as on the sixtieth. So if the engine will not start with the second or third attempt, it is not likely to start with three or four hundred attempts; consequently it is better to find out the cause of the trouble than to turn the engine over indefinitely and run the battery down.

To Make an Engine Run Two Things Are Essential

Always remember, when diagnosing troubles, that **there are two essentials to the running of an engine:** first, gasoline; second, a spark.

The gasoline must reach the inside of the cylinders, and the spark must be there at the proper time to ignite the gas. If you have both, something is bound to happen, even though it is but a single explosion.

Next, remember that even though you have a spark and gasoline—**the engine will not run properly if the gas does not enter the cylinder at the right time** "and stay there," and be in a proper gaseous form.

The gas cannot be ignited regularly if there is not a good, hot spark at the correct time.

Next, remember that **if an engine is not properly lubricated and cooled** it will heat. If the engine is too cold, heat must be applied for proper carburetion.

Therefore, speaking generally, we find that **most troubles are found to originate in ignition, carburetion, and lubrication.**

If trouble occurs, first find which of the three headings the trouble comes under and then reason it out.

The object of this digest or condensed account of troubles and remedies is simply to give you an idea of what would be likely to cause certain troubles and what would be likely to remedy them. The reader will then decide which one is most probably the trouble confronting him, and if he does not know the meaning of certain adjustments called for, he will then turn to the Index, find the subject mentioned, and read up on that subject.

Systematic Trouble Hunting by a Process of Elimination[1]

In dealing with engine troubles, one should always try to figure out the possible cause of a trouble before starting to adjust something that does not need adjusting.

An adjustment never should be changed without a knowledge of why the change is made, the effect the change should have, and how to restore the mechanism to its original adjustment.

If one will **first reason out the probable causes** of a trouble, **the real cause can be quickly located.** For instance, if a single lamp fails to burn, you will know that the trouble is not in the battery or the generator if all the other lamps burn. Therefore the cause must be in that particular lamp, in the socket, or in the wiring of that particular lamp.

Similarly, **if the starting motor fails to start** the engine, yet you know that it is turning the engine crank shaft, and your lights burn brightly, you would not look to the battery for the trouble, but you would know that the trouble must be with the ignition or carburetion. It is then a matter of applying the process of elimination—that is, test each of the remaining probable causes until the final cause is the only one left.

When the possible cause of trouble cannot be imagined, then begin with a careful examination of all the features of the engine that are likely to give rise to the trouble.

If nothing out of order is found, then begin testing out the various features, beginning with the easiest and most accessible, and thoroughly complete each test before starting on another possible cause.

For example: If your **ignition system** is suspected, the easiest thing to test would be the spark plugs. First find the faulty plug; then proceed from the spark plugs to the wiring between the plug and the distributor; then examine the battery connections, the switch connections and, last of all, the adjustments of either the timer, the coil, or the magneto.

Do not examine a spark plug and then leave it and try a few carburetor adjustments, and later come back for another spell of tinkering with the ignition, etc.

If you suspect the ignition system, go to it from beginning to end in a **systematic** manner before proceeding with the carburetor, and likewise with all other parts.

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[1] See Index for "Digest of lighting troubles" and see Index for "Storage battery troubles" and "Tire troubles," as well as for subordinate subjects involving "troubles." See also pages 512 to 519.

DIGEST OF GENERATOR TROUBLES[1]

When troubles occur in the electric system of a car, remember that the electric system is divided into four parts: **the lighting circuit, the generating circuit, the starting-motor circuit,** and **the ignition circuit.** The idea is then to determine in which of the circuits the trouble is, and then to test it from beginning to end, as previously explained.

The troubles and the indications and causes of **generator troubles** can be classed under two heads: those which are due to **mechanical defects** and those due to **electrical defects.**

Mechanical Generator Troubles

Indications: Noise; low current generated, or no current at all.

Causes: (1) Broken bearing (examine by turning armature by hand. If it sticks or turns hard, look to ball bearings and replace); (2) loose driving gear or pinion (if loose, key to shaft); (3) armature off center (may be due to loose pole pieces. See that the screws with counter-sunk heads on outside of generator are tight); (4) shaft bent (this is more common on starting motors than on generators. A new armature is required if shaft is bent); (5) commutator burst (when this happens the brushes and brush-holders, etc., are also damaged. A new armature, brushes and brush-holders are required).

Electrical Generator Troubles

Electrical troubles can be classified as: (*a*) open circuits; (*b*) grounded or short circuits; (*c*) defective regulation system; (*d*) defective cut-out.

(a) **Open-circuit indications** would be a low current generated, or none at all.

Causes: (1) Brush connections poor; (2) brushes stuck; (3) brushes worn too short; (4) brush spring broken, with consequently no spring pressure to hold brush to commutator; (5) dirty commutator; (6) if the armature is open by connection being loose at commutator, or owing to a broken coil, it would cause intense blue sparking at commutator and flattened commutator bars; (7) field coils, if open, will show no current at all, or if partially open, a low current generated.

(b) **Ground or short circuits** may be (1) at main terminals; (2) at brush connections; (3) at brush holders; (4) armature, if short-circuited, will cause excessive heating of armature, burned insulation, and low current; (5) field coils, if short-circuited, will cause field coils to heat and low current to be generated; (6) commutator, if short-circuited, will produce no current at all, or a low current output.

(c) **Regulation:** In this instance we shall deal with the "third-brush" system of regulation. If a "voltage-regulated" system is used, see Index.

Indications will be that the charging current is too low or too high, and does not remain constant at high speeds.

Causes: (1) Incorrect setting of third brush; (2) brush not sanded in; (3) spring pressure on brush not sufficient.

(d) **Cut-out remaining open at all times:** Result will be: (1) no current to battery; (2) generator will get very hot; (3) generator will burn out.

(e) **Cut-out remaining closed at all times:** Result will be: (1) battery will discharge back through generator at about 20 amperes (on the Ford), when the engine is not running or not running fast enough. This will discharge the battery.

GENERATOR TROUBLE CHART

- GENERATOR TROUBLES
  - **Mechanical Troubles**
    - Broken Bearing
    - Loose Pinion
    - Loose Pole Piece
    - Commutator Burst
    - Bent Shaft
    - Indicated by Noise, Low Current or No Current Generated.
  - **Electrical Troubles**
    - OPEN CIRCUIT
      - Brush Rigging
        - Brush Connections
        - Brush Stuck
        - Brush Too Short
        - Brush Spring Broken
        - Dirty Commutator
        - Indicated by Low Current Generation or No Current at All
      - Armature
        - Intense Blue Sparking at Commutator and Flatted Commutator Bars
      - Fields
        - No Current Generated
        - If Partial Open—Low Current
    - GROUND OR SHORT CIRCUIT
      - Brush Rigging
        - Main Terminal
        - Brush Connections
        - Brush Holders
        - Low or No Current Generated
      - Armature
        - Excessive Heating of Armature
        - Insulation Burned—Low Generation
      - Fields
        - Coils Heat
        - Low Current Generated
      - Commutator
        - No Current Generated or Low Current
    - THIRD BRUSH
      - Incorrect Setting
      - Brush Not Sanded in
      - Spring Pressure Not Right
      - Indicated by Charging Current Being Too High or Too Low and Not Remaining Constant at High Speed
    - CUT OUT
      - Open
        - No Current to Battery
        - Generator Very Hot
        - Will Burn Out Generator Quickly
      - Closed
        - Battery Will Discharge Back Through Generator at About 20 Amperes When Engine is not Running. This Will Discharge Battery

DIGEST OF STARTING-MOTOR TROUBLES[2]

Starting-motor troubles, their indications and causes may also be classified under two heads: those which are due to **mechanical defects** and those due to **electrical defects.**

Mechanical Starting-Motor Troubles

Indications: Excessive current draw, slow cranking or complete failure to crank, and excessive noise.

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[1] The "Generator Trouble Chart" is reproduced here through courtesy of the Service Station Equipment Co., Chicago, Ill.

[2] The "Motor Trouble Chart" (page 456) is reproduced through courtesy of Service Station Equipment Co., Chicago, Ill.

Causes: (1) Worn bearings; (2) shaft bent; (3) commutator burst; (4) loose pole-pieces; (5) broken Bendix drive system; (6) armature off center (may be due to loose pole-pieces, in which case tighten screws).

Gummed oil on Bendix drive: It sometimes happens that oil has come in contact with the Bendix drive shaft and becomes gummed, thus preventing the drive pinion from moving to its position and engaging the fly-wheel gear. This condition can be remedied by squirting some gasoline with an oil gun upon the Bendix drive shaft through the opening at the rear of the starting motor.

Electrical Starting-Motor Troubles

Electrical troubles are classified under (*a*) open circuits; (*b*) ground or short circuits.

Open-circuit indications would be suggested by low current or no current, and by failure of starting motor to operate. If a partially open circuit is found to exist, the current draw will be low and cranking slow.

Open-circuit causes: (1) Brush pigtails loose; poor brush-spring pressure; brushes too short; dirty or burned commutator; (2) armature commutator blue sparking, or flattened commutator with slow cranking; (3) fields open; (4) starting switch open; (5) loose connections at battery, ground, or switch.

Ground or short-circuit indications are excessive current required, no cranking, or slow cranking.

Grounds or short-circuit causes: (1) Shorted fields cause excessive current and slow cranking; (2) armature shorted causes excessive current, burned insulation, slow cranking; (3) commutator shorted causes excessive current, no cranking; (4) when the brush rigging is shorted, the causes may be in the main terminal, in the brush holders, or the pigtails may be loose.

MOTOR TROUBLE CHART

- MOTOR TROUBLES
  - **Mechanical Troubles**
    - Worn Bearings
    - Shaft Bent
    - Commutator Burst
    - Loose Pole Piece
    - Broken Bendix
    - Armature Off Centre
    - All Indicated by Excessive Current Draw and Slow Cranking or Complete Failure to Crank and Excessive Noise
  - **Electrical Troubles**
    - OPEN CIRCUIT
      - Brush Rigging
        - Pigtails
        - Brushes Not Contacting
          - Brushes Too Short
          - Poor Spring Pressure
          - Dirty or Burned Commutator
          - All Indicated by Low Current or No Current and Failure to Crank. **If** Only Partial Open Occurs the Current Draw will be Low and Cranking Slow.
      - Armature
        - Intense Blue Spark at Brush and Flatted Commutator with Slow Cranking
      - Fields
        - No Current
        - No Cranking
    - GROUND OR SHORT CIRCUIT
      - Fields
        - Excess Current
        - Slow Cranking
      - Armature
        - Excess Current
        - Burnt Insulation
        - Slow Cranking
      - Commutator
        - Excessive Current
        - No Cranking
      - Brush Rigging
        - Main Terminal
        - Brush Holders
        - Pigtails and Connectors
        - Indicated by Excessive Current and No Cranking or Slow Cranking

STORAGE-BATTERY TROUBLES

This subject is treated under the discussion on the "Storage Battery." See Instruction No. 49: "Digest of Storage Battery Troubles; External and Internal."

See also, Instruction No. 48: "Testing Storage Batteries."

LOCATING TROUBLES OF THE ELECTRIC SYSTEM IN GENERAL

In addition to the electrical troubles enumerated above, the following data, graphically presented, will assist in quickly locating troubles in the electric system.

Assume That Battery Is Fully Charged

Trouble: Motor will not crank engine.
Possible causes:

1. Bendix drive or starting mechanism out of order.
2. Engine too stiff.
3. Open circuit in wiring.
4. Ground in wiring.
5. Defective starting motor.
6. Broken or loose wiring connection in starting-motor circuit or ground.
7. Starting switch does not close, or contacts burned out.
8. Open circuit internal to the motor: field, armature, or brush rigging.
9. Ground or short in motor: field, armature, or brush rigging.
10. See Motor Trouble Chart, under "Electrical Troubles."
11. See Motor Trouble Chart, under "Mechanical Troubles."

Assume That Battery Is in a Discharged Condition

Trouble: Battery not being charged at proper rate.
Possible causes:

1. Generator not working properly.
2. Generator charging at a low rate, or not at all.
3. Open generator circuit.
4. Grounded generator circuit.
5. Defective cut-out; will not close.
6. Broken or loose connection on generator line.
7. Shorted or open coil in cut-out windings.

8. Cut-out contact points defective, or improper spring tension.
9. Low charging rate.
10. Third brush not set properly.
11. No charging current.
12. Generator may be new, or perhaps has been operated for some time with field fuse removed. Field can be excited by momentarily connecting one side of the fuse clip with the metal part of the generator when the engine is running slightly above idling speed.

Trouble: Battery being charged at proper rate, but will not hold charge.

Possible causes:

1. No water over plates.
2. Battery has internal or external ground.
3. Excessive use of current in starting and for lights; very little day driving with lights off; mostly night driving with lights on.
4. Cut-out stuck.
5. Wiring defective.
6. Added electrical equipment using too much current.
7. Bulbs with too high a candle power.
8. Bulbs old and using too much current.
9. Stiff engine, using excess current, especially during cold weather.

Starting-Motor Trouble Tests

Trouble: Motor will not start:

Turn on the lights and try the starter. If the lights do not dim, then the battery is probably charged, as the condition of the battery is the first thing to test when the starting motor does not operate. **Then examine:**

(1) For an open circuit in the starting switch.

(2) For an open circuit at the motor terminals.

(3) For an open circuit at the ground connection to the frame of the car.

(4) The commutator; examine, and see if glazed.

(5) The brushes; see if they are bearing on the commutator, and if they are seating properly.

(6) The brushes; remove and inspect—they may be worn or stuck, or one of the brush-holders may be loose.

(7) The brush material; it may be of too high a resistance.

Trouble: If the ammeter shows no reading when lights are switched on; if the starting motor kicks over spasmodically or not at all; or if the lights do or do not dim when the starting button is depressed, examine the inside of the motor as follows:

(1) For a short circuit in the field or armature coils. This will cause the lights to dim, or the ammeter will show no reading when the starting switch is closed. The ammeter referred to is in the lighting circuit, not the starting-motor circuit.)

(2) For an open circuit in the armature where the coils are soldered to the commutator segments. (This will cause the motor to kick over spasmodically or not at all.)

Next, check the external motor circuit:

(1) To the frame. (If open, slow cranking or none at all will result.)

(2) To the switch. (If open, the lights will not dim; if grounded, the lights will dim excessively or the ammeter will show no reading when the starting switch is closed and lights are turned on.)

(3) To the battery. (Same indications as 2.)

Trouble: Starting motor starts, but not enough to turn engine over:

(1) Crank the engine by hand to see if it is unusually stiff.

(2) If the engine will not start readily by hand cranking, then look for engine trouble.

(3) Bendix drive may be stuck, or there may be a broken Bendix spring.

Next, if the engine, the ignition, the carburetion, etc., are in order, then look for:

(1) Poor contact at battery terminals.

(2) High resistance contact at brushes.

(3) Poor connection between brush and shunt-field.

(4) Poor connection between brush and brush-holder.

(5) All brushes not bearing on commutator.

(6) Brushes stuck in brush-holder.

(7) Grounded brush-holder.

(8) Loose ground connection (if car has a ground-return system).

(9) Battery below cranking capacity.

(10) Open circuit in armature coils.

Next, disconnect battery, and make a temporary connection to a fully charged storage battery. If the starting motor will then turn the engine over, the battery in the car is at fault.

Test storage battery with hydrometer. If the storage battery is low, look to the generator. (Note. Always make a hydrometer reading before adding distilled water. See "Storage Battery" instruction.)

If battery is low or lights are dim, test out the ampere charging rate of the generator. (Do not rely upon the ammeter on the car.)

Trouble: Lights and ignition are cut off entirely when the starting switch is depressed.

(1) Starting switch may be loose, where the wire connects from one side of the starting switch to lead to the ammeter, ignition, and lighting switch.

(2) A short circuit may exist at the switch, which will short this circuit.

Generator Trouble Tests

The following will explain where to test a generator for open circuits, short circuits and grounds.

Test for open circuit in:

(1) Generator terminals.

(2) Battery connection.

(3) Ground connection to car frame (if car has a grounded return system).

(4) Fuse.

(5) "Cut-out" or ignition and lighting switch.

(6) Field windings and armature coils.

Test for short circuit in:

(1) Generator itself; field windings and armature coils.

(2) In external wiring.

Examine brushes and commutator for:

(1) Pitted or burned segment surfaces and brush seats.

(2) Dirty or glazed commutator, high wired, rough commutator.

(3) High resistance contact at brushes.

(4) Worn-out brushes.

(5) Poor connections.

(6) Brushes not bearing on commutator (faulty spring or holder).

Examine generator for:

(1) Worn bearings causing unequal air-gap.

(2) Reversed polarity. (Storage battery is sometimes reversed in position in car.)

Examine regulator and cut-out for:

(1) Dirty or pitted contact points.

(2) Contacts out of adjustment.

(3) Regulator cuts out too soon or not soon enough, owing to gummed mechanical parts.

(4) If in a third-brush regulation, see brush connection or look for defective mechanism. The third brush failing to seat properly is a common cause of an open circuit and a low charging rate.

DIGEST OF ENGINE TROUBLES: CAUSE AND REMEDY[1]

Ordinary engine troubles are generally of three kinds:

(1) Engine will not start.

(2) Engine starts but misses.

(3) Engine starts and runs regularly but has no power.

The following matter refers principally to **ignition** and **carburetion** troubles.

ENGINE FAILS TO START.

(1) **Lack of gasoline:** See that there is gasoline in the tank and that the shut-off cock is open. Make sure that gasoline is flowing to the carburetor by priming or pushing down the carburetor float. If the carburetor is too full, the gasoline will drip. If the carburetor is not full enough, look for a stoppage in the gasoline pipe and see that the vent hole in the tank cap is open.

(1A) **Carburetor needs priming:** Either prime carburetor or close air intake valve.

(2) **Poor quality of gasoline:** Some of the gasoline offered for sale is of such poor quality that it will not vaporize when the engine is cold.[2] The gasoline may contain water, which will freeze in cold weather and clog the gasoline pipe. Old or stale gasoline may also cause difficult starting.

(3) **Too much gasoline:** The cylinder may be flooded with gasoline; the spark plug may be soaked. Open the relief cocks, cut off the throttle, and crank the engine until the excess is eliminated and an explosion occurs. Then close relief cocks, open throttle only partially and try cranking again; engine ought to start. Float may be loose; or a grain of dirt may be under the needle valve.

(4) **No pressure in fuel tank:** If the system is a pressure fuel system, then use the hand pump and try priming carburetor. See that the gasoline tank filler cap is tightly screwed on.

(5) **Lack of ignition current:** If battery ignition, see if battery is strong. Remove one of the spark-plug wires and hold it about ⅜″ away from plug and terminal, and see if the spark jumps the gap when the engine is cranked. If there is no current at all, then look for broken or loose wires at the switch and on the battery and the battery ground connection; Also on the connections on the coil and distributor and timer. If the spark is very weak, then look to the battery and test coil and the ignition resistance unit and the condenser.

(6) **If starting motor fails:** See Index under "Starting motor fails to start."

(7) **Spark plugs:** Spark plugs may have become sooted from over-lubrication, or if they have seen considerable usage the points may be burned and corroded. If water has been splashed on the engine when it was hot, the porcelain of the plugs may be cracked. See that the sparking points are perfectly clean and that the gap does not exceed .020″ to .031″.

ENGINE STARTS BUT MISSES.

(8) **Carburetion adjustments:** If on a cold day and engine has just been started, wait a few minutes for engine to warm up—closing air intake.

If missing still occurs, with popping back or "sneezing," this indicates that the mixture is too lean; give the needle valve of the carburetor a slight opening until the engine runs smooth. If no needle valve is provided, give less air in the auxiliary air valve.

(9) **Ignition:** If missing continues after engine is warmed up, and more gasoline is fed as directed in (8), examine the spark plugs and test as suggested in (7). Weak battery may be the cause, if coil and battery ignition.

ENGINE STARTS, BUT "POPS" AND "SNEEZES" IN CARBURETOR.

(10) **Carburetion:** See Index under "Carburetion troubles."

ENGINE STARTS, BUT WILL NOT PULL.

(11) **Carburetion:** See (8); or there may be an over-rich mixture. This would be indicated by black smoke.

(12) **The valves:** May be leaking, and there might be poor compression.

(13) **Ignition:** The spark may be weak. This, however, would be indicated by missing. Test battery.

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[1] See "Digest of Lighting Troubles," and "Storage Battery Troubles."

[2] Very common in cool weather. See Index under "Carburetion troubles."

ENGINE RUNS REGULARLY FOR A FEW MINUTES AND THEN STOPS.

(14) **Carburetion:** In cold weather this is more liable to occur until engine is warm; give slightly more gasoline by closing air valve (if one is provided); gasoline may not be flowing freely to carburetor. Prime carburetor and see if it drips. There may not be enough gasoline; closing air valve will determine. May be too much gasoline (see 3).

(15) **Ignition:** Battery may be weak, Ignition may be retarded too much. If there are two systems of ignition, try the other one.

ENGINE STOPS SUDDENLY.

(16) **Carburetion:** Lack of gasoline. Stoppage of gasoline pipe (prime carburetor, and if no gasoline, examine tank, then fuel strainer). See (73).

(17) **Ignition:** Loose wire. Short circuit, loose switch connection. If magneto ignition, switch to coil and battery. Weak battery. Points of interrupter may be closed by pitting.

(18) A sudden stoppage is almost always due to ignition trouble, for gasoline trouble will stop engine slowly.

ENGINE STOPS SLOWLY WITH MISFIRING.

(19) **Carburetion:** See (16). The needle valve sometimes jars itself closed.

(20) **When an engine stops slowly, the explosions** becoming weaker and weaker until they cease, it is likely due to gasoline trouble. The fault will be found in the failure of the mixture to reach the cylinder. (See 73.)

(21) **Ignition:** Batteries exhausted; plugs fouled through over lubrication.

ENGINE LOPES OR LOADS UP.

(22) **Carburetion:** When the engine slows down irregularly, speeding up and then slowing down again as though fitted with a governor, and if throttle be closed further in order to slow down more, engine stops. Air has leaked in between carburetor and cylinders. Examine gaskets around the joints of inlet pipe or where carburetor is attached to intake manifold. Too much gasoline will also cause "loping." Cut down on the carburetor gasoline feed.

(23) **Ignition:** The spark may be set too far advanced. If this is the case, loping is likely to occur when spark is fully advanced. Therefore test the time of ignition.

LACK OF FLEXIBILITY.

(24) **Carburetion:** This trouble is almost exclusively a carburetor fault, and is due to the fact that the auxiliary air intake is so constructed that it furnishes an abundance of air on high speed, and is not sensitive enough on low. When the throttle is nearly closed the engine stalls; or when the throttle is suddenly opened there is no "get away," because the auxiliary air inlet valve allows an inrush of air forming a mixture good enough for high speed running, but too weak for "pick up" purposes. This calls for careful adjustment of the auxiliary air valve and gasoline needle valve, or for more gasoline.

ENGINE MISSES EXPLOSION.

(25) **Defective or dirty spark plug:** With the engine running idle, short-circuit the spark plugs one at a time by touching a screwdriver from the metal of the cylinders to the terminals of the plugs. (See page 238.) This prevents the plug from firing, and when one is short-circuited—that makes no difference in the running of the engine—you have probably located the plug at fault. If the spark-plug wire is properly connected to the distributor, either clean or install a new plug in place of the one that has been found defective. If a vibrator coil, see page 222 (also see 17).

(26) **Spark-plug gap too wide:** The distance between the spark-plug points should not exceed .025″. (See 7.)

(27) **Examine interrupter points.** Weak battery.

(28) **Too lean a gasoline mixture:** If the engine misses with a popping noise in the carburetor, the indications are that too much cold air is being admitted through the air-regulating valve; the carburetor jets have become clogged with dirt, or there is a partial stoppage somewhere in the gasoline pipe connections. See that carburetor intake header gaskets are perfectly tight, and do not admit air, which would thin the mixture.

(29) **Look for gasoline trouble:** Dirt in gasoline tank over outlet; dirt or water in carburetor; float leaking; jet in carburetor clogged up; supply cock loose; inlet valve sticking or leak in inlet pipe; weak exhaust valve spring; may be a leak of air in inlet pipe.

(30) If the engine misses, and the following explosion is accompanied by an explosion in the muffler, ignition is at fault, for the charge has reached the cylinder correctly, but has been exhausted without being exploded.

ENGINE MISSES ON HIGH SPEED.

(31) **Ignition:** Weak battery (if coil and battery ignition). If the engine misses at high, but not on low, or on a hard pull, then it is evident the spark plugs are in proper order but the contact-breaker needs adjusting.

A word of explanation on this: the engine may fire all right at lesser speeds, because the speed is slow enough and the contact is long enough to allow the coil to build up, but at high speeds the time of contact is so short that the coil does not have sufficient time to build up, thus indicating that the contact-breaker gap is too wide. See pages 296–303.

Try switching to the other ignition system, if a dual system is provided. This will determine which ignition system is at fault.

The coil may be defective internally, in its winding, or the resistance unit or condenser may be defective. See Index for "Testing a coil."

(32) **Carburetion:** The carburetor may have been adjusted for slow speed, but requires more gasoline on high speed, or it may be getting too much gasoline. Proper adjustment of carburetor ought to suffice.

ENGINE MISSES ON LOW SPEED.

(33) **Ignition:** If magneto ignition, the cause may be the slow speed of magneto, and weak cur-

rent generated. Try advancing the spark more. Also examine the interrupter points.

Examine spark-plug points (see 7). If not remedied, try switching to the other system of ignition. If missing still occurs, there are two other points to consider: loose connection, or a broken-down coil, if one coil is used for both systems, such as a low-tension magneto.

(34) **A spark plug may be fouled:** It has been known that often a bad plug will not cause missing at all speeds, but will miss at high speeds.

(35) **Carburetion:** Mixture at fault—readjust slow-speed adjustment. The float may be too low, giving over-rich mixture.

(36) **There may be a leak in the intake pipe:** This is a very common cause for missing at low speeds, and is best detected by allowing the engine to run at the missing speed. Take a squirt can full of gasoline and squirt around all the intake pipe joints. If you detect any difference whatsoever in the running, there is a leak. The remedy is obvious.

ENGINE MISSES AT ALL SPEEDS.

(37) **Ignition:** Defective spark plug (see 7 and 25). Loose connection. Weak battery. Loose switch parts. Broken wire. Slight short circuit. Defective coil, ignition resistance unit or condenser, pitted or incorrectly adjusted breaker points.

(38) **Carburetion:** See Index under "Carburetion mixture."

ENGINE DOES NOT DELIVER FULL POWER.[1]

(39) **Compression:** Leaky exhaust valves, scored cylinder, worn or loose rings, cause loss of compression. Timing of valve may be wrong. Exhaust and inlet may not open at correct time. See Index, under "Checking valve timing," "Valve grinding," "Valve clearance." Weak inlet or exhaust springs. Examine cams for wear.

The spark plugs will indicate condition of engine, as follows: If the end of the spark plug is oily it indicates too much lubricating oil or leaky piston rings. If black soft soot, like that which accumulates in a lamp chimney, this indicates that too much gasoline is being fed to the cylinder through intake, causing too rich a mixture. This may come from improper carburetor adjustment or an air leak in intake manifold. If the ends of the plugs are oily and sooty, this would indicate that the valves leak, as this permits burned gases being drawn into the mixture, which would result in poor combustion and lack of pressure in cylinder, which would permit oil to pass and foul plug.

(40) **Carburetion:** Too rich a mixture (see Index under "Carburetion mixture."

(41) **Overheating of engine:** Lack of oil. Circulation system defective (see Index under "Engine overheats; cause of."

(42) **Ignition:** Timing of ignition may be wrong—set too far retarded or too far advanced. Weak ignition. Defect in distributor.

(43) **Miscellaneous causes:** Dragging brakes, leaky piston rings, lack of lubrication. Tight bearings. Flat tires. If new piston rings fitted, they may be not fully set. Use plenty of oil.

ENGINE OVERHEATS.[2]

(44) **Valves:** The exhaust valve may not open early enough to permit the burned gas to pass out.

(45) **Carburetion:** Too rich a mixture (see Index under "Carburetion mixture"), or driving with throttle open too far and spark retarded too much.

(46) **Ignition:** Running on retarded spark invariably causes heating. Test the ignition timing.

The spark lever should be raised up or advanced as far as possible at all times without causing the engine to knock. See Index "Spark control and over-heating."

(47) **Lack of lubrication:** Examine the oiling system.

(48) **Cooling:** Constricted water circulation; examine the water circulation and pump. Under-sized radiator.

(49) **Carbon deposit:** See Index under "Relation of carbon deposit to lubricating oil." Choked exhaust.

(50) **Slipping fan belt:** Tighten the belt.

(51) **Brakes dragging:** Examine the brakes with rear wheels jacked up.

(52) **Bearings:** If engine is new or just overhauled, the bearings may be too tight. Put in plenty of oil and run the engine until loosened up.

(53) **Driving too long on low gear:** This is bad practice and should be avoided.

Note. Refer to page 148 and note the "motometer." This is an excellent device to assist in diagnosing overheating troubles. Overheating is always manifest when engine begins to run slow and pounds.

ENGINE KNOCKS.

(54) **Ignition:** The most common knock is the ignition knock, caused by too much advance of spark. Back lash in timing wheel teeth. See Index for "Knocks."

(55) **Bearings:** The connecting rod or main bearings may be loose. Lubrication may be poor. (See Index for "Testing," also "Tightening bearings.")

(56) **Carbon deposit:** This is also a frequent cause of knocking; see Index for "Carbon troubles."

(57) **Loose or worn pistons:** Will cause a "piston-slap." See Index. Loose piston pin also causes knocks.

(58) **Carburetion:** Too rich a mixture will cause a gas knock.

(59) **Engine overload on hill:** Shift to lower speed.

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[1] See Index under "Engine Why It Loses Power."

[2] When the engine overheats by steaming, owing to frozen water, feel the radiator at bottom. If cold, it is frozen; if warm, then the circulation is right, and the trouble is due to lack of water or something else. See also pages 154, 150, 153.

ENGINE WILL NOT STOP WHEN SWITCHED OFF.

(60) **Ignition:** If firing is regular, the switch is defective. If firing is irregular, pre-ignition is the cause. Caused by poor oil. This carbon hardens and becomes red hot, hence "pre-ignition." (See Index under "Pre-ignition.")

Stop engine by closing throttle, and as soon as the engine cools, locate the cause.

(61) **Miscellaneous other causes:** Overheating, as explained from (44) to (53), may be the cause.

DIGEST OF ENGINE AND CHASSIS TROUBLES: CAUSE AND REMEDY

ENGINE RUNS WELL, BUT CAR DRAGS.

(62) **Clutch is probably slipping:** The spring needs tightening. If leather-faced cone type, too much oil on the leather. Clean with gasoline squirted on with an oil gun. If this does not hold, use Fuller's earth (last resort). If multiple disk type, clutch spring at fault or plates worn.

A slipping clutch is detected by the engine speed not conforming with speed of car when throttle is opened. This ratio between car and engine is soon learned by experience.

Brakes may be dragging.

CLUTCH DRAGS.

(63) **If cone type:** The clutch may not clear the fly wheel when thrown out. If multiple disk type, the oil may be too heavy and sticks to plates.

CLUTCH GRABS, OR IS FIERCE.

(64) **If cone type:** Leather too dry. Clean with gasoline (see 62); then put on castor oil or neats-foot oil to soften.

If multiple disk, use lighter oil after cleaning. Spring may be too tight (see repair subject, "Care of clutch," and Index under "Borg & Beck clutch").

CLUTCH SLIPS (Ford)

(65) See Ford instruction and Index.

CLUTCH BRAKE WORN, CAUSES TROUBLE IN SHIFTING GEARS

(66) See Index: "Borg & Beck, single-plate clutch".

OIL ON CLUTCH LEATHER (cone type). See Index "Clutch repairing."

(67) **Cause:** Too much oil in crank case—oil works out of engine bearing.

ENGINE BACK FIRES IN MUFFLER.

(68) **Ignition:** Usually occurs when coasting with spark off and retarded, and suddenly throwing on switch, thereby firing charges which have entered muffler unfired.

(69) **Carburetion:** Mixture too weak to fire, or mixture right but sparking wrong. One cylinder missing fire and pumping explosive charges into muffler which ignites from heat of the next exhaust charge. Missing of ignition, valves leaking. Gasoline supply failing.

Remedy: (1) Examine as in sections (25) to (30); particularly see if the plug points are too far apart. (2) See that all cylinders are firing regularly. (3) Adjust carburetor. (4) See if plenty of gasoline is in tank.

CRANK CASE BECOMES VERY HOT AND ENGINE WEAK.

(70) **Cause:** Serious leak of exploded gas past piston rings; rings worn or broken; crack in head of piston; piston pin loose in piston and allowing gas to escape along bearing. See Index under "Testing piston ring leaks."

OVERHEATING OF EXHAUST PIPE AND MUFFLER.

(71) **Cause:** Carburetor trouble; over-rich mixture; valves out of time; very late spark; running too long on low gear; using too much gas; exhaust throttled; insufficient lift on valve or choked muffler.

This condition is the result of the mixture not being completely burned in the combustion space, but continuing to burn in the exhaust pipe and muffler.

A mixture that is too rich or too poor, usually the former, will burn slowly and will still be burning during the exhaust stroke.

If the exhaust valve opens too soon, the charge will escape before it has done its work.

Very late ignition will not give enough time to permit the charge to be burned before the exhaust valve opens.

ENGINE MAKES AN UNUSUAL HISSING NOISE.

(72) **Cause:** Spark-plug porcelain broken; joint between engine and exhaust pipe loose; exhaust pipe cracked; compression cock worked loose; spark plug not tightly screwed into cylinder; valve caps may be loose; cylinder head may be loose. Probabilities are that the exhaust pipe or a spark plug is loose.

GASOLINE FAILS TO REACH THE CARBURETOR.

(73) **Cause:** Gauze strainer in base of carburetor choked; obstruction in the supply pipe; air lock at a bend in supply pipe; pressure leakage from tank, or, if a gravity tank, it may be air-bound; floating obstruction in gasoline tank covering the gasoline outlet; gasoline pipe near exhaust pipe causing a vapor lock; vent hole in filler cap clogged. See Index: "Vacuum-tank troubles."

CONTINUAL EMISSION OF SMOKE FROM MUFFLER.

(74) **Cause:** Engine being over-lubricated. Readjust lubrication to give a slower rate of oil flow. The emission of black smoke indicates that the carburetion is too rich. Piston rings leak. Cylinders may be "scored."

CRACK IN CYLINDER.

(75) **Effect:** Water in combustion chamber or in crank chamber; air bubbling through radiator on pulling engine over compression. (See Index.)

CARBURETOR DRIPS.

(76) **Cause:** Float-valve mechanism out of order. Examine float and reseat the float needle valve. Usual cause is dirt under needle valve, or float set too high. (See also Index.)

ABNORMAL NOISE FROM TRANSMISSION GEAR.

(77) **Cause:** (Other than unskillful changing of the gears)—want of lubrication of gears in change-gear box or bevel drive on back axle; pinions damaged; teeth broken or worn down; nut loose in gear box and fouling gears; clutch drum or flywheel loose; universal joints on transmission shaft badly worn or damaged; bearings in gear box worn, allowing shafts to rock about; sliding member of clutch out of alignment with cone (sets up harsh grating noise); wear of jaws of positive clutch in gear box.

SQUEAKS AND SIMILAR NOISES.

(78) **Cause:** Fork actuating clutch wants lubrication; one or more bearings overheating and want of lubrication; one or more of the brakes partly on; bearings of spring shackles want lubricating (on some cars the spring ends work in a slide, which requires occasional lubricating); valve stems running dry in the guides. Fenders and hoods are usually the cause of most noises. Spring leaves require lubrication between them.

LUBRICATOR STOPS WORKING.

(79) **Cause:** Oil pipe choked; feed nipples choked; pump shaft may be broken, usually due to clogged pipes—may need priming; loose connections.

OIL-FEED GAUGE DOES NOT SHOW FLOW OF OIL.

(80) **See if oil in crank case.** Clean strainer. Air leak. Examine pump and pipe connections. Oil may be too cold to flow (see page 164). Oil pump may need priming. When testing an oil-feed pipe for an air leak, remove and test with air pressure, submerging pipe in water to make the test.

OIL LEAKAGE FROM ENGINE.

(81) **Cause:** Bearings badly worn and passing out bearing journal; gaskets not tight; screws loose; crank case flooded with oil (lubricator working too rapidly); cap screws holding lower crank case not tight; gaskets leaking.

For "Ignition troubles," "Magneto troubles," "Carburetor troubles," "Starting-motor troubles," "Cooling troubles," "Generator troubles," "Carbon troubles," "Storage-battery troubles," "Miscellaneous repairs and adjustments," "Tire troubles," "Lighting troubles," see Index.

INSTRUCTION No. 42

TESTING DEVICES FOR ELECTRICAL TESTS: Ammeter and Voltmeter Construction and Tests

ELECTRICAL TESTING DEVICES

Most tests of any part of an electric system are for "open circuits," "grounds," or "short circuits"—that is, **electrical** troubles. There are, of course, many **mechanical** troubles which are not tested with instruments.

Devices used for testing circuits can be classified under two headings:

1. Visible circuit-testing devices.
2. Audible circuit-testing devices.

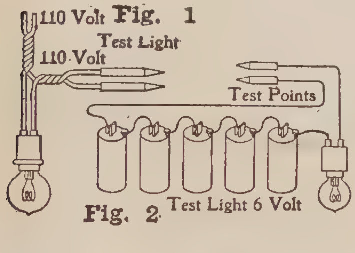


Fig. 1

Fig. 2

Fig. 3

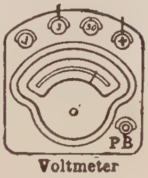


Fig 5

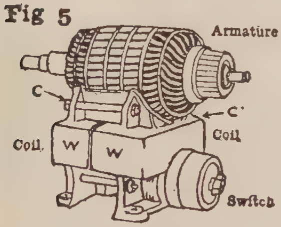
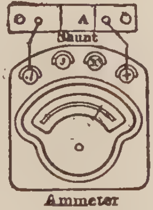


Fig. 4.



Visible circuit-testing devices include such devices as are mentioned below:

(a) Test-light and test-points in series with a 110 or 220-volt lighting circuit (Fig. 1), termed a "high-voltage test-light."

(b) Test-light and test-points in series with a set of dry cells or a storage battery (Fig. 2), termed a "low-voltage test-light."

(c) A voltmeter (Fig. 3).

(d) An ammeter (Fig 4).

Frequently the voltmeter and ammeter are combined in one instrument.

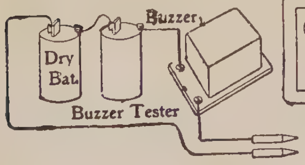


Fig. 6

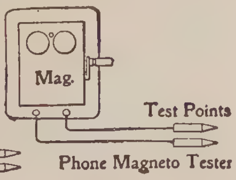


Fig. 7A

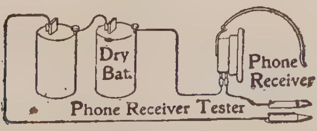


Fig. 7

Audible circuit-testing devices include such devices as a growler (Fig. 5) for testing armatures; a buzzer and test-points (Fig. 6); a phone receiver and test-points (Fig. 7); a magneto and test-points (Fig. 7A).

Test-Lights

The test-light and test-points can be used for testing for open circuits, grounds, and short circuits in the lighting, the horn, ignition, the generator, and, in fact, in all circuits, including the field-windings and armature. Tests will be explained farther on.

Next to the combination volt-ammeter, the most important testing arrangement for the electric mechanic is a set of "test-points," to use in connection with the electric light circuit. This is very easily made by tapping one wire of an ordinary extension lamp, and splicing the wires on to suitable points with insulated handles, in order that these may be handled with no danger of electrical shock, as explained below.

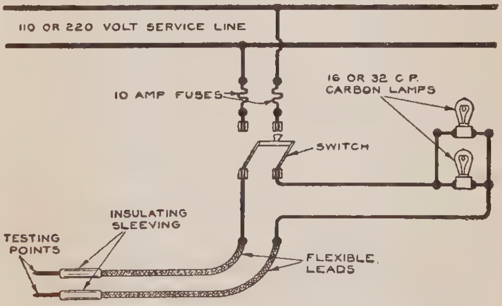


Fig. 8. High-voltage test-lamp with fuses in the circuit.

High-voltage test-lamp: The circuit shown in Fig. 8 is for a 110 or 220-volt circuit. Carbon filament lamps are used as they stand more vibration.

With a set of test-points as described, the lamp will burn when the test-points are together, or when there is an electrical connection between the points.

This will give more satisfactory results for testing for grounds, leaks, or open connections than will a bell or buzzer used with dry batteries, as the voltage is higher and it requires a small amount of current to operate the lamp.

With a bell or buzzer, a ground may exist, but the resistance is so high that enough current will not be forced through it by the dry batteries, to operate the bell or buzzer.

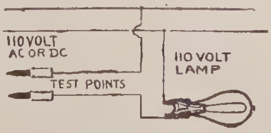


Fig. 8A. High-voltage test-lamp without fuses.

No harm can be done to any part of the apparatus by test-points as described above, when the ordinary carbon or tungsten lamp is used for testing purposes.

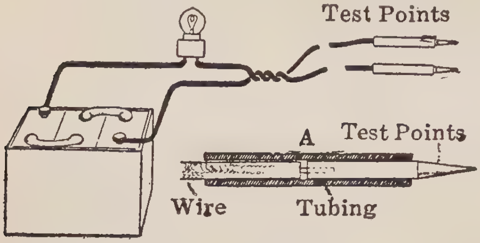


Fig. 9

Fig. 9A

Fig. 9. Low-voltage testing lamp.

Fig. 9A. Construction of the test-points.

A low-voltage test-lamp is shown in Fig. 9. In many instances it is advisable to use a small 2 c.p. lamp and a storage battery. Note that the lamp is in series with the circuit. The voltage of the lamp is the voltage of the battery used. Usually, a 2 c.p. lamp is used.

Test-points: An example of how the test-points can be made is shown in Fig. 9A. The end of the wire is scraped clean and inserted into a hole drilled into a brass rod about 6″ long, and soldered securely. The rod must have a very sharp point, so that it will make good contact. A fiber tube is then tightly fitted over the pointed brass rod and wire, as shown in Fig. 9A.

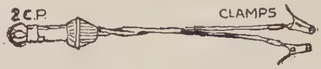


Fig. 10. Test-lamp for timing the ignition.

A test-lamp for testing the opening and closing of the contact-breaker points of the primary ignition circuit when timing the ignition is shown in Fig. 10. See page 371 for directions for use of this.

Buzzer, Phone Receiver, and Magneto Tester

The buzzer or bell (Fig. 6) **and the phone receiver** (Fig. 7) can be used with the test-points for testing out different sections of the armature coils.

The magneto tester (Fig. **7A**) generates a high voltage and is adapted for tests which will force a current through a high degree of insulation, such as poor connections or a leaky path and coil windings. This device is nothing more than a telephone magneto generator with a bell, test-cords, and test-points. It is cranked by hand (seldom used).

AMMETER AND VOLTMETER FOR DIRECT CURRENT TESTS

The ammeter and voltmeter can be used in many instances where a test-light can be used, and vice-versa. In fact, the voltmeter and ammeter are more often used for all general electric tests than any other type of testing device. Therefore, before taking up the subject of tests of the various parts and circuits, an explanation of these will be given.

A voltmeter is always placed **across,** or parallel with, a circuit to be tested, as in Fig. 12A.

An ammeter is always placed **in series** with a circuit to be tested, as in Fig. 13.

The positive or (+) terminal of each instrument is placed on the (+) side of the line, otherwise the instrument would read backwards.

Combination Voltmeter and Ammeter for Electrical Testing Purposes

Instead of having a separate voltmeter and ammeter, it is possible to combine both in one instrument using the same scale and moving coil. The Weston model 280 garage testing voltammeter will be used as an example (Fig. 12).

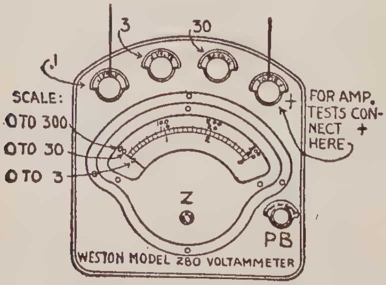


Fig. 12. Showing the three scales on the volt ammeter. The contact button (PB) is pressed when making readings. If it is desired to obtain a continuous deflection, the key (PB) should be given a turn, which locks it. When starting to use the instrument, see that the needle is at zero; if not, adjust with (Z).

As a Voltmeter

When using the instrument for voltage tests: See Fig. 12, and note that terminals are marked .1, 3, 30, +.

The positive or (+) terminal of the instrument is **always** connected with the positive (+) wire of the circuit being tested. When making connections where the polarity is not known, the needle will deflect to the left if wrongly connected—reverse connections.

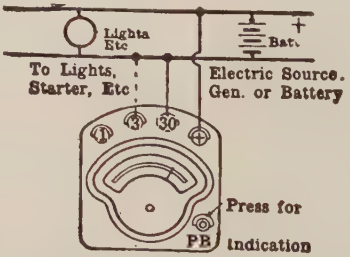


Fig. **12A.** **When used as a voltmeter,** the connections are always made across the line. The circuit of this is from (+) of the battery, to lights, to (−) of the battery. Note that (+) of the meter is connected to the (+) side of the line. Thus if the circuit is 3 to 30 volts, connect the other side of the line with meter terminal 30. If the voltage is from 0 to 3 volts, connect with terminal 3.

If the voltage to be tested is known to be between 3 and 30 volts, then connect the other, or negative (−) wire to terminal marked 30, and use the scale 0 to 30, the divisions of the scale being 0.5 volt for each line (the scale has 60 divisions).

If the voltage is known to be between 1 and 3 volts, connect the negative wire with terminal marked 3, and use scale 0 to 3, the divisions of the scale being 0.05 volt for each line.

If the voltage is known to be less than 1 volt, connect the negative wire with terminal marked .1, and use scale 0 to 3.

When making voltage or ampere tests, the button (PB) is pressed for indication.

The zero adjustment (Z), is merely used to line up the needle with zero or O, when starting to use the instrument.

A voltmeter is always connected across the line, as shown at (V1) and (V2), page 470, and in Fig. 12A. It is used to indicate the voltage pressure of an electric circuit.

As an Ammeter

When using the instrument for measuring amperes, it is connected in series (that is, the shunt is in series) with the circuit, and is intended to indicate the quantity or rate of flow of current.

It is important to note that a "shunt" (Fig. 14) must be connected as shown in Fig. 13. The reason for this is explained farther on. A shunt is not used with the voltage tests.

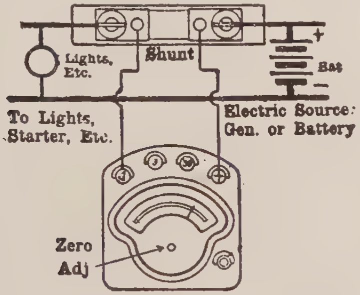


Fig. 13. When used as an ammeter, a shunt is placed in series with the line and the meter is connected to the shunt. The circuit is from (+) of the battery, to shunt, to light, to (−) of the battery. Note that the ammeter is connected to each side of the shunt.

An ammeter is a millivolt meter, adjusted to a known drop in the shunts used with it.

Shunts

Construction: A shunt consists of a special alloy, called manganin (Fig. 14), which, in this instance, is placed between two copper bars mounted on a wood or hard rubber base. The shunt is placed in series with the circuit being tested.

The meter is connected at each end of the manganin at (M) and (M1) (Fig. 14). Thus the manganin is shunted across the meter terminals, and this is why it is termed a "shunt." A shunt is used with the meter for ampere tests and not for voltmeter tests.

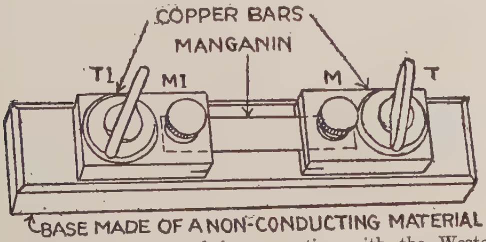


Fig. 14. A shunt used in connection with the Weston ammeter.

The manganin alloy was discovered by Dr. Weston. It possesses the faculty of holding a **constant** resistance, whether it is hot or cold, and directly proportional to the current flowing through it.

It is a well-known fact that other metals which are used for resistance purposes, when cold, offer less resistance than when hot. In other words, other resistance metals when heated offer greater resistance to the flow of current (some metals more or less than others).

The shunts which are used with this model 280 instrument are designed to give a **100-millivolt drop** between the terminals (**M**) and (**M1**), (Fig. 14A).

Explanation of Millivolt Drop

A millivolt is a one-thousandth part of a volt One hundred millivolts would then be one hundred times more, or one-tenth of a volt, expressed decimally as .1. The terminal of the meter (Fig. 12), at the left, which is marked .1, is then, the one-tenth of a volt, or 100-millivolt terminal of the meter.

The moving coil of model 280 voltmeter and ammeter is designed for a passage of 100 millivolts (or .1 of a volt) through the coil. If this amount of voltage passes through the moving coil (K) (Fig. 15), it will cause the coil to move its maximum distance of travel across the scale. As the needle moves with the coil, it would give a full-scale deflection of the needle, that is, the needle would move from 0 at the left of the scale, to the extreme right. Thus it will be noted that **one-tenth of a volt (.1), or 100 millivolts, which is the same, is the voltage required to cause the needle to give its maximum or full-scale reading.** This voltage is used for the instrument when it is used as an ammeter or as a voltmeter.

If less than one-tenth of a volt (.1) (or 100 millivolts) is passed through the coil of the meter, then **the needle will not move as far** on the scale. The scale is graduated to show in volts or amperes, although the actual voltage which is permitted to pass through the coil of the meter is only 100 millivolts, or one-tenth (.1) of a volt, or less.

This drop in voltage depends on the size or quantity of the manganin used in the shunt, when the instrument is used as an ammeter.

When the instrument is used as a voltmeter, the shunt is not used, but resistance is used as shown in the figure of the meter in Fig. 15.

For example: Let us assume that the instrument is to be used as an ammeter to test the rate of flow of amperes passing from the (+) brush of the generator to the (+) terminal of the battery, as shown in Fig. 14A. We will also assume that **30 amperes** will

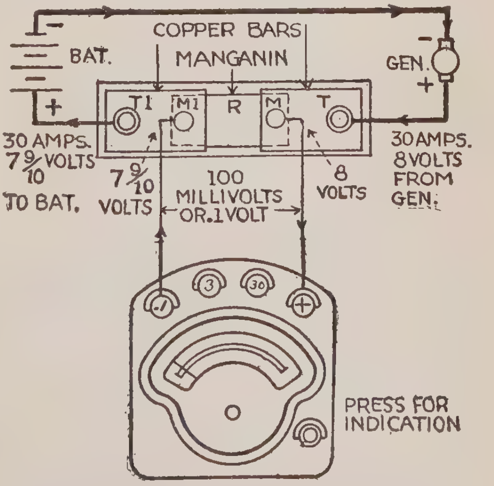


Fig. 14A. Illustrating how the voltage is dropped one-tenth of a volt (100 millivolts), when 30 amperes are passed through the shunt. Only one-tenth (.1) of a volt, or 100 millivolts, or less, passes through the meter—**never** any more.

pass from generator to battery when the former is generating its maximum current output,[1] and about 10 amperes when it is generating its minimum output.

A 30-ampere shunt is then placed in series with the main charging circuit, as shown in Fig. 14A. We use the 30-ampere size because we know the maximum current is not over 30 amperes, or is less. If it was more, then a shunt with a greater capacity should be used.

The main circuit is then as follows: The (+) current starts at (+) of the generator brush, to a copper bar terminal (T), through the manganin, to the other copper bar terminal (T1), to the (+) terminal of the battery, through the batttery, to the (−) terminal of the battery, to the (−) brush of the generator.

Thus we have, say, 30 amperes flowing in the main circuit and through the shunt. Therefore, 30 amperes will flow through the manganin from the (+) brush of the generator, and will **not be reduced,** and thus 30 amperes reach the battery.

The ammeter circuit: The meter terminals (when used as an ammeter) are always connected from one terminal (M) of the shunt, which is the (+) side, where the connection of the copper bar makes contact with the manganin, thence to the (+) terminal of the meter, through the moving coil in the meter (Fig. 15), to the 100-millivolt terminal, or .1 terminal, of the meter, to the terminal (M1) on the shunt (Fig. 14A) which is the (−) or other end of the manganin.

We will now see what would cause the needle to deflect a full-scale deflection and show 30 amperes. The reading is made on the second scale, 0 to 30 (Fig. 15), because we are using a 30-ampere shunt.

In the preceding paragraphs, it was stated that if one-tenth (.1) of a volt, or 100 millivolts, passed through the meter coil, this would cause the coil to travel such a distance in the direction of rotation as to cause the needle to make a full-scale deflection. Therefore we must now pass .1 of a volt (or 100 millivolts) through the coil, which is the purpose of the shunt.

For instance: If the voltage was 8 volts from the generator, then 8 volts would start into the manganin at (M), but after passing through the manganin, the voltage would have **dropped 100 millivolts,** or one-tenth (.1) of a volt, or to 7 9/10 volts at (M1).

Therefore, as the meter terminals are connected with the manganin at each end (M) and (M1), this difference of one-tenth (.1) of a volt, which represents the millivolt drop, would pass through the coil of the meter, and the needle would have moved to the extreme right and would read 30 amperes on the scale (Fig. 15).

Thus the shunts used with this meter are designed for **a 100-millivolt drop,** and it is this voltage drop which is used to operate the meter. It will be clear, therefore, that if the meter was connected in series with the circuit without the shunt, the full voltage (8 volts) would pass through it and damage it.

We will now assume that the output of the generator is but 10 amperes, instead of 30 amperes.

If it required 30 amperes of current to pass through the shunt to cause a drop in voltage of 100 millivolts, or one-tenth (.1) of a volt, then if only 10 amperes passed through the shunt, the millivolt drop would be proportionately less. Therefore, as only one-third of the current is passing through the shunt, only one-third of the 100 millivolts would drop. Instead of the voltage dropping to 100 millivolts at (M1), it would drop only one-third as much, and only one-third of 100 millivolts would pass through the coil of the meter. Thus the coil of the meter would move but one-third of the distance, and as the needle moves with the coil, it would move but one-third the distance on the scale, or to the reading of 10 amperes, as calibrated on the scale.

The same rule applies to all the other shunts. If a 3-ampere shunt is used, only 3 amperes must pass through it, and consequently it contains a proportionally less amount of manganin. If full 3 amperes pass through the shunt, the result will be a voltage drop of 100 millivolts, or one-tenth (.1) of a volt. The same applies to the 300-ampere shunt, or to any shunt designed for this instrument.

The point to bear in mind is that one-tenth (.1) of a volt, which is 100 millivolts, is what is required to give a full deflection of the needle on the scale, and that a shunt must be used, which will give a drop of 100 millivolts if the full amperage for which it is designed, is passing through it, or that it will give a proportionally less drop, if less amperage than that for which it is designed is passing through it.

Thus the shunt, which is shunted between the two terminals (+) and .1 of the meter, when used as an ammeter, is for the purpose of giving this 100-millivolt, or one-tenth (.1) of a volt drop, or less, in proportion to the current passing through it.

Internal and external shunts: Where currents are small, as on a dash ammeter, the shunts are usually **internal,** or contained in the meter case. But for large currents or for testing instruments, **external** shunts are used, so as to keep the heat developed in the shunts outside of the meter as well as for convenience, as the shunt can be located in the circuit wherever it is easiest, and can be connected with the meter by a small cable, thus saving the running of heavy wires to the instrument.

Note. When testing amperes, use the testing cables which come with the instrument, from the meter to the shunt, as the cable is figured out for the exact length and size. From the shunt to the part being tested, use a wire of sufficient size to carry the load or amperes which will pass through it; for instance, if 30 amperes, use No. 10 or 8 wire.

Capacity of Shunt to Use with the Model 280 Instrument, and Range of Scale

Shunts to use with this instrument:[1] There are three external shunts figured on a 100-millivolt drop between terminals.

1. **A 300-ampere shunt** with which use the scale 0 to 300. Each division or mark on the scale represents 5 amperes (see Figs. 12 and 15).
2. **A 30-ampere shunt,** with which use the scale 0 to 30. Each division or mark represents 0.5 amperes.
3. **A 3-ampere shunt,** with which use the scale 0 to 3. Each division or mark represents 0.05 amperes.

When testing where you do not know what the amperage is likely to be, as when testing for short circuits, it is advisable to assume that the highest possible amperage is to pass through the meter. In such cases use the 300-ampere shunt. If the deflection obtained is less than 30 amperes, then use the 30-ampere shunt and scale, to gain a more accurate reading. Should the indication now be less than 3 amperes, use the 3-ampere shunt.

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[1] A generator seldom delivers more than 20 or 22 amperes maximum. We have arbitrarily taken 30 amperes to illustrate our explanation of how the needle will make a full-scale deflection from 0 to 30 when a 30-ampere shunt is used and 30 amperes are passing through it.

[1] Other sizes can be obtained.

The 3-ampere shunt and range are convenient for measuring single lights and ignition.

The 30-ampere shunt and range are convenient to measure current delivered by a generator to the battery as shown at (A1), page 470; for measuring current required by the lights, horn, etc., and also for testing short circuits and open circuits.

The 300-ampere shunt and range are convenient for measuring the current required by the starting motor, as shown at (A2) page 470 and also for testing for short circuits.

Shunts Not Used with Instrument as a Voltmeter

When the instrument is used as a voltmeter, the same coil winding as shown in Fig. 15 is used, and it is necessary to have the same 100 millivolts or .1 volt drop, just the same as when it is used as an ammeter, but the shunts are not used to obtain this drop. Resistances (C), (B), and (A) are used (Fig. 15). This resistance is in series with the meter circuit and its connections to the main circuit being tested. Note, however, that the voltmeter connections are across the line of the main circuit.

The (+) terminal of the meter is always connected to the (+) side of the circuit being tested, and the terminal .1, 3, or 30 is connected to the other side of the circuit.

This instrument is designed for testing the voltage of a circuit, from 0 to .1 volt (100 millivolts); 0 to 3 volts; and 0 to 30 volts.

By means of a multiplier, used in conjunction with the 30-volt range, the range is extended to 150 volts. This multiplier can be obtained of the Weston Electrical Instrument Co., Newark, N.J. (or of A. L. Dyke, Electrical Dept., St. Louis, Mo.).

Millivolt Reading

When testing a circuit of 100 millivolts or less, the connections are made for the (+) side of the circuit, to the (+) terminal of the meter, through the moving coil, to the .1 (100-millivolt) terminal on the extreme left.

If 100 millivolts (1/10 volt) pass through the moving coil, then the needle will deflect from 0 to the extreme right.

If 50 millivolts pass through the meter coil, then the needle will deflect half-way of the scale, and so on.

The millivolt connections are used for testing the voltage drop in armature and field coils.

The scale 0 to 30 is used, and it will be noticed that this scale has 60 divisions. The scale, however, is not calibrated for millivolt readings. Therefore a **comparative test** is usually made when using it.

For example: If each armature coil is being tested for short or open circuits, the procedure would be to test an armature coil that is known to be in good condition, and then to note where the needle goes on the scale. Then test all of the other armature coils, which should compare with the good coil in the reading. There will, of course, probably be a slight variation in the readings of the different coils, owing to the fact that they may not all be exactly the same length, but the variation should be very slight.

If there is a noticeable difference, where the reading is greater than in the good coil, then the coil is probably open-circuited. If the reading is noticeably less, then there is probably a short circuit in the coil.

As previously stated, **the scale is not calibrated for readings in millivolts,** but if the needle moves from 0 to the right of the scale, then we know that 100 millivolts are passing through the meter coil. The scale has 60 divisions, therefore one division would equal one-sixteenth of one hundred, or 1 2/3 millivolt.

Purpose of resistance in the circuit when testing armature or field-coils: It will be observed by referring to the subject of: "Testing armature or field coils with a meter" (page 488), that resistance, termed a **resistor,** is used in series with the circuit.

If the millivolt connections of the meter were made to an armature coil in good condition, the drop would be very slight and difficult to read, unless a meter with a millivolt scale was used.

The object is to place enough resistance in the armature or field-coil circuit to cause a **voltage drop** sufficient to obtain a **millivolt drop** which will be easy to read. A good armature coil is then tested, and the needle is deflected to a certain distance on the scale. This reading is then taken as a **standard** to go by; then the tests of all the other coils should **compare** with it, as previously explained.

This resistance is variable, that is, more or less can be used, in order to obtain the deflection of the needle to a distance on the scale where it can most easily be read.

This resistor can be purchased of Ward-Leonard Electric Co., Bronxville, N.Y., at a cost of $5.00. It is designated as "Weston Special 6–10." (It can also be obtained of A. L. Dyke, Electrical Dept., St. Louis, Mo.)

Sometimes a lamp is used in series with a 6-volt battery for the same purpose.

Readings 0 to 3 Volts

When testing a circuit of 3 volts or less, the connection is made at the (+) of the meter with the (+) side of the circuit, then from terminal 3, to the (−) side of the circuit.

The lower scale 0 to 3 is used, and if 3 volts are passing through the circuit, then 100 millivolts, or .1 of a volt will pass through the meter coil, because the resistance (C) and (B) will reduce the 3 volts to one-tenth (.1) of a volt. Therefore the needle would make a full-scale deflection from 0 to 3.

If less than 3 volts is passing through the circuit being tested, then the voltage passing through the meter coil would be proportionately less.

Readings 0 to 30 Volts

When testing a circuit of 30 volts or less, the same connections are made as in the 3-volt test, except that the 30-volt terminal of the meter is used instead of the 3-volt terminal, and the scale 0 to 30 is used.

The resistance (C), (B), and (A) would be in the circuit, and it would therefore be reduced to .1 of a volt, which amount would pass through the meter coil; and this amount would be required to give a full-scale deflection of the needle from 0 to 30.

If less current than 30 volts is passing in the circuit, then a proportionately less voltage than .1 of a volt will pass through the meter coil.

Internal Connections of Model 280 Combination Volt-Ammeter

Note on Fig. 15: When button (PB) is pressed down, the circuit is from the (+) terminal of the meter, through the moving coil (K), to the terminal being used.

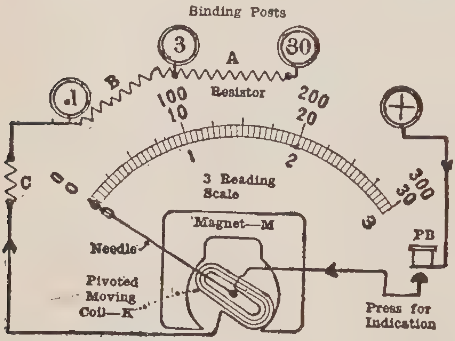

Fig. 15. Internal connections of the Weston model 280. The D'Arsonval or moving-coil principle.

Resistance (C) is the adjusting resistor for the 100-millivolt range; (C) and (B) are in series for the 3-volt range, and (C), (B), and (A) in series for the 30-volt range.

The scale is divided into three sections, and, unlike the dash ammeter, the 0 (zero) is placed at the extreme left, instead of being in the center. Therefore the needle and coil move to the right. It is well to mention that the scale of this instrument is carefully drawn and calibrated by hand. In order to do this and check the instrument with a master meter, three weeks' time is required. This instrument is guaranteed to be accurate within 1 per cent.

When connecting the meter, care must be taken to see that the connections are correctly made; that is, the (+) terminal of instrument should be connected with the (+) side of the circuit being tested, otherwise the needle will deflect to the left, indicating that the (+) terminal of the meter is connected with the (−) side of the circuit.

Cadmium scale: A scale for making cadmium tests of a storage battery, as explained in the storage battery instruction, has been added to the Weston model 280 instrument. This is not shown in the illustration (Fig. 15).

The scale in Fig. 15 has added to it four lines to the left of "0," the first line being one-half of one-tenth of a volt, or .05 of a volt, or 1/20 volt. The second line would be .1 (one-tenth) of a volt; the third line would be .15, or 3/20 volt, and the fourth line would be .2 or 1/5 volt. This scale is used for cadmium readings when testing a storage battery, and is explained in the storage battery instruction.

Principles of the Ammeter

Two principles are in general use: one is the "D'Arsonval type," which is termed a "moving-coil type," and which is the principle on which the Weston model 280 instrument is constructed.

The other type is the "polarized vane" type, which has a "stationary coil."

Moving-Coil Principle

D'Arsonval type: Refer to Fig. 15. Note the permanent magnet (M) which has a permanent N and S pole polarity. A fine, light spiral spring (not shown) serves to lead the current into and out of the moving coil (K), and also to keep the coil in its zero position and to provide a force against which the magnetic action of the current in the coil acts.

The electric current to be measured is passed through the moving coil (K) and magnetic lines-of-force are set up around the coil which becomes an electromagnet,[1] with the N pole at one end and the S pole at the other, depending upon the direction of flow. Therefore, as a N pole will atttract a S pole, or repel the N pole,[1] this principle is utilized. The coil endeavors to place itself in line with the **magnetic circuit** flowing from N to S from the permanent magnet. The coil is pivoted so that it can move, and the needle, being connected with the coil, moves with it.

The D'Arsonval, or moving-coil principle, is the type of ammeter and voltmeter in general use, especially for testing purposes, where close accuracy is required. This type of instrument is designed for only a fraction of a voltage to pass through it, and if a greater amount than a 50 per cent overload is passed, it will damage the instrument.

Stationary-Coil Principle

The polarized vane type of ammeter uses a fixed or "stationary coil." This type is more rugged and will withstand severe strains and shocks without damage, but it is not as accurate in its readings. This principle is often used for dash ammeters and indicators, **but not for testing purposes.**

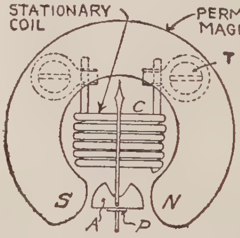

Fig. 16

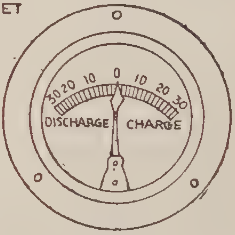

Fig. 17

The principle of its operation is shown in Figs. 16 and 17. A piece of soft iron, rigidly attached to a steel pivot placed equally distant from the poles of a permanent magnet, is attracted or repelled by the passing of an electric current in one direction through the coil of wire (C) fixed or stationary in the plane of the iron. The magnet, being of the permanent-magnet type, holds the piece of iron (called the armature) exactly in position, so that the pointer attached to the pivot is held at zero.

As current is admitted to the coil, it becomes an electromagnet, the N pole being at one end and S pole at the other, dependent on the direction of flow.

When the end nearer the armature is North, it repels the North end of the armature and attracts the South end, with the result that the needle moves across the scale.

As a result of the manner of the construction of this instrument it is capable of withstanding the current from the battery to the starting motor without damage, as the coil (C) is of very heavy construction.

Dash Ammeter

The dash ammeter of the moving-coil type (for direct current) is similar in principle to that shown in Fig. 15, except that it has internal shunts and its dial is calibrated to read in two directions. That is, the zero (0) is placed in the center of the dial, as shown in Fig. 18.

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[1] Why the N pole attracts the S pole and repels the N pole is explained on page 179. See also, page 183, explaining how a coil becomes an electromagnet with a N and S pole polarity.

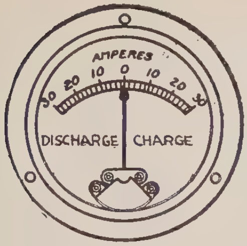

Fig. 18

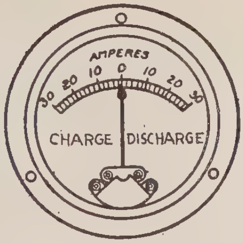

Fig. 18A

If the moving-coil type of instrument is used on a circuit of more than 30 amperes, it will be damaged. The starting-motor current is never taken through a dash ammeter of this type. The generator charging current is carried through it and as the generator seldom delivers over 22 amperes, the 30-ampere range is sufficient.

Meaning of Zero Center

Note that the "0" is in the center, and when no current is flowing the needle will remain at 0 or zero. The needle can read up to 30 amperes on the "charge" side, to the right, or to 30 amperes on the "discharge" side, to the left, and is termed a "30-0-30" scale.

If the generator is running at sufficient speed to charge the battery, the cut-out points will close and connect the generator with the battery and charge the battery. Then the needle will move to the right or "charge" side of 0—if correctly connected.

If the engine slows down, and the cut-out points open, then the battery is disconnected from the generator, and as ignition is being consumed from the battery the needle will move slightly to the left of 0, or "discharge" side of zero—as the battery would be discharging instead of taking a charge. If lights were on, then the needle would go farther on the discharge side, as more current will be discharging from the battery.

This shows that the needle moves in one direction when current is flowing from the positive connection (+) of the generator to (+) of the meter, to (+) of the battery. But the needle operates in an **opposite direction,** when current is flowing **back from the battery** to the meter, as connection is with the negative side (−) of the meter in this instance. This is the reason for zero (0) being in the center on the dash ammeter.

Note. The instrument just described, as is the case also with the other instruments illustrated in these instructions, shows the "charge" side on the right of "0" and the "discharge" side on the left of "0."

The **standard** now adopted by manufacturers of dash ammeters is to have the "charge" side on the left and the "discharge" side on the right of "0" (see Fig. 18A). There are many instruments which came into use before this recent standard was adopted, which read as shown in the illustration (Fig. 18). This makes no particular difference, however.

An Indicator

A battery indicator (Fig. 19) **is used for the same purpose as a dash ammeter,** that is, to show when the battery is being "charged" by the generator and when it is being "discharged." Instead of showing the rate of charge or discharge, it merely indicates what is taking place, by the movement of a cylinder inside of the instrument bearing the wordings, "off," "charge," and "discharge," which appear at an opening in the dial of the instrument.

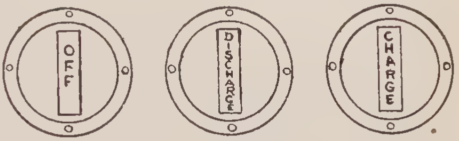

Fig. 19. Battery indicator showing its three indications.

This instrument will operate on as low as 2 amperes and, unlike the dash ammeter of the moving-coil type, it is capable of withstanding any voltage or amperage without damage.

This type of instrument **can be placed in series with even the starting-motor circuit** without injury, and will show "discharge" when current is flowing to the starting motor from the battery.

This type of instrument is used on the Franklin (see footnote bottom of page 424), and is placed in the motor circuit as shown in this diagram. The same type was also formerly used on the Dodge.

This type of **indicator** is termed the "polarized vane" type, with a "stationary coil" (of a principle similar to that shown in Fig. 16).

The Roller Smith Co., Woolworth Bldg., New York, manufactures a dash-type ammeter of the polarized vane type which can be placed in the starting-motor circuit. The same concern also manufactures instruments of the moving-coil type. Another concern manufacturing the moving coil or rotary type, as well as stationary-coil type instruments, is the Hoyt Co., the instruments being sold by Burton-Rogers, Boston, Mass.

HOW THE VOLTMETER AND AMMETER ARE USED FOR TESTING THE ELECTRIC SYSTEM OF A CAR; EXTERNAL TESTS

As an example we shall use the Weston, model 280 combination volt-ammeter. The **tests** shown in Fig. 20, **can usually be made on the car** without removing any of the parts. Internal tests of the different parts, or "bench tests," will be treated farther on.

The idea of this combination electric system is to show where and how a voltmeter and amperemeter can be used on the average electric system for testing circuits on the car. It is understood that the battery is a 6-volt, 3-cell battery, and also that the only instrument which is a regular equipment of the electric system in this example is the "dash ammeter." The other instruments (V1), (V2), (V3), (A1), (A2), are **testing instruments,** the use of which will be explained.

Voltmeter Tests

The voltmeter is always placed **across** the line, and shows the voltage or pressure of a circuit. The instrument used is the Weston, described on page 464 (Fig. 12), which read carefully.

Test V1: To test voltage of generator: Use the "0 to 30 connections" and "0 to 30 scale" of instrument. Place the test points (TP) on the connections leading from the two main brushes. The brush to the left leading to the shunt fields is the third brush and is a part of the shunt-field circuit, or the source of the shunt-field current supply. This test does not include the field circuit, but is for the voltage of the "charging circuit." The maximum voltage of the generator from its "main brushes" will be indicated when the generator is operating at from 7 to 10

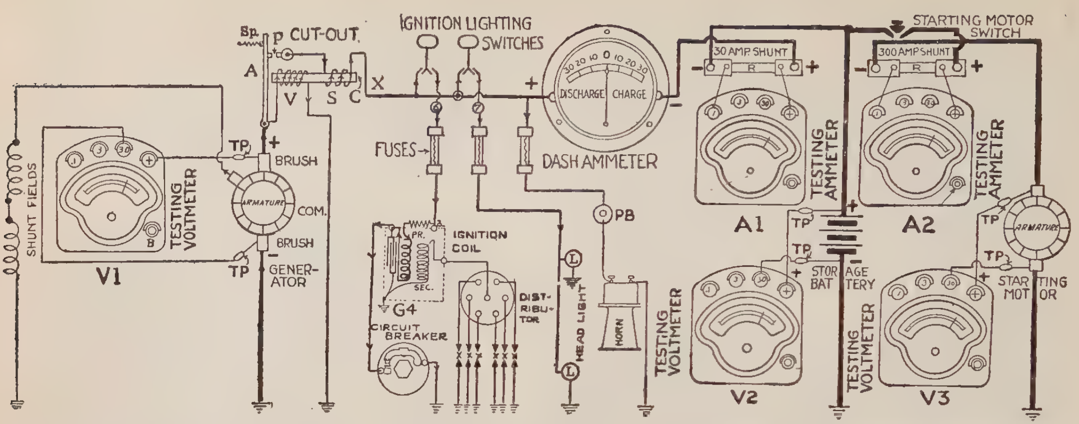

Fig. 20. The dash ammeter is so connected that it shows all current which would "discharge" from the battery, except starting-motor current. All current passing from the battery to the ignition or lighting circuit must first pass through the ammeter, which will show "discharge" on the left of zero in this example. Current passing from the generator to the battery will be indicated on the "charge" or right side of zero. The ignition circuit and light circuit will reduce the amount of charge going to the battery.

The testing meters (V1), (V2), (A1), (A2), and (A3), are not connected permanently in the circuits, but are intended to show how various tests can be made as explained in the text, and only one test is made at a time.

m.p.h. car speed, and the cut-out points (P) should be closed. The voltage of the generator should be slightly more than that of the battery, otherwise the generator will not have pressure enough to overcome the battery voltage. The battery voltage can be tested as shown at (V2).

If the generator voltage is found to be less than the battery voltage, then the cut-out points (P) will probably not close, because the purpose of the fine wire voltage winding (V) of the cut-out is to magnetize the core (C), thus drawing (A) to it and causing the points (P) to close. This winding is so wound that it does not exert sufficient magnetizing effect to draw the points (P) so that they are closed, until the generator voltage is slightly more than the battery voltage.

If the generator voltage is lower than the battery voltage, then the first place to examine is the "third brush" to see if it is seating properly. If it is seating only enough to make slight contact, or if a new third brush has been fitted without properly seating it to the curvature of the armature, the field strength cannot build up sufficiently to assist the armature in building up its full voltage.

The proper seating of the "main brushes" is also important. The commutator may have the mica protruding, or dirty, or the commutator may be rough, or the armature or field windings may be grounded.

If there is no indication of voltage at all, at the generator, then loose connections or open circuits exist, either at the brush-holders, the brushes, or the field-windings.

It is seldom that there will be no indication of current at all, if one armature coil is open, because, they are connected in parallel, and while one armature coil may be open, some indication would come from the other coils. Tests for internal troubles of the generator will be shown farther on.

If the generator voltage is above that of the 6-volt battery, and cut-out points (P) fail to close, then the cut-out spring tension may be too strong, or the cut-out voltage winding may be open-circuited or grounded, or there may be loose connections.

If the cut-out armature (A) makes a feeble effort to close, but does not close tight, when the generator voltage is 6+, then it indicates that the spring tension is too strong, or that there is a ground, or a partial short circuit in the windings.

If the generator voltage is over 6 volts and the cut-out armature (A) makes no attempt to close at all, then the cut-out windings should be tested, providing the spring tension is not too great.

Sometimes the cut-out points (P) fail to open when the engine slows down or stops. This is caused by the points burning together, and thus the battery will discharge back through the generator, but the "discharge" would show on the "discharge" side of the dash ammeter when all switches are "off."

Tests of the cut-out windings are explained farther on.

Test V2: To test voltage of battery when discharging with lights on only, use the 0 to 30-volt connections and scale. The voltage, if charged for a 3-cell battery, will be 6 to 6.3 volts, or 2 to 2.1 per cell. **If discharged,** it will be 5.4 volts, or 1.7 volts per cell.

If tested when the starter is on, a charged battery will drop to 5.4, or 1.7 volts per cell, but will regain its normal voltage after a short while. If it drops to 5 volts or less, or 1.6 volts per cell, it is discharged; or, if fully charged, and it drops as low as this, then the plates are sulphated or an internal short circuit exists. See also the instruction on storage battery.

On testing the voltage of the generator (V1), and the voltage of the battery (V2), when the generator is charging the battery, if any difference is found, or a drop in voltage occurs, it will be the difference between the two readings.

Test V3: To test the voltage which reaches the starting motor from the battery, to see how much drop there is in voltage at the starting motor when operating, close the starter switch for an instant. There will be some drop. If the engine is cold and stiff, it will cause the motor to draw more current. The more current that is drawn, the greater the drop.

If the starting motor should fail to start when the starting switch is depressed, then test to see if there is an open circuit in the armature of the motor, or in the brushes or the brush-holders. This test will determine if the current is reaching the motor.

If there is **an open circuit in the armature,** then the meter would indicate the voltage of the battery, because the top test-point would connect with the (+) of the battery, and the lower (TP) would connect with (−) of the battery. The armature being open, there would be a break at this point.

If the field-circuit is open, there would be no indication at all, because the field is in series with the brushes of the armature.

When a battery is supplying current to a motor and the amperage draw is heavy, there is a drop in voltage at the motor and also at the battery itself, which delivers the current.

Ammeter Tests

Ampere tests are to ascertain the quantity of current flowing. A "shunt" must be used (see page 465). Connect the shunt in the circuit as shown at tests (A1) and (A2), being sure that the positive (+) wire of the circuit is connected to the (+) connection of the meter, and the negative (−) wire of the circuit to .1 binding post of the meter.

Should the charging rate appear to be abnormally low with no apparent reason, it is a good plan to check the ammeter by connecting the test meter (A1) in series with it.

Reliable meters may become defective, as automobile service is extremely hard on a sensitive ammeter.

Test A1: To test the accuracy of the dash ammeter, use the 30-ampere shunt and connect as shown. Speed the engine up and note if the reading is the same on the dash ammeter as on the testing instrument.

A rough check on the accuracy of the ammeter may be obtained by noting the ampere readings of the various lights on the car, and then switching them on one at a time. The reading of the ammeter should correspond to the total amperage required for the lights.

With the engine running and the lamps on, the ammeter may register either "discharge" or "charge," depending on the speed of the engine, the capacity of the generator with respect to the lamps, and the condition of the battery, that is, whether it is charged or not.

Unsteady reading of the ammeter may be due to a defect in the instrument, or to loose contact, or to intermittent ground.

Tapping the ammeter should jar the hand loose if it is only stuck. If it still refuses to register, examine the connections, and if these are all right, look at the cut-out points and see if they are closed. Finally, disconnect one of the main wires from the generator terminal to see whether any current is flowing from the generator, and follow the wires thence to the ammeter, examining them at each terminal to see whether current is flowing, by touching the disconnected wire to its terminal.

Test A1: To test cut-out: Use 0 to 30 shunt and scale. At a car speed of 7 to 10 miles per hour, cut-out points (P) should close, and at 15 or 20 miles car speed, the generator should be charging the battery at 10 to 20 amperes, if lights are off (this varies on different systems). If it shows less than 9 or 10 amperes, the "regulator" or "third brush" should be regulated to bring the current up to at least 10 amperes, 15 amperes being the average.

Throttle the engine slowly, and note that the needle will drop back towards zero. When it reaches zero, note whether cut-out points (P) open, and at what car speed.

Test A2: To test the amperage required by the starting motor: Use the 300-ampere shunt and connect as shown. Test with engine idle. It is assumed that the battery shows 1,275 to 1,300 hydrometer test, and is supposed to be charged.

The average starting motor requires 150 to 200 amperes, if the engine is warm and flexible, or 250 to 300 amperes, or even more, if cold and stiff. If the engine is flexible and an excessive current discharge is shown, then there may be a short circuit in the motor or brush-holders, or possibly the starter mechanism is out of order.

Note. The actual amount of current required by a starting motor varies according to the temperature, condition and size and compression of the engine. If it is extremely cold, the oil is congealed and all parts are stiff; thus a great deal more current is required than when the engine is warm and flexible.

If an engine has been standing for a long time, or out of use, it is likely that the motor will require more current than if in daily use.

HOW THE DASH AMMETER INDICATES TROUBLES

In this instance we refer to the ammeter as usually attached to the dash (cowl) of a car.

The dash ammeter indicates when the generator "charges" the battery, and at what rate. It indicates the rate of "discharge" from the battery to the lamps. It also indicates whether or not the system is working properly. When the battery is neither "charging" nor "discharging," the pointer should indicate "0."

Ammeter troubles may be divided into two classes: those that manifest themselves when the engine is **idle** and those that show only when it is **running.** Both classes have two subdivisions, with **lamps on** and with **lamps off.**

Remember that **the ammeter should show "charge" at speeds above 8 or 10 miles per hour;** and that when the engine is at rest with lights turned off, the needle should stand at "zero," and should not show "discharge."

It shows "discharge" when lights are on and the engine is idle, or at a speed of less than 8 miles per hour. In other words, the battery is then discharging, and is not being charged.

With these points always in mind, it is possible to diagnose many troubles by noting the action of the ammeter, for if it varies from its intended purpose, or its usual action, something is wrong.

When the generator is not charging the battery, and if the battery is being used for lights, ignition, or horn, the needle will be on the "discharge" side of (0) and the amount of current being consumed will be shown in figures on the dial.

When the car is running 10 or 12 miles or more per hour, the ammeter should indicate "charge."

If on connecting an ammeter to the circuit, the needle should go to the "discharge" side, when the engine is running at sufficient speed for the generator to charge the battery, then it indicates that the terminals have been wrongly connected. Reverse the connections.

If the battery is wrongly connected, when the generator is running the ammeter will read in the opposite direction, or the cut-out points will vibrate back and forth, opening and closing the points and causing the needle to swing back and forth as it opens and closes.

On most of the third-brush regulated generators now in use, the cut-out would soon close, however, as the polarity of the generator would adapt itself to the battery polarity. In such case the needle of the ammeter would be steady, but it would read in an opposite direction to its former reading.

If the ammeter indicates zero when the generator should be charging the battery, it shows that the circuit is open, or that the generator is at fault.

If the ammeter does not indicate "charge" when the engine speeds up, but indicates "discharge" when the lights are turned on, then the generator is not delivering its proper output. Look to the "third-brush" or other regulation system, and see if it is properly adjusted; also see if the brushes seat properly; or there may be a short circuit in the lighting wiring.

If the needle is forced to the scale limit on the "discharge" side, it indicates an overload or a short circuit.

When the engine is running and lamps are burning and the ammeter hand stands at zero, it indicates that the generator is producing exactly the same amount of current that the lamps are consuming. Thus the battery is "floating on the line" and is not receiving a charge, nor is it discharging.

If the ammeter shows excessive "discharge" at low speeds, or when the engine is idle, this is caused by the cut-out contacts being held closed or "stuck." Thus current is flowing from the battery through the generator. This must be corrected at once by disconnecting the points. If the light switch is "on," then a ground or short may be in this circuit.

The ammeter will always indicate if a short circuit exists in any part of the wiring, except from the battery to the switch bus bar, and in the starting-motor circuit.

If the ammeter does not indicate "charge" with the engine speeded up, and does not indicate "discharge" with the lights on, and the engine at rest, there is an open or loose connection in the battery circuit; or the battery terminals may be loose; or the generator terminals are loose; or the ammeter may be at fault.

If the ammeter indicates "discharge" with the lights turned off, and the engine at rest, the ammeter pointer may be bent; insulation on the wires may be injured, permitting contact with frame, causing ground or short circuit, or the cut-out points may be stuck.

If the trouble seems to be in the ammeter, it is well to place a test ammeter in circuit, to check the first instrument. If the instrument registers incorrectly it should be returned to its makers for repair.

If the ammeter indicates "charge," with the engine at rest, the ammeter pointer may be bent.

When the ammeter "charge" indications are below normal, the generator output varies with the condition of the battery on some generators. This may also be due to the regulation of the generator not being properly adjusted. For instance, the third brush may need resetting, or the brushes may not be making good contact, or the commutator may be dirty or rough, or may have high mica.

When the ammeter "discharge" indications are above normal, the lamp load may be excessive or the lamps may be old; wires may be grounded or shorted.

If the ammeter pointer jerks intermittently to "discharge," limit of scale while engine is speeding up, there is a short circuit or a ground in the system or in the field-windings.

If fuses blow out repeatedly, look for a heavy ground, or the fuse may be too small for the current required, or a short circuit may exist in the system.

If larger bulbs than standard or extra lamps are used, "discharge" indications will be higher. The generator may not be capable of charging the battery sufficiently to overcome the excess load, especially if there is insufficient day driving or excessive use of lamps at night, thereby permitting the battery to discharge more rapidly. Therefore, before adding more lights or appliances to the electric system, the amount of charge that the battery receives should be considered, especially during cold weather, when the starting motor is used more and the drain on the battery is greater. If the battery receives less than 10 to 15 amperes on an average, it will be necessary to have it charged at an outside source occasionally.

INSTRUCTION No. 43

TOOLS AND EQUIPMENT FOR THE AUTOMOTIVE ELECTRICAL REPAIR SHOP:[1] When to Test on the Car and on the Bench

TOOLS FOR ELECTRICAL WORK

This subject is a broad one. The amount of repair work to be done would determine the equipment in each case. Therefore only a few of the really necessary tools are mentioned here.

Pliers: An assortment of about 5″ long-nose, short-nose, and cutting pliers.

Screwdrivers: An assortment of about five or six, from very small ones to larger ones.

Chisels: Two or three sizes, and also a center punch for locking and unlocking pole screws in generator frames.

Files: One very fine jeweler's file for contact points, and a mill file and round for cleaning wires and battery terminals.

Thickness gauge to adjust contact-breaker points, cut-out, regular points, and spark plugs.

Flat wrenches: Various sizes; these can usually be purchased in sets or with tool kits.

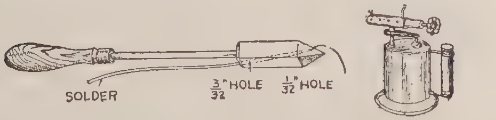

Fig. 2. Illustration at left shows a simple and handy method for soldering. The wire solder is inserted in a hole drilled in the soldering copper. A blowpipe torch is shown on the right.

Soldering irons: Three sizes, a pair each of ½ lb., 1 lb., and 2 lbs., for soldering coil terminals, wire connections in field coils, commutator wires, armature wires, terminals, cut-out and regulator points, etc.

Soldering flux for electrical work. Wire solder with flux inside is used extensively.

Blow-pipe torch: Very essential.

Tape: For taping inside of generators, etc. Where there is excessive heat, a tape called "English superfine twilled tape" is used. It is then coated with shellac and the alcohol is burned off by lighting with a match. **Friction tape** is the kind generally used for outside wire connections.

Shellac is used for armature work, connections, etc. See Index, "Shellac, how to mix and keep."

Note. When grounding a wire to the frame or to the engine, clean off all paint. Scrape thoroughly. After making the connection, coat with vaseline to keep the connection from corroding or rusting.

When soldering a wire into a lead terminal, such as a heavy storage battery connection, clean well. Add flux, and then melt the solder in the terminal by means of a torch. When hot, insert the wire and let cool; this is termed "sweating."

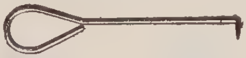

Fig. 3. This hook, 4″ long, is used for pulling brush springs.

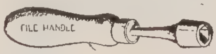

Fig. 4. Socket wrench for brush mechanism and coil nuts.

A brush lifter for lifting brush springs on generators and motors is shown in Fig. 3.

A socket wrench suitable for the nuts on brush-holders, coils, etc., is shown in Fig. 4. Several sizes can be made.

A fine-pointed scratch awl to dig out copper dust and material that will short-circuit between commutator segments is another necessary tool. A tool made on the order of that in Fig. 3 would be suitable for this work.

Tools for undercutting mica are explained farther on.

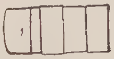

Fig. 5

Fig. 7

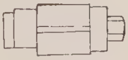

Fig. 6

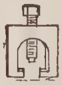

Fig. 8

Pole-piece double gauge: It often happens that it is necessary to put new field-coils in the generator or motor, owing to the fact that they become shorted or grounded. In order to do this, it is necessary that the polar diameter be exactly right—that is, the distance between the faces of the pole-pieces. This distance is measured with a pole-piece double gauge (Fig. 5); one end of the gauge being a "Go" indicator, and the other end a "No Go" indicator.

Pole-piece spreader: If the gauge does not slip into the polar diameter on one end and fails to go on the other, the dimension is wrong, Generally it is too small, and the pole-piece must be spread farther apart and the tool (Fig. 6, pole-piece spreader) is used for this work. There is no possible way for spreading the pole-pieces so as to get the proper clearance between the armature and the poles without this tool. In other words, the object of these tools is, first, to spread the pole-pieces and frame to give the right air gap between the armature and pole-pieces with tool No. 6, and then to measure these dimensions with No. 5, after the work has been done, to see that it is right and, if not, to correct it.

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[1] This subject does not include storage-battery equipment. This is fully treated under instruction on Storage Batteries.

A pinion puller, used for pulling the generator-drive pinions off the armature shaft (Ford), is shown in Fig. 7[1].

A bearing puller, used for pulling ball bearings off the armature shaft, is shown in Fig. 8.

Lathe for Electrical Repair Work[2]

A lathe suitable for turning down armature commutators, and for making motor repairs and electrical work in general, suitable also for cutting screws and other small work, such as tools, gauges, taps, etc., and for making battery and ignition parts, is shown in the illustration below.

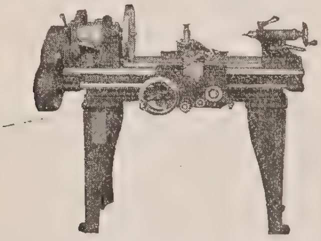

Fig. 9. This lathe has an 11″ swing, with 1¼″ swing over the bed, and is made in 3, 4, and 5-foot beds. It can also be supplied with milling attachments, and keyway cutting attachments.

Bench Lathe for Commutator Work[1]

The illustration below is that of the Onan Lathe, which can be placed on a work bench and operated from a line shaft.

With this lathe it is possible to true up and turn the commutator of any starter or generator armature. Without removing the armature from the lathe, it is possible to undercut the mica between the bars.

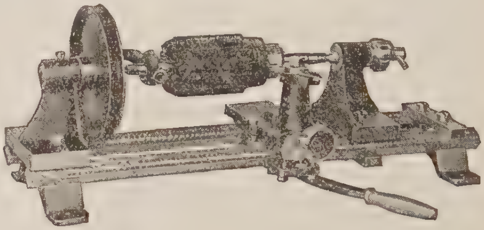

Fig. 10. The turning tool is controlled by a hand-wheel screw feed—the carriage is operated lengthwise by a drop-forged handle with suitable adjustment for every commutator. The lathe is built with 7″ swing; bed 22″ long; furnished with two Armstrong high-speed tool bits, lathe dog, suitable wrenches, etc., and is complete, ready for operating. It is driven from any available power. Shipping weight complete, 35 lbs.

The subjects of **commutator troubles, tests, and repairs,** and also **brush troubles** (fitting and seating brushes, etc.) are treated on pages 491 to 496.

INSTRUCTIONS FOR CLEANING REPAIR PARTS OF ELECTRICAL APPARATUS

The cleaning outfit should consist of three sheet-steel tanks of suitable size (preferably about 35 gallons), which are mounted in such a manner that the contents may be kept heated to the desired temperature; three stone jars of approximately 15 gallons capacity; and a sawdust box.

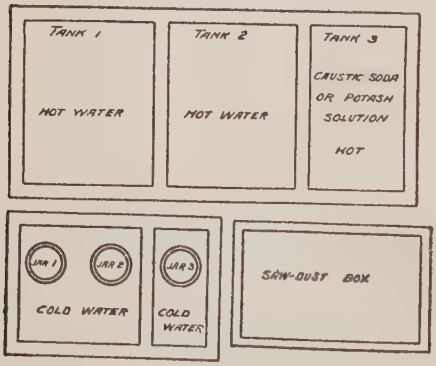

Fig. 11. Plan of arrangement of tanks and jars for cleaning.

Two of the steel tanks should be equipped with overflow pipes so that they can be kept about two-thirds full at all times. These will be spoken of as tank No. 1 and tank No. 2. They are used for clear, hot water for rinsing the apparatus after it has been cleaned. A supply of water should be available, so that this water can be kept as clear as possible.

The third tank does not need either a drain or overflow pipe, and should be used for the potash or caustic soda solution. This solution can be used for a long time without changing it by simply adding a small amount of potash or soda as the solution is found to be weakened. All three tanks are maintained at a temperature of from 180° to 212° Fahrenheit, or approximately at boiling point.

The three jars mentioned above are to be used for the acid solutions, and will be spoken of as jar No. 1, jar No. 2, and jar No. 3, respectively.

A wooden tank should be provided which is large enough to permit the three jars to be set in it, and also to carry a supply of clear, cold water. This tank should also be divided so that jars No. 1 and No. 2 are in one division, and jar No. 3 in the other. This is very important, as the work cannot be rinsed in the same cold-water bath after being immersed in these various solutions. The sketch shown in the figure will give an idea of the outfit.

Cleaning Solutions

The solutions recommended are as follows:

In tanks Nos. 1 and 2, place clear, hot water.

In tank No. 3, place a solution of potash or caustic soda, made by mixing 1 lb. of potash or caustic soda with one gallon of water.

Jar No. 1 is filled with a solution made up carefully from the following formula: four gallons of nitric acid; one gallon water; six gallons sulphuric acid. The water is placed in the jar first, the nitric acid is added slowly, and the sulphuric acid is poured in last. This order should be very strictly observed, as it is dangerous to attempt to mix up a solution of these acids in any other manner.

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[1] Can be secured for Ford work from Service Station Equipment Co., Chicago, Ill.

[2] Illustration is that of a new 11″ screw cutting lathe, especially adapted for electrical repair shops, manufactured by The South Bend Lathe Works, South Bend, Ind.

[1] Can be secured of A. L. Dyke, Electrical Department, Granite Bldg., St. Louis, Mo.

The solution in jar No. 2 is made up from the following formula: one gallon hydrochloric acid to three gallons of water.

Jar No. 3 is filled with the following solution: ½ lb. of cyanide to one gallon of water.

Tank No. 2 should be used for parts which have been in the potash solution, and for no other purpose; tank No. 1 is for general rinsing.

Cleaning Various Metals

Steel is boiled in the potash solution until the dirt is removed. This should take only a few minutes. It is then rinsed in tank No. 2, and dried in sawdust.

Cast iron is boiled in the potash solution until the dirt is removed, rinsed in tank No. 2, dipped in the acid solution in jar No. 2, rinsed in cold water, then rinsed in tank No. 1, and dried in sawdust.

Brass is boiled in the potash solution until the dirt is removed, rinsed in tank No. 2, dipped in the acid solution in jar No. 1, rinsed thoroughly in clear, cold water, dipped in the cyanide solution, rinsed in clear, cold water, rinsed in tank No. 1, dried in sawdust. **Copper** can be cleaned in the same manner.

Polished aluminum should first be thoroughly washed in benzine or gasoline, rinsed in tank No. 1, dipped in the acid solution in jar No. 1, rinsed thoroughly in clear, cold water, rinsed in tank No. 1, and dried in sawdust.

Plain aluminum (**polished**) should be dipped in the potash solution, rinsed in tank No. 2, dipped in jar No. 1, rinsed thoroughly in clear, cold water, rinsed in tank No. 1, and dried in sawdust.

Plain aluminum (**not polished**) should be dipped in the potash solution, rinsed in tank No. 2, dipped for a few seconds in the acid solution, rinsed in tank No. 2, dipped for a few seconds in the acid solution in jar No. 1, rinsed thoroughly in clear, cold water, rinsed in tank No. 1, and dried in sawdust.

It will be noticed that when the aluminum is put in the potash solution the metal is attacked or eaten away very rapidly. Care should therefore be taken not to leave the work in this solution any longer than is absolutely necessary. In cases where the work is covered with caked grease or has hard grease deposits on it, these pieces should first be washed in benzine or gasoline. Aluminum parts should never be washed in the potash or soda solution unless they can be put through the acid immediately after. The acid dip is used to neutralize the effects of the potash solution. Parts should be held in the acid solution for only a few seconds.

Paint on aluminum should be removed with a good varnish or paint remover, unless it is a very small quantity and the work is to go through the potash solution.

For enameled work, it is recommended that it be washed with soap and water, dried thoroughly, and then polished with a cloth dampened with Three-in-One or O'Cedar oil.

The methods described above are for solid metals only, and should not be used on any plated materials. Practically all Delco clips are tinned, and should be cleaned, therefore, in benzine or gasoline. All plated parts should be cleaned in benzine or gasoline.

A HOME-MADE ELECTRICAL TEST STAND

Tests for the internal parts of a generator, motor, cut-out, etc., will be explained in what follows. These tests might be termed "bench tests," and are usually for internal troubles. They are such tests as are necessary when the troubles are such that they cannot be remedied on the car, such as testing armatures, field windings, etc. Therefore some sort of testing apparatus is necessary in such cases.

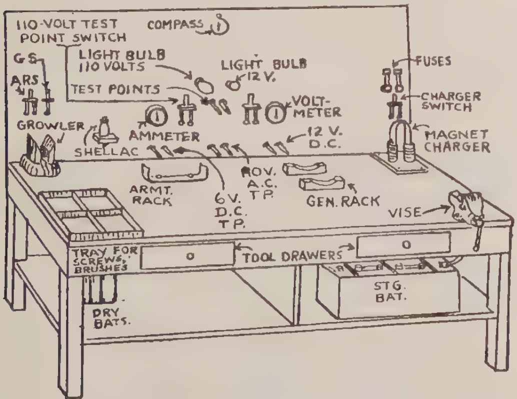

Fig. 12. Electrical test bench.

The bench (Fig. 12) can be made about 36″ high and about 5′ or 6′ long, with a lower shelf about 6″ or 7″ from the floor.

A vise, with jaws opening to about 8″, can be used to hold the generator when being driven by a motor. The vise is also handy for other work.

Note that the test leads, or cables, are of flexible wire and run through pulleys with weights (Fig. 12A), similar to pulleys and weights on a telephone switchboard, thus keeping the wires off the bench.

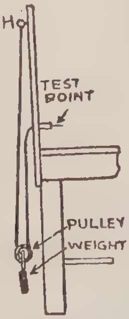

Fig. 12A

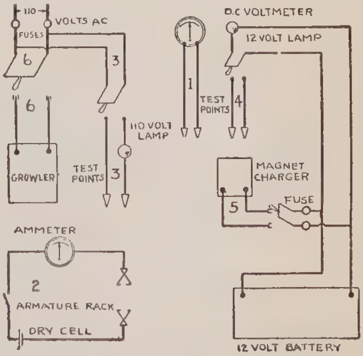

Fig. 12B

Necessary Parts and Wiring Circuits

Volt and ammeter: Model 280 Weston, combination volt and ammeter, as described on page 464, is recommended. This instrument is also fitted with a scale for cadmium tests of storage batteries (explained under the instruction on Storage Batteries).

If this represents too great an outlay of cash, then Model 301 Weston voltmeter and Model 301 Weston ammeter are recommended. These instruments are suitable for readings up to 30 amperes or 30 volts. See Index under "Weston voltmeters and ammeters."[1]

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[1] These instruments can be furnished by A. L. Dyke, Electrical Dept., St. Louis, Mo.

The wiring of the different circuits is shown in Fig. 12B, as follows:

(1) **Voltmeter** (Model 301 Weston) with test points.

(2) **Armature rack** for testing for open and short circuits in armature. Dry cells can be used. Note that the ammeter (Model 301 Weston) is in series with the circuit.

(3) **Test-light and points** (high voltage) for use with 110-volt circuit through a double pole switch. For testing for short and open circuits. The 110-volt lamp is in series. A tungsten carbon filament lamp of about 15 watts can be used.

(4) **Battery test-light and points** (low voltage) are connected with a storage battery. Note that in (4) a low-candle-power lamp is in series, the voltage being same as battery (6 or 12 volts).

(5) **Remagnetizer** for remagnetizing magnets. Connected with the battery by a double-pole switch and with fuses in the circuit.

(6) **Growler** connected with a 110-volt alternating-current line for testing armatures for open and short circuits (explained farther on).

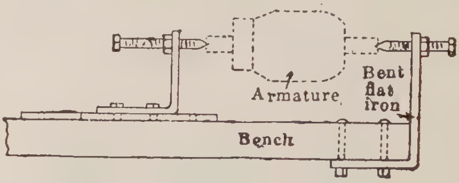
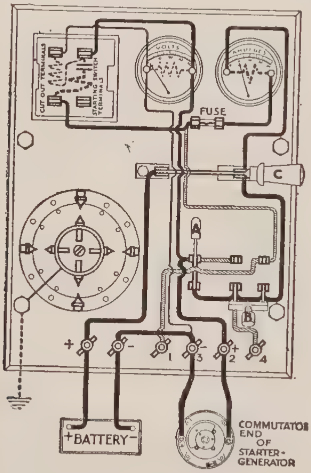


Fig. 13. Adjustable armature rack.

A method of making an adjustable armature rack is shown in Fig 13. This can be substituted for the one shown in Fig 12, as it is more serviceable, being adjustable.

NORTH EAST TEST-BOARD

The test-board shown in Fig 14 below, is that put out by the North East Electric Co., and supplied to their service stations for testing the N.E. motor-generators and ignition units. It is shown in order to give the reader an idea of its construction. In order clearly to understand it, first read the description of N.E. electric system installed on the Dodge.


CUT OUT TERMINALS
STARTING SWITCH TERMINALS
VOLTS
AMPERES
FUSE
C
A
B
+
-
1
3
-
+
2
4
+BATTERY-
COMMUTATOR END OF STARTER-GENERATOR

TYPE 8901-B, 8901-C OR 8901-D TEST BENCH

Fig. 14. Test-board.

With this test-board it is possible to operate the motor-generator and all its parts as if connected on the car. It will, of course, be necessary to drive the motor-generator by some means, when used as a generator. The different circuits are as follows:

Starting-motor circuit: From (+) of the battery, to and through switch (C), through heavy black wires to switch (A), to terminal of board (+2), to and through the motor, to (−3), to (−) of battery.

Note that the voltmeter is connected across this circuit at switch (A) (on the left), and by the small wire at (−3) terminal. The ammeter is not in the circuit, as it is open at the cut-out points of the cut-out (upper left corner).

Cut-out voltage circuit: Start from the motor-generator, which we will assume is being driven as a generator. Start at (+2) terminal of the board, which connects with the (+) main brush of the generator, to voltmeter (switch **A** is open), above the voltmeter to the cut-out, then through the fine wire voltage winding (small dotted lines), through the smaller or lighter wire to the voltmeter, to terminal (−3) of the board, to (−) main brush of the generator.

Note that the voltmeter is connected directly across this circuit and will indicate at what voltage and speed of the generator the cut-out points will close the charging circuit.

Generator charging circuit: We will assume the cut-out points closed at a certain speed of the generator when a certain voltage was reached (see page 370, giving these details of the N.E. Dodge motor-generator and cut-out). The charging circuit would then be from (+2), to the voltmeter, above the voltmeter to the cut-out, through the closed points of the cut-out, through the cut-out series winding, to the fuse, through the ammeter, through switch (C) (switch **A** is open), to the (+) terminal of the board, to the (+) terminal of the battery, out the (−) terminal of the battery, to the (−) terminal of the board, to the (−) terminal of the generator.

Note that the voltmeter is across the circuit, and the ammeter is in series with the circuit. Thus the voltage and amperage generated at various speeds of the generator can be observed. For instance, at maximum speed, the generator should show a certain amperage and voltage and the third-brush regulation can be set accordingly.

At a certain low speed the cut-out points should open at a certain voltage when a certain amperage discharges back through the series winding of the cut-out (see page 370 for these data). All of this can be observed with the voltmeter and ammeter connected with the circuits.

The device on the left of Fig. 14 is for testing the ignition. See also, pages 228, 226, 371, 230.

HOME-MADE METHODS OF DRIVING A GENERATOR FOR TESTING

Various methods are used for driving a generator so cut-out and output of the generator can be tested.

We suggest two simplified methods, as follows:

1. By using a ½ h.p. electric motor,[1] (Fig. 15), with a speed of about 1,800 r.p.m.

Cone pulleys can be placed on the motor (Fig. 15), to drive the generator, on which there are two sizes of cone pulleys. The cone pulley on the motor, of which there are five sizes, and also the one on the generator, of two sizes, can be made in one piece of hard maple or metal, by turning them up on a lathe. A ½″ round belt is used to transmit the power.

Sizes of motor pulleys: 2″, 3″, 4¾″, 6″ and 8″.

Sizes of generator pulleys: 6″ and 8″.

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[1] A ½ h.p., 110-volt, direct-current motor is priced at $65.00 and can be obtained of A. L. Dyke, St. Louis. The cone pulleys we do not furnish. The General Electric Co., Ft. Wayne, Ind., manufactures a type "RSA," ½ h.p. motor suitable for alternating current, and a type "SD" for direct current.

The variations of speed of the generator which can be obtained with the pulleys of the sizes as figured out are as follows:

8″ motor pulley to 6″ gen. = 2,400 r.p.m.
6″ motor pulley to 6″ gen. = 1,800 r.p.m.
4¾″ motor pulley to 6″ gen. = 1,425 r.p.m.
3″ motor pulley to 8″ gen. = 675 r.p.m.
2″ motor pulley to 8″ gen. = 450 r.p.m.

On different generators there are different sizes of shafts. Some are tapered, but most shafts on later generators are straight keyed shafts, and average about 1½″ to 2″ in length. The average diameter varies. The Delco is 11/16″, the Westinghouse ⅝″ and ¾″, the Remy ⅝″ and ¾″. Therefore bronze bushings should be provided for the generator pulley which can be removed, and in time a valuable collection will be at hand ready to use on subsequent tests.

Some sort of sliding base (V, Fig 15), with a screw (S) to adjust the tension of the ½″ round belt, should be provided. A clamp, similar to a woodworker's clamp, can be used to hold the generator to the base.

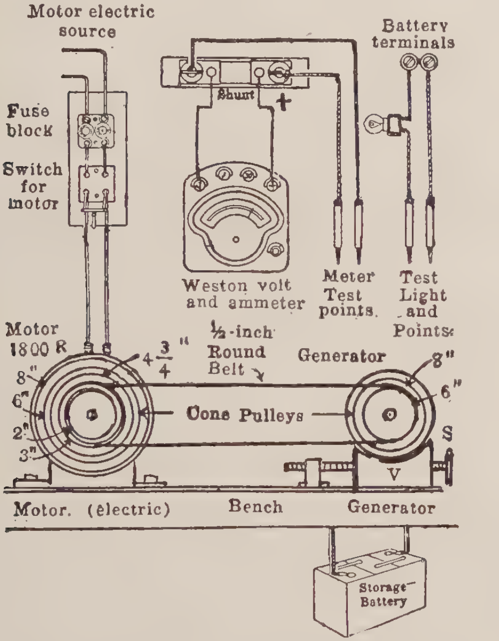

Fig. 15. Method suggested for rigging up a motor for driving a generator on a test.

To figure the speed and size of pulleys to use for other speeds than those given, see Index under "Speed of pulleys, how to figure."

2. **Another method of driving the generator** (Fig. 16) **is by means of a line shaft** (300 r.p.m.). Use a 4″ face pulley, 18″ diameter. This will give a speed to the countershaft of 1,800 r.p.m. if a 3″ diameter 2″ face pulley is used on the countershaft. Note that two pulleys are used on the countershaft, one with a 2″ face by 3″ diameter, which is tight to the shaft; the other is of the same size, but is loose, thus permitting the 2″ flat belt to shift from one to the other, to start or stop the line countershaft.

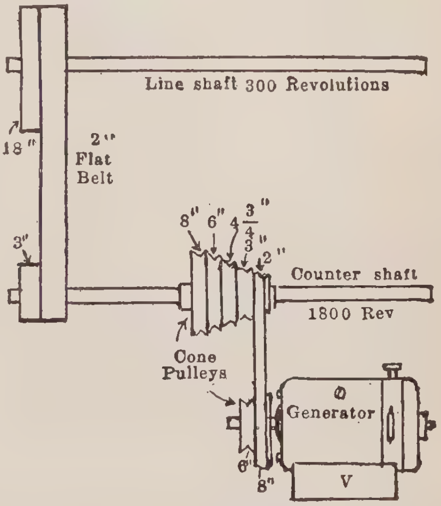

Fig. 16. One method of driving a generator from a line shaft.

As we have the same number of revolutions of the countershaft in Fig. 16, as we have of the motor in Fig 15, we can therefore use the same diameter of cone pulleys.

Other methods can be employed. These are suggestions only.

See page 507 for: "A modern electric testing stand."

HOW TO START TO MAKE ELECTRIC TESTS AND HOW TO LOCATE ELECTRICAL INFORMATION IN THIS BOOK

The greatest difficulty that the electrical repairman experiences in starting into this line of work is to know just how to start and where to obtain parts, etc. The object of these next few pages is to acquaint him with the details of making tests on the **car** and on the **bench**, and to furnish suggestions as to how and where he may obtain data and information. **Refer to the Index often.**

See **Digest of Troubles,** page 454, also pages 512 to 518, for locating other motor and generator troubles.

It will be noted that reference is frequently made to the fact that A. L. Dyke, Electrical Dept., St. Louis, Mo., is in a position to furnish testing instruments and books of data, etc., and also to do electrical repair work. This service is not so much conducted for profit as it is to assist the student in getting his initial start. The parts we purchase for filling orders are purchased of the local branches of the different manufacturers. Later on, after the student is established and actively in business, he can no doubt purchase direct.

The books and instruments that we recommend are those we know are needed. It is impossible to give all data in this one book; hence the necessity of purchasing a few others, such as a Wiring Manual and Service Manuals. See advertisements in the back of the book.

When a car owner drives to your shop and tells you that his generator fails to generate current, or that the generator fails to charge properly, or that the lights burn dim, or that the battery constantly runs down, you must, like a good physician, make careful note of the troubles and then in your own mind **analyze the symptoms** and formulate a plan for your tests and diagnosis of the case.

The first procedure is to endeavor to **make tests on the car** without removing any of the parts. These tests are given under various headings in this book. Before any tests are made, however, turn to the "Digest of Troubles" and find the probable cause, and figure out in your mind which one of the causes would most likely apply to the case. Sometimes troubles are attributed to the electric system, when in reality they are engine troubles, or ignition troubles.

Then make the tests, first one, then another, thus eliminating one cause after another, until the real cause is finally found. This is termed the "process of elimination," and is a mighty good term to memorize and keep in mind. See "Digest of Troubles." The good electrical repairman is classed as a very intelligent man, just as a good physician is, and he must study and be able to concentrate in order to do his work intelligently.

If, after making the tests, it is found that the internal parts are defective, such as a defective ignition coil, generator, cut-out, or battery, then it is time to remove the part to the bench and to make the tests.

Procedure of Tests, and Diagnosis

When starting to locate troubles in the electrical system of a car, first divide the electrical system into parts, as explained on pages 448, 455.

If the trouble is in the lighting circuit, see page 482.

The large blue print Wiring Manual is very necessary in tracing circuits.

If the trouble is in the ignition system or circuit, determine the make of the system, see Index, and study up on that system. Refer to the Index for testing for ignition troubles.

If the trouble is in the storage battery, see the instructions on Storage Battery, and the "Digest of Troubles."

For battery work, we recommend the Cadmium Test Outfit, and also a book entitled, "The Automobile Storage Battery," price $5.00.

If the trouble is in the generator or cut-out, turn to the Index and the "Digest of Troubles."

Starting Motor

If the trouble is in the starting motor, refer to the "Digest of Troubles" page 454, and the Index on "Starting motors." The troubles with a starting motor are either **electrical** or **mechanical.** See also, pages 455, 517 and 486 to 490.

Mechanical troubles with the starting motor that are most common are as follows:

1. **Worn bearings:** Many starters have plain bronze bearings which become worn from lack of oil and long service. Thus when heavy charges of current of 200 to 300 amperes pass through the starter, the armature revolving is forcibly drawn to the pole pieces, as the air gap is very slight, thus damaging the armature. Worn bearings can be replaced if you are equipped with a lathe for turning up and boring out a new bushing.

The end plate can be returned to the manufacturer or to A. L. Dyke, Electrical Dept., St. Louis, Mo., and an end plate with bushing fitted will be supplied.

2. **The starter armature shaft is sometimes bent or twisted out of true,** as a result of back-firing of the engine and of hard strains. To test, place in lathe centers and straighten with a forked bar or otherwise. This trouble is more common with starters than with generators. See also, pages 455, 486, 489, 320.

Electrical troubles, most common with the starting motor are described below. But before making any tests of the starting motor electric system, the engine should be tested first to see if it is stiff or hard to crank. The next test is of the battery.

1. **Examine battery:** See if the electrolyte is above the top of the plates. If not, the battery is probably discharged, or nearly so. If the electrolyte covers the top of the plates, then test the electrolyte with a hydrometer to see if it is charged.

If the hydrometer shows 1.200 s.g., or less, it indicates that the battery is fairly well discharged. If it shows 1.225, it is fairly well charged, but not fully charged. The hydrometer should show 1.250 to 1.300. When testing the battery with a hydrometer, the temperature of the electrolyte should be about 70°, otherwise the readings will not be correct. See Index under "Testing battery, temperature."

2. **Loose or poor connections:** These are usually at the ground connection of the battery or on the starter switch. The starting switch blades may be bent or burned and corroded. These connections as well as all internal connections should be clean and tight.

3. **Poor brush contact.** Usually the result of lack of spring tension or worn brushes. Carbon brushes have a tendency to stick in the holders, especially if gummed with carbon dust and oil. Gauze brushes are sometimes used on starters, and should seat perfectly. See Index under "Brushes, seating of."

4. **Rough commutator:** This will necessitate removing the armature and turning the commutator down on a lathe (see Index under "Commutators"). Do not undercut mica on the starting-motor commutator.

5. **Soldered armature coil terminals loose from commutator.** Resolder. Loose terminals are often the result of heat produced by excessive current; also of poor soldering in the first instance. See Index under "Commutators."

The average speed of a starting motor, fitted with a Bendix drive, on a "free running test," or no load is: 3,725 r.p.m. minimum and 4,950 r.p.m. maximum. The amperage is about 70. Under load, the speed varies 1,000 to 2,300 with 8 lb. pull on a 6″ pulley. The average amperage of starters when starting is given on page 471. This varies, however, as starters are designed in different sizes to start different sizes of engines. See page 489, giving an example of how starting motors are tested according to data given in the "Service Manuals."

Generator

The generator circuit is divided into parts as follows:

1. Generator.
2. Generator regulation system.
3. Cut-out.
4. Storage battery.
5. Wiring system connecting the above.

Generators are usually shunt-wound, and there are four different regulation methods in general use:

1. Third-brush (inherent constant current) regulated.
2. Voltage regulated; where resistance is inserted in the shunt-field winding by an electromagnetic regulation system (see Index under "Voltage regulation").
3. Current regulated; where resistance is cut into the shunt-field winding by an electromagnet (see Index under "Current regulation, electromagnetic").
4. Compound winding with a "differential" action (see Index).

The third-brush regulation is used most. The output of the generator can be **increased** by moving the third brush in the direction of the rotation of the armature, or **decreased** by moving it in the opposite direction. See Index under "Adjusting third brush."

The principle of the third-brush regulation is explained on pages 357, 361. After an approximate speed of about 1,800 r.p.m. is reached, the output begins to drop off, for the reason explained under "Armature reaction." See Index. It is important to see that the third brush always makes good contact with the commutator.

The output of the generator with the voltage or current-regulation method, using an electromagnetic principle, can be increased or decreased by decreasing or increasing the spring tension. See Index under "Adjusting regulators, electromagnetic."

A compound-wound generator, which is an inherent method of regulation, with constant current, has the two windings on fields opposing each other at high speeds of the generator, such as the "bucking-series" winding, and the "cumulative-compound" winding, explained under this subject; see Index.

With the compound-wound generator, not using a third-brush or electromagnetic principle of regulation, but depending upon the differential action of the two windings, there is no provision made for increasing or decreasing the output. Sometimes the series winding can be shortened, or lengthened, as explained on page 356.

The cut-out opens and closes the circuit between the generator and battery, the function of which is explained under this heading; see Index, generally, and also under "Testing and adjusting cut-out."

Generator Troubles

Conditions which necessitate tests of a generator are as follows:

1. When the generator fails to charge the battery.
2. When the generator output is low or excessive.
3. When the ammeter fails to indicate properly.
4. When the ammeter is not steady.

There are many other conditions but those just mentioned are the usual or most common causes for the necessity of testing. See also "Digest of Troubles."

First, test the generator on the car.

Before removing the generator, study out the internal circuits of the system by referring to your "Wiring Manual" and "Service Manual."

Then make the following tests while the generator is on the car:

1. **There is a fuse which is sometimes placed in the shunt-field circuit** of the generator. See if it is making good contact and is not blown.
2. **Examine the brushes** and see if they are making good contact.
3. **Examine the cut-out points** and see if they close at about 650 to 1,000 r.p.m. of the generator, and if they open at lower speeds. A "Service Manual," which gives all these data for all generators is advised. For cut-out troubles, see Index.
4. **See that all connections are tight** from the generator field connection of the brushes and from the generator to the cut-out, to the ground connection of the generator and the battery. The "Wiring Manual" will assist you in tracing.
5. **Examine the commutator—see whether it has thrown solder,** that is, whether the solder which binds the ends of armature windings to the commutator bars is loosened. If so, the generator must be removed and resoldered.
6. Examine the commutator and see whether it is rough or whether mica protrudes. If so, there will be sparking at the brushes. This will require removal of the generator, so that the commutator can be turned down and the mica undercut and the brushes made to fit properly. See Index under "Undercutting mica."
7. **Place your testing ammeter in the generator circuit,** as explained on page 470, at test A1, to see if the dash ammeter is reading properly. Then run the engine and check the readings.
8. **If the generator output is lower or higher at maximum speed** than the "Service Manuals" give for the type of generator being tested, then increase or decrease the output. See Index under "Regulation methods." See also "Digest of Troubles."

Generator Bench Test

Conditions which necessitate removal of the generator from the car are as follows:

1. **If no current is indicated** by the ammeter tests.
2. **If the ammeter needle is not steady.**
3. **If the generator will not produce its proper output** after adjusting the third brush or other regulation method. Failure of the third brush to seat properly is the cause of many generators not giving their proper output, or even giving none at all, or intermittently.
4. **If there is excessive sparking at the brushes,** and it cannot be remedied by proper brush adjustment.
5. **If the commutator is rough** and mica protrudes.
6. **If there is noise.**

After removal of the generator to the bench, there are four methods of testing:

1. By motoring the generator.
2. By examining the commutator.
3. By driving the generator.
4. By testing the armature and field windings.

Testing Generator by Motoring It

Connect the generator with a fully charged battery: It makes no difference which wire is connected, as most generators will automatically reverse their polarity. If, however, you know the (+) terminal of the generator, use it. The motoring test will determine if trouble is in the armature or the field.

Running the generator as a motor is a quick method of determining the general condition, and is easily and quickly tested out. See also page 491.

An ammeter with the 30-ampere shunt is connected in the line; the ammeter must be connected through the (+) pole of the meter to (+) of the circuit. See page 465 for description of the Weston meter, which we assume is being used for the tests.

The cut-out is not in the circuit in this test. If, however, the cut-out is in the generator, close the points, otherwise the generator will not motor. The generator should run in the driven direction, unless the field connections are wrong. In this case change the internal wires at the brushes.

If the generator fails to motor, the trouble is probably due to an open field circuit or to absence of brush contact.

If the generator motors, it should do so without undue sparking at the brushes or any unusual noise.

It should draw approximately from 3 to 5 amperes. On the Ford, the amperage is 4, and on a N.E. motor-generator (model G), it is about 5 amperes with the 12-volt battery. If it is over 8 amperes, then there is evidence of a short-circuited armature, providing the machine is free of mechanical defects.

The "Service Manuals" give these data for all generators.

The average speed of a generator when being motored is 400 r.p.m. with a voltage or relay type of regulation, and 350 r.p.m. with a third-brush type of regulation.

If the generator draws too much current when being motored, the trouble is very probably to be found in the armature.

If the needle of the ammeter vibrates, there is probably a short circuit.

The armature should then be removed, and placed in the stand (Fig. 13, page 476). Separate tests should then be made. See Index for "Armature tests."

Testing Generator by Examining Commutator

Eighty per cent of generator troubles are indicated by the condition of the commutator. Remove the cover (Fig. 17), and examine for the following:

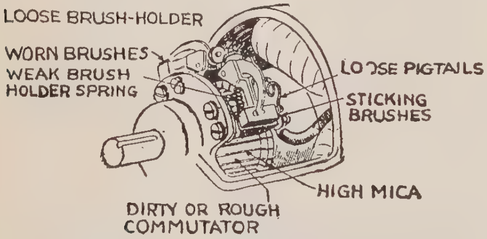

Fig. 17. Commutator and brush inspection.

1. **If the commutator is burned black** over its entire surface, it is usually due to grease, or carbon dust from the brushes. If caused by carbon dust, the commutator is probably rough, and should either be turned down on a lathe or sanded in (explained under "Commutator troubles"; see Index). It is best to turn the commutator down, but sanding will do in an emergency. Blow carbon dust out of the generator housing with air pressure.
2. **Improper brush-spring pressure,** which permits arcing, will also produce a rough commutator.
3. **If there is an open circuit in the armature,** there will in all probability be a flat place on the commutator segment or bar, the result of a heavy spark at the brush occurring on the open commutator bar when the brush makes contact with it. The cause of such an open circuit in the armature coil is usually a loose connection where it is soldered to the commutator bar. Examine all of the connections carefully.

   Sometimes troubles of this nature occur only when the armature is revolving, which causes the wire to fly loose, through centrifugal action of rotation. Hence the connections must be carefully examined.
4. **If the mica protrudes above the commutator bars,** or if the brushes or brush holders are loose, or if the brushes are worn, this indicates that there has been excessive sparking at the brushes. These parts should be examined carefully and remedied. See Index under "Commutator and brush troubles."

Testing Generator on the Bench by Driving It

Various methods are used for driving a generator so that the cut-out and output of the generator can be tested. A home-made outfit is shown on page 477. See also Index under "Electrical testing outfit."

Additional Pointers

If a generator fails to deliver its proper output, or if the cut-out fails to operate, the first step is to find out why. If the tests suggested above determine the fact that the generator armature coils, or the field coils, or the cut-out windings are defective, it does not pay to attempt to repair them, as armature winding is a trade learned only by careful study and long experience. It is best to return the part to the factory,[1] and order a new part. In many instances an allowance will be made on defective armatures toward a new one.

The electrical repairman can, however, do such work as testing, cleaning, and sanding the commutator, under-cut mica, fit or seat and adjust brushes, solder loose wires at commutator segments, etc., as explained under these different subjects.

He can also adjust and regulate the output of generators. Most generators now have the third-brush regulation. It is therefore a simple matter to increase or decrease the output by moving the third brush, after determining what make of electric system is used, and then referring to the Index of this book, or to the Service Manuals.

A Data Book or Service Manual giving the speed of different generators at which the cut-out should cut in and cut out, the amperage at various speeds, etc., is very necessary.

Bearings and Brushes

Bearings: Many generators had ball and roller bearings. Delco still uses ball and roller bearings. Most of the other generators and starters now use plain bronze bearings. You can fit new bearings if you are equipped with a lathe and can do the work accurately. It is advisable to send the end plate to the factory, and obtain a new bearing fitted into the end plate.

If the shaft is worn, then it is best to true it up on a lathe and to fit new bearing bushings and ream them out, so as to have the shaft correspond with the bore of the bearing bushing, or else to send the entire generator or motor to the factory.

Brushes: Generators usually use carbon brushes copper plated. Starting motors use a composition of graphite and carbon or some similar substance which is softer than generator brushes. Some starting motors use gauze brushes. See Index under "Brushes." It is best to obtain brushes as recommended by the manufacturer.

On page 494 we advise how to sand brushes. On some generators this is not possible, as the brush arm is too short. In this case, the brush should be placed on the generator, the generator should be "motored," and thus the high spots on the brushes will show. Scrape high spots of brushes down.

Good brush contact is very essential on both generator and starter.

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[1] A. L. Dyke, Electrical Dept., St. Louis, Mo., is in a position to supply these parts and advise you where the nearest representative of the different electric companies is located. This service on our part is rendered not so much for the small profit, as for the benefit of our readers, in order to assist them in getting started.

Oil the generator and starting-motor bearings often. **Don't oil or grease** the commutator.

Parts to Carry in Stock

If you propose to do electrical repair work, then in addition to testing instruments and tools, you should carry parts in stock, such as:

1. Brushes.
2. Lamp bulbs.
3. Fuses (see Fig. 18).
4. Ignition coils: ignition resistance units, condensers, contact-breaker arms for Atwater-Kent, Delco, Remy, Westinghouse, and Connecticut ignition systems.
5. Ignition cable.
6. Primary and lighting wire.
7. Ignition switch keys.

Some of the parts which should be carried in stock by the electrical repairman are illustrated. **Addresses of some of the manufacturers** are: Chicago Fuse Mfg. Co., Chicago ("Union" fuses); Delco Electrical Laboratories, Dayton, Ohio; Remy Electric Co., Anderson, Ind.; Westinghouse Electric Co., Pittsburgh, Pa. (motors, generators, and ignition); Connecticut Tel. and Elect. Co., Meriden, Conn.; Atwater-Kent Co., Philadelphia, Pa. (ignition); K.W. Ignition Co., Cleveland, Ohio (magnetos, coil units).

Ignition replacement parts can be secured of Jefferson Elect. Mfg. Co., 426 So. Green St., Chicago, Ill.; New York Coil Co., 338 Pearl St., New York, N.Y.

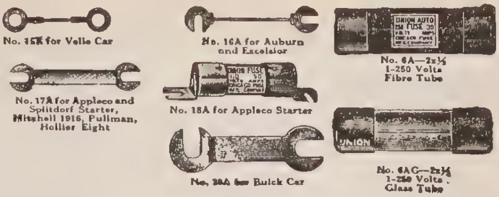
No. 15K for Velie Car
No. 16A for Auburn and Excelsior
UNION AUTO FUSE 30
No. 6A—2x½ 1-250 Volts Fibre Tube
No. 17A for Appleco and Splitdorf Starter, Mitchell 1916, Pullman, Hollier Eight
UNION FUSE 30
No. 18A for Appleco Starter
No. 20A for Buick Car
UNION
No. 6AG—2x½ 1-250 Volts Glass Tube

Fig. 18. Different types of fuses.

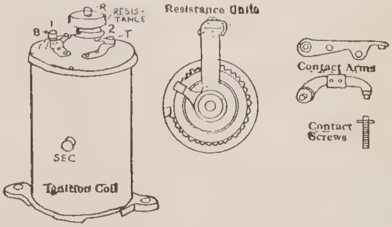

Fig. 19 (left): ignition coils; (center) ignition resistance units; (right) contact breaker points.

It is advisable to find out the make of cars in your vicinity and the electric system used on the cars, in order to have appropriate parts on hand. By referring to "Specifications of leading automobiles," you will find the specific make of electric system listed with each make of car.

INSTRUCTION No. 44

DIFFERENT METHODS FOR TESTING THE ELECTRICAL PARTS OF A CAR: Lighting Tests; Armature Tests; Field Tests; Generator Tests; Starting Motor Tests; Cut-Out Tests

This instruction will deal with the subject of various methods of making tests. For instance, grounds are usually tested with the test light, although a meter can be used.

Armature and field ground tests are also usually tested with a test light, but a meter can also be used.

Armature tests for open circuits and short circuits are usually tested with a meter, using the millivolt drop test.

An ammeter of a 30-range capacity can be used for testing generator armatures for short circuits and open circuits, as explained under the F. B. test-stand tests.

The "growler" is best for testing motor armatures, owing to the very low resistance of the motor coils. Torque tests and free-running tests can also be made of the motor, but the object of a "free-running test" of a motor, or a "torque test," is to find out if the trouble is in the field or in the armature.

Likewise, the "motoring test of a generator" is for the purpose of localizing the trouble: to discover whether it is in the armature or the fields, and whether it is an open circuit, a short circuit, or a ground.

LIGHTING TROUBLES

Lighting troubles are attributed to one or more of the following causes:

1. Poor connections.
2. Open circuits or broken connections.
3. Grounds.
4. Short circuits.
5. Weak battery.

Poor connections and open circuits may exist at any point on the lighting circuit, from the battery to the lamp bulb.

Grounds and short circuits may exist at any point on the lighting circuit.

Lighting Trouble Indications

If lamps do not light up:

1. Examine the fuse block for blown fuses. **If the fuse is blown,** do not replace it immediately, but look over the wiring for an accidental ground or short circuit. If the fuse in the headlight circuit blows, turn off the headlight switch until the trouble is located and removed. In looking for grounds, any abrasion of the insulation on the wire, or a metallic contact between the wires or between the current-carrying part of the wiring devices and the metal of the car should be watched for.

   When the trouble has been located and corrected, then replace the blown fuse with another of the same capacity, making sure that it is of the proper size.

2. **If the fuse is not blown,** look for burned-out lamp bulbs, open circuits, loose contacts; or the lighting wire to the battery may be loose, or disconnected, or the battery may be run down, or discharged.

3. **In case the battery is discharged,** recharge it immediately, and if possible, give it a gassing charge. See Index under "Hydrometer test."

If lamps in one circuit do not burn:

1. The lamp may be burned out. Try another lamp in the same socket.

2. If the fuse is thought to be blown, try the same fuse in another circuit. If the fuse is blown do not replace it immediately, but look over the wiring for a ground or short circuit.

   If the trouble cannot be located immediately, turn off the switch on the damaged circuit until the trouble has been located.

   If the trouble is in a particular lamp socket, disconnect the attachment plug from this socket until the trouble can be removed, and see that the removed attachment plug does not dangle in such a way as to make a short circuit on the metal of the car.

3. There may be an open circuit or a broken connection in the wiring. Examine the places where the connections are made on that particular circuit.

4. In case the trouble is due to a short circuit on some particluar lamp socket, disconnect the attachment plug leading to this socket until the difficulty can be remedied.

If none of the lamps will burn—and no spark is obtained for ignition:

1. Terminals of the battery may be disconnected or corroded, so that they do not make good contact.
2. Ground wire, from the battery to frame of car, may be disconnected or broken.

If the ignition is all right, the trouble may be due to:

1a. The lead wire from the switch to the lights may be disconnected or broken.

1b. The lead from the generator terminal to the fuse box may be disconnected or broken, or the fuses blown, owing to a short circuit.

1c. The lamps may be burned out.

1d. The battery may be run down.

If there are no lights or dim lights, with the engine running: There is a group of troubles which can be classified under the general head of open circuits. There are seven of these which are prominent:

1. The generator terminal or brush connections may be loose, or may make poor contact. If, how-

ever, the generator is charging the battery—which is indicated by the ammeter showing "charge"—then the trouble is not in the generator.

2. The wire connections to the switch may be defective.

3. The wire connections to the lamp connector terminals may be defective.

4. Lamp-socket terminal may be loose.

5. Bulbs may be burned out.

6. Bulb bases may be out of contact with lamp sockets.

7. There may be broken wires, especially where connections are made to the lamp sockets.

If lamps go out for an instant only: When the lamps in one circuit act this way, there is probably a loose connection on the circuit so affected. It may be in any part of the system, and the first place to look is at the fuse connection.

A slight short circuit which occurs at intermittent periods would also cause this trouble, but in this instance, a higher "discharge" rate will be shown on the "ammeter."

If lamps flicker: This trouble is attributable to loose connections, usually at the lamp socket or fuse.

It can also be caused by bad contact or an intermittent ground. For instance, a contact might be just loose enough so that vibration would cause the circuit to be made and broken repeatedly.

A grounded wire would cause this trouble by alternately making and breaking the ground connection. Every time the ground is made, the light goes out because the current flows through the ground instead of through the lamp.

Obviously the trouble may be roughly located by noting whether all the lamps flicker, or only one. If all do, then the test should start at the ammeter; then at the switch; then at the circuit. If only one light flickers, then the trouble is in this individual circuit.

If lamps flicker and the ammeter is unsteady: This may be due to a loose connection in the light wires; a loose connection between battery and generator; a loose contact at lamp bulb; or, finally, to an exposed wire touching the frame intermittently, causing a short circuit.

If one lamp burns dim: Change the bulb; it may be old and blackened, or partially short-circuited in the filament. If the same lamp is still dim, test the wiring to the lamp. Examine the lamp socket. A great many of these troubles are found in poor connections in the lamp socket, or in a slight ground in this circuit.

If all lights burn dim: The usual trouble in this case is loose or slightly grounded connections, or poor or corroded connection at the battery. More likely the battery simply has not had sufficient charging. This can be determined by watching whether the lights brighten up when the engine is speeded up, at which time the generator is supplying current.

If the wiring is all right, run as much as possible with lights off, so that the dynamo will charge the battery at a higher rate. Or it may be necessary to set the charging rate of the generator higher.

If the battery continues to run down, examine the cut-out. If the cut-out is in good order, then test battery with switch off, for a "ground" or slight "short circuit" in the sockets, or switch.

If there is no ground, then test the battery electrolyte, and also each cell separately, as directed in the instructions given under "Storage Battery."

Lamps may also be old and blackened, in which case, try new bulbs.

If the lamps are bright with the engine speeded up, and dim when the engine slows down or is idle:

In this case the battery is discharged, because, when the engine is speeded up, the generator current is used, and if the lights brighten up, then it is clear that if the engine slows down and the battery supplies current and the lights are dim, the battery itself is weak. Loose or poor contact of the battery terminals might also cause this trouble, or probably the **battery terminal is sulphated.**

If possible, have the battery charged at once from an outside source. If this cannot be done, endeavor to run with fewer lamps than normal turned on for a few days, or until the battery voltage picks up again.

If the lights grow dim when the engine is speeded up, the wires are probably reversed at the generator.

If lamps burn very dimly when the starting pedal is used: The battery is weak, and probably almost discharged; or the battery is injured in one or more cells, probably due to lack of water; or battery terminals or ground wire is not tight.

If lamps will not light, but the starter cranks the engine: Lamps are burned out, or the filament is broken; or the system is short-circuited, or there is an open circuit at the fuse or the switch or the wiring.

If lamps seem to burn brightly, but fail to illuminate the road sufficiently: Lamps are out of focus. The rays of light are directed too far upward. (See "Focusing of lamps and reflectors.")

If lamps are too bright: The regulation of the generator is evidently set for a higher voltage. Use lamps of higher voltage.

If lamps burn out often: This is due either to a poor grade of lamps, or to an improper voltage of lamps; also to **sulphated battery terminals,** or to loose battery connections.

If fuses blow repeatedly: Lamps are defective—probably with short circuits. First try new bulbs. The fuse may not be of large enough capacity.

TESTING THE LIGHTING CIRCUIT FOR OPEN CIRCUITS, GROUNDS, AND SHORT CIRCUITS WITH A TEST LIGHT

In this example we shall use a test lamp and test points from a 110-volt lighting circuit of either direct or alternating current. A voltmeter could be used.

A point to remember, when testing any circuit, is that a **complete circuit is necessary** in order to have the electric current do its work.

When using a test light, it is advisable occasionally to bring both test points together or to touch one with the other, to make sure that the test light is still in working order, as very often the filament of a lamp breaks, owing to the rough nature of test work. When this happens, one is led to erroneous conclusions.

It is a good plan to inclose the test lamp in a wire cage to prevent excess vibration to the lamp bulb and also to avoid injury to the small glass tip on the end of the lamp bulb.

Wiring-System Troubles

Wiring troubles are:

1. All lights out; none burn.
2. Only one branch of lights burns.

Cause of 1: Fuses blown; battery discharged or disconnected; poor connection at battery terminal or ground wire; open circuit; short circuit. Test the battery; examine connections.

Causes of 2: Open circuit; short circuit or ground in this branch. Test as suggested below. May be due to burned-out lamp bulbs or poor contact at lamp sockets.

A single-unit Delco electric system, using a single-wire grounded return wiring circuit is shown in Fig. 1 as an example. The tests however will apply to many of the other systems. The idea here is to point out how to make the tests for the different external circuits.

To Test for Grounds

See test No. 4; place one of the test points (T) on the frame of the car and the other test point (T1) on the negative (—) terminal of the battery (A).

If the test lamp lights, then a ground is indicated, and will likely be on the switch or in the motor windings (if all the switch buttons are pushed in).

Note. **If the battery box becomes badly acid soaked, it may cause the lamp to light,** owing to grounding through the box. Disconnect the (+) terminal of the battery from the wiring system, and test as before. If the lamp lights now, the battery **box should be insulated** from the frame of the car with a piece of dry wood and the battery should be cleaned and dried, and the battery box should be painted. See Index under "Battery box acid-soaked."

4. Now with one of the points still grounded to the frame of the car, touch with the other point different terminals of the combination switch.

If the lamp lights, then a ground is indicated. It should be found and removed.

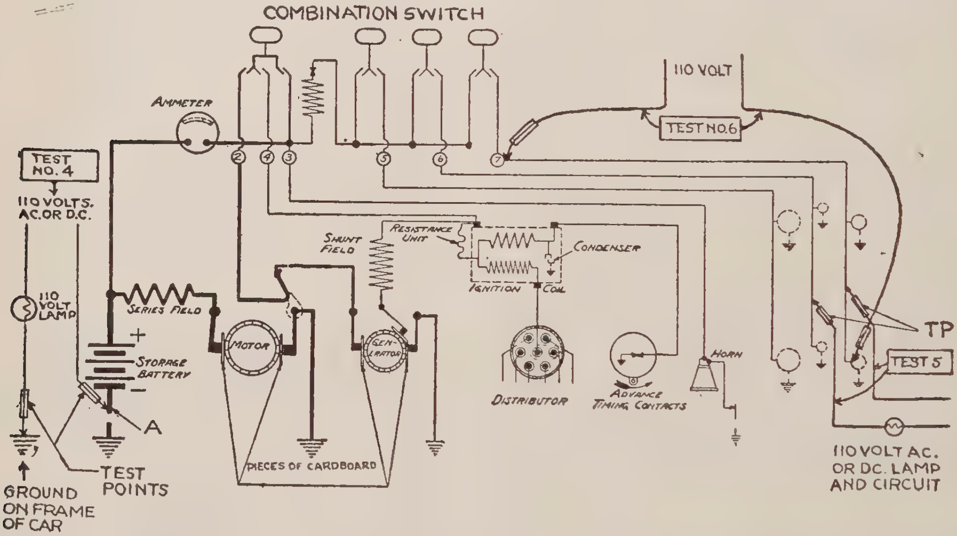

Fig. 1. Diagram explaining how to use a test light for testing for open circuits, grounds, and short circuits in the lighting circuit of a car or wiring system.

Most of the troubles in the wiring system are grounds, short circuits, and open circuits.

It will be observed that certain portions of this circuit are intentionally grounded to the frame of the car. The battery terminal, the lamp return wires, one motor and one generator brush, one of the timer contacts, one terminal of the horn push-button, and one terminal of the condenser in the coil are grounded.

When Testing for Grounds

1. Remove these grounded connections by disconnecting the battery terminal (negative [—] in this instance) from the battery which is grounded to the frame of the car, and remove all lamp bulbs.

2. Place a piece of cardboard between the commutator and the brushes of the motor and the generator (third brush also). See Fig. 1.

3. Disconnect the lead wire from the horn button and distributor and raise the base of the ignition coil so that it is insulated from the top cover of the motor-generator.

To Test for Short Circuits

For testing for short circuits between two wires which are supposed to be insulated from each other —see test No. 5; place one test point (TP) on one wire and the other point on the other wire.

If the lamp lights, a short circuit is indicated between the two wires.

If the lamp does not light, then this portion of the circuit is in proper condition.

To Test for a Broken Wire

To test for a broken wire—see test No. 6; place the test point at each end of the wire as shown.

If the lamp lights, the circuit is complete.

If the lamp does not light, then there is a break somewhere between the two points. By gradually moving the test points toward one another, the break can be definitely located.

If Lights Burn Out Often

This is likely due to using a lower-voltage lamp than is used on the generator circuit. Test the voltage at the lamp socket with the voltmeter when the generator is running at normal speed, and use lamp bulbs accordingly.

TESTING THE LIGHTING, HORN, AND IGNITION CIRCUITS WITH A METER

Lights

Causes: If all the lights do not operate, the trouble may be due to the lighting system being short-circuited, open-circuited, or grounded.

If individual lights do not operate, the branch systems may have any of the defects mentioned, and, in addition, that of burned-out lights.

Testing[1]

Short circuit: To test for a short circuit in the general lighting system, insert the 300-ampere range shunt in the circuit. Connect the instrument to the shunt. An indication will be obtained if a short circuit exists. (An indication may also show a ground.)

If some of the lights only do not operate, connect the instrument as just described and close the switch for the branch containing those lights, for instance, between switch 7, Fig 1, and the light circuit. An indication will be obtained if the branch contains a short circuit or ground. If a short circuit is indicated, the wiring and light sockets should be carefully examined.

Note. If the indication obtained is less than 30 amperes, the 30-ampere range shunt may replace the 300-ampere range shunt.

If any lights are burned out, measure the voltage at the socket, using the 30-volt range. This should be done for various engine speeds.

If a voltage is indicated which is higher than is proper for the particular system being considered, examine the generator regulator system to locate the trouble.

Open circuit: If all lights do not operate, and the instrument does not show a short circuit or ground, the general lighting system is open-circuited. This is probably due to a disconnected wire.

If some lights only do not operate and no short circuits or grounds are indicated, the branch systems which contain these lights are open-circuited. This may be in the wiring, or because the lights are burned out.

Grounds: Disconnect all wires from the battery and all intentional ground connections. Then proceed as described under "Short Circuits."

Horn

The causes for the horn failing to operate may be similar to those affecting the operation of the lights.

Open circuit: Connect the 30-ampere range shunt and instrument in the horn circuit, between the switch terminal 3 (Fig. 1) and the horn circuit. Close the horn switch. If no indication is obtained, the horn circuit is open-circuited. By inspection, the place at which trouble exists can readily be found.

Short circuit: If a test for an open circuit does give an indication, the horn circuit is short-circuited or grounded.

Note. If the indication is less than 3 amperes, the 3-ampere shunt may replace the 30-ampere shunt on the ammeter.

Ignition Troubles

Causes of trouble: Ignition troubles may be caused by loose connections, open circuits, grounded wires or spark plugs, short-circuited wires or spark plugs, improper adjustment of spark gap of plugs, incorrect order of cylinder firing, broken-down or short-circuited spark coil, and broken-down or grounded condenser.

If a magneto is supplied, trouble may be in the magneto.

Ignition troubles and tests are treated under the ignition instructions. See Index.

A visual inspection and the application of tests already described will undoubtedly enable one to locate the fault.

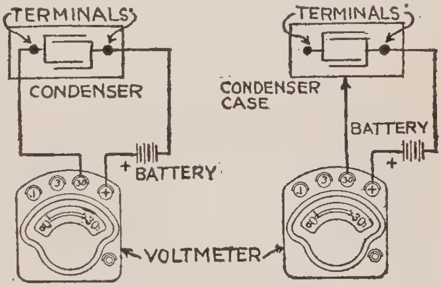

Fig. 2

Fig. 3

Condenser broken down: Connect the negative (−) binding post of the battery to one terminal of the condenser (Fig. 2). Connect the positive (+) terminal of a battery to the (+) binding post of the instrument. Then, finally, complete the circuit from the 30-volt binding post to the other condenser terminal.

If the condenser is good, no indication will be obtained. **If it is broken down,** an indication will be obtained.

Condenser grounded: Remove one connection from a condenser terminal and touch it to the condenser case (Fig. 3). **If an indication is obtained,** that section of the condenser is grounded. Replace the connection to the condenser terminal and repeat, removing the connection from the other terminal and touching it to the case. See also Index, under "Condenser tests."

General Wiring Troubles

Causes of trouble: Troubles in the general wiring of an automobile may be due to short circuits, grounds, open circuits, and poor connections. These faults can result from oil and water-soaked insulation, from damaged insulation caused by rubbing of the wires against the metallic parts of the automobile, and from vibration of the automobile when in service.

These faults can be located by visual inspection and by the application of the various tests already described.

It is well to consult the manufacturer's wiring diagrams before attempting to make any changes in the wiring.

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[1] The Weston "model 280" instrument is used as an example in these tests. See page 464.

TESTS OF A STARTING MOTOR WITH A METER (ALSO APPLICABLE TO THE GENERATOR EXCEPT THE OPEN-CIRCUIT FIELD TEST)[1]

The subject of starting-motor troubles is also treated on pages 455, 517, 518. The purpose here is to explain first the common troubles of a starting motor and then how to make the tests.

Starting-Motor Troubles

Starting-motor troubles can be divided under two headings:

1. Failure to operate.
2. Operates slowly and without sufficient power to crank the engine.

Causes of 1: Battery weak; open or short circuits, or grounds may exist in wiring from battery to starter switch; sticking of starting switch (common); mechanical troubles, such as a stuck Bendix drive gear, worn bearings, waste or foreign substance between armature and pole pieces; trouble with starter mechanism.

Test by examining each carefully. If none of these causes exist, then the trouble is an internal one of the motor, and may be due to an open circuit in the motor armature or field. Tests are shown elsewhere.

The trouble may also be due to a dirty commutator, to grounded brushes, or to the fact that the brushes are not making good contact. Tests are shown elsewhere.

Causes of 2: Battery discharged—test battery; poor contact at battery terminal or ground wire from battery to frame; poor brush contact; dirty commutator. Test. See also "Digest of Troubles."

The first test, however, which should be made, before making other tests, is to **test the engine,** to see if it cranks easily when cranked by hand. If the engine is stiff, it is probably using more than the normal amount of current, thus rapidly discharging the battery; or the engine may not start easily owing to carburetion or ignition trouble.

The second test should be that of the **battery** (see Index under "Testing the storage battery").

Failure of the engine to start when the starting motor is working satisfactorily: This may be due to failure of gasoline or spark. Test out as follows:

(1) **Ignition switch:** Examine to see if "on."

(2) **See that there is gasoline in the carburetor,** and that it reaches the engine, by priming. If there is no gasoline in the carburetor, which can be determined by depressing or raising the float to see if gasoline drips, then it is useless to waste current trying to start the engine with the starting motor. The gasoline may be used up, it may not be turned on, or the gasoline feed pipe or valve may be stopped up. If the system involves gravity feed, the gasoline may not flow into the carburetor on steep hills.

(3) **If there is gasoline in the carburetor,** take out one of the spark plugs and lay it on the engine with the sparking point in the air while the engine is turned over by hand or by the starting motor. Also examine the spark plug points—they may be too far apart. $\frac{1}{64}''$ to $\frac{1}{32}''$ apart is about right. If a spark passes, the trouble is not in the electric system, but is probably caused by cold gasoline or the need of priming.

(4) **If there is no spark,** then see "Digest of Troubles" and Index, and follow the diagnosis.

Before an engine will start, there must be gasoline and a spark.

If sometimes the gears mesh and the motor runs satisfactorily, and at other times it is impossible to mesh the gears, the motor refusing to turn when the contacts are closed, it indicates the possibility of an open circuit in the switch or starting motor.

If the engine does not pick up immediately after two or three trials, even though the motor turns the engine over, the trouble is in either the gasoline supply; the spark plugs; the carburetor; or the ignition system.

If the starting motor continues to run after the switch lever is released, see that the return spring on the switch, or switch lever, is strong enough to return the parts positively and fully to the "off" position.

If the starting motor cranks the engine very slowly: Battery is almost discharged; battery may be sulphated; engine may be stiff; brushes may be loose or may make poor contact.

If the starting motor does not rotate at all: Battery may be discharged; starting switch may not be making good contact; the motor brush may not make contact with the commutator; the battery terminals may not make good contact; switch contact may be poor.

Owing to the high volume of current carried through starting motor brushes, if they are worn or not properly adjusted, the commutator may become pitted and cause excessive wear—result: failure of starting motor to operate properly or excessive sparking and weak motor. Remedy: Take the armature out and true up the commutator on a lathe.

If the starting motor rotates but does not crank the engine: Roller clutch does not work properly (Delco system), or the Bendix drive is out of order; gears may be improperly meshed; if a Bendix automatic, spring may be broken. See pages 320, 456.

If the starting motor cranks the engine a few revolutions and then stops: Battery may be weak—almost discharged; a loose switch contact may exist.

If the starting motor cranks the engine and the engine does not start: These symptoms indicate that trouble is not in the starting system.

If the battery is all right proceed to examine the connections, beginning with the battery. The current may be shorted, because of electrolyte spilled over the top of it; or the terminals may be sulphated, in which case enough resistance will be offered to the current to prevent proper operation.

Scrape off the sulphate, wash surrounding metal parts in carbonate of soda or some other alkali.

Clean the battery terminals inside with a round file; **clean the wire terminal** with a flat file; replace the wire, and draw connections tight.

Next examine the ground connection of the battery to the frame. This should be cleaned and tightened, if not soldered. Looseness here is a frequent cause of open circuit. Then examine the connections from battery to starting motor switch; thence the brushes to the commutator. Good battery and ground connections are very important.

See "Digest of Troubles" for other starting-motor troubles, both "electrical" and "mechanical."

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[1] Taken by permission from the Weston Instruction Book. Copyrighted, 1920.

Starting-Motor Troubles in Relation to Testing with a Meter

The following tests are made with a Weston "model 280" instrument.

Causes: If the starting motor does not operate, the fault may arise from several causes, acting separately or collectively. The more important causes are fully discussed in the following text:

The battery: The battery is generally the most abused part of the starting and lighting system, and consequently may easily become discharged. In this condition it is not capable of supplying sufficient current to operate the starting motor. The hydrometer test should be applied, and if this condition exists, the battery should be investigated. See Index for "Storage battery tests."

Wiring and starting switch: Open circuits, short circuits, or grounds may exist in the wiring from the battery to the motor, including the starting switch. A common cause is sticking of the starting switch.

Defective motor: The motor may not operate because of internal troubles. These may be an open-circuited or short-circuited armature or field, dirty commutator, brushes not bearing on the commutator, or grounded brush holders, armature, and field.

Mechanical troubles are not included in these tests. See "Digest of Troubles."

Testing for Trouble: Motor Will not Operate

To locate trouble: If the battery is in good condition and the starting motor does not operate, connect the 30-volt range of the instrument to the terminals of the motor as directed in test V3, page 470. Press down the starting switch. Quickly observe the indication of the instrument.

Caution: Do not hold the starting switch down any longer than absolutely necessary to obtain a reading, as the battery is under a heavy strain which may damage it.

Open circuit in wiring or starting switch: If no indication is obtained, an open circuit exists either in the wiring from the battery to the motor or in the starting switch. A visual inspection will locate the cause.

Short circuits and grounds in wiring or starting switch: If an indication is obtained when the voltmeter is connected to the motor terminals, but the indication is much less than the normal voltage of the battery (test battery as directed in test V2, page 470), the trouble may be due to loose connections at the battery, starting switch, or motor; or to grounded or partially short-circuited wiring. A visual inspection will locate these causes.

Short circuits and grounds in motor: If no troubles are found to exist in the wiring, the cause must be in the motor. The faults as indicated by the instrument would be short-circuited or grounded armature and field, or grounded brush-holders. See under "Short Circuits" and "Grounds" for details of tests.

Open circuits in motor: If an indication approximately equal to the battery voltage is obtained with the voltmeter connected to the motor terminals, the motor is open-circuited. **An open circuit may exist in the armature or field,** or it may be due to the commutator being dirty or the brushes not bearing on the commutator. A visual inspection will eliminate the last two faults. See under "Open Circuits" for details of tests on other faults.

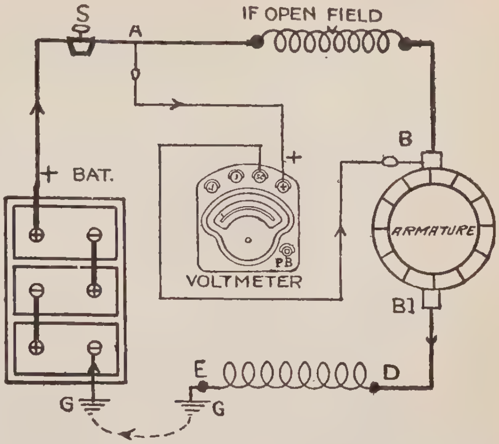

Fig. 4. Test for an open circuit in the motor field which would cause the motor not to operate. Use 30-volt terminal and scale.

To test for an open circuit in the motor field: See Fig. 4. Connect meter with the 30-volt terminal. Place voltmeter connections on one end of the field at (**A**) and the other at brush (**B**). Press starting switch (**S**).

If an indication shows on the meter that is approximately equal to the battery voltage, then there is probably an open circuit in the field, because the circuit would then be from (**A**), through the meter to (**B**), through the armature, to (**B**1), through the other field, to ground (**G**), to (−) of the battery.

If no indication is obtained, then the field is good and the motor should operate if the battery is strong. If it does not operate, then the armature may be open, and this is discovered by another test. If the field is good, there would be (approximately) no reading, because the meter would be connected on one side of the line. Therefore this test would not tell definitely if the armature is open, but it would be sufficient reason to test for an open armature.

This motor-field test is not applicable to the generator-field test.

Testing for Trouble: Motor Operates, but Slowly

If the motor will turn over, but too slowly to start the engine, any one or more of the troubles already mentioned may exist, except the open circuit in fields. In other words, an open circuit could be in one or two armature coils, or a short in one or two armature coils, and the motor would operate to a certain extent. Therefore tests of armature and field troubles will be given, which are also applicable to the generator, except the meter test of the open-circuit field of a generator, which is given on page 502.

Testing for open circuits in the armature: Connect the 30-volt range of the meter to the brushes, as shown in Fig. 5. Be sure that the brushes are bearing on the commutator. Press the starting switch.

If an indication shows on the meter and it is (approximately) equal to the battery voltage, then the armature is probably open. The current would then flow through the meter from the battery around the armature. All of the armature coils may not be open; turn the armature slowly and observe.

To test each individual armature coil to localize or find the open-circuited coil, is then the next procedure, if the armature is suspected of being open.

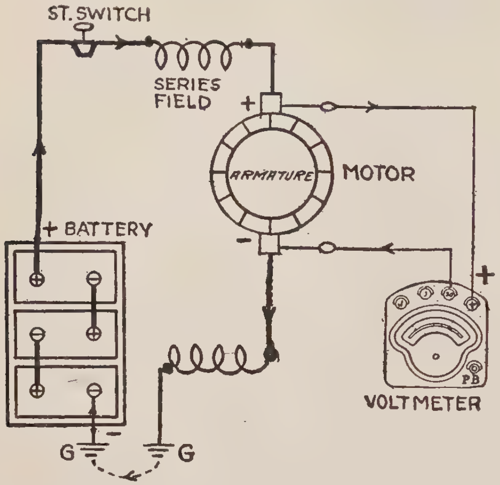

Fig. 5. Testing for open circuit in armature. Use the 30-volt terminal and scale.

Proceed as follows: Disconnect the fields from the armature, as in Fig. 6. Connect the brushes to a source of current, such as a single cell, and have a controlling **resistor**[1] in series to increase or decrease the current flow (see **R**, Fig. 6). Using the 3-volt range of voltmeter, measure between adjacent segments of the commutator.

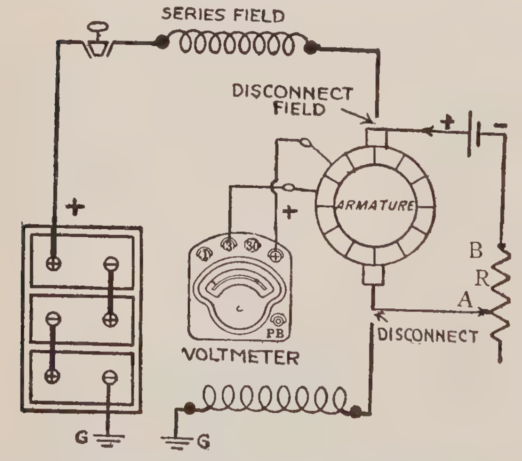

Fig. 6. Testing for open-circuited armature coils. Use the 3-volt terminal and scale. When testing for short circuits in armature coils, use the .1-volt terminals and scale. This test is what is termed a **"comparative test,"** that is, the test points of the meter are placed on two adjacent bars all the way around the commutator, and the readings on each pair should be the same. Note resistor.

If an open-circuited coil is across the ends of the meter test-points, then **an indication will be obtained** which is relatively large as compared to that obtained from a good coil (see page 498 for the reason).

It is absolutely necessary that good contact should be had at the commutator segments in order to obtain reliable results.

Note. This method can also be used when testing the generator armature for open circuits.

Testing the armature for short circuits: Disconnect the field from the armature. Connect for test to determine open circuits in the armature (Fig. 6), and try the armature for open circuits as already described. Now change the connection from the 3-volt range to the .1-volt range and measure between commutator segments.

If a short circuit exists in any of the armature coils, **the indication obtained,** when the voltmeter test-points are connected to the ends of that coil, **will be very much less** than the indication obtained from a good coil (see page 498 for the reason).

Note. This is one of the special cases when the .1-volt range should be used.

If the indication is too large, decrease the current supplied through the brushes by increasing the controlling resistance.[1]

This method is applicable to the generator.

Caution: Good contact must be had at the commutator segments in order to get reliable results.

Testing fields for short circuits: Connect one cell with a regulating resistor (**R**) in series to the ends of the entire field, as in Fig. 7. (The field is usually made in two or more sections.)

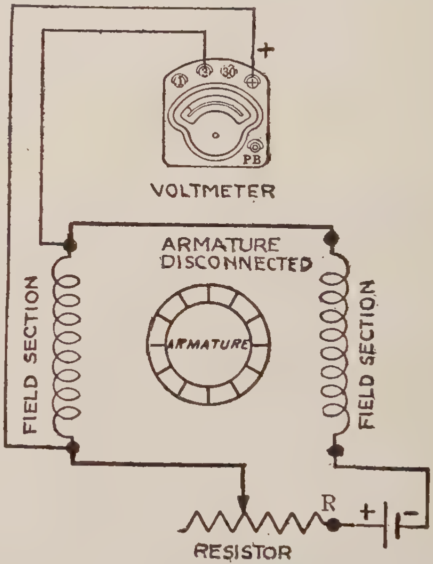

Fig. 7. Testing the fields for short-circuits. Use the 3-volt range to start with.

Using the 3-volt range, measure the voltage across one field section. Transfer the voltmeter leads to the other section in turn.

If on one of the sections **no indication is obtained,** that section is short-circuited, because there is no **resistance offered by the field which is short-circuited.** If it were not short-circuited, then the reading would be that of the voltage drop, due to the resistance offered to the flow of current passing through the coil winding. The greater the number of turns and the smaller the size of wire, the greater is the resistance. Therefore if a short circuit exists, there would be less resistance, depending upon the number of turns short-circuited.

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[1] **The purpose of the resistor** is to furnish enough resistance in the circuit to cause sufficient voltage drop to obtain a satisfactory reading. The amount of resistance cut into the circuit can be varied with the resistor shown in Fig. 6; for instance, (R) is the resistance. By moving (A) down, more resistance is cut into the circuit; by moving (A) up, resistance (R) is cut out of the circuit. See page 467 for explanation, and for information as to where resistor can be obtained.

If on one section the indication is very much less than on the other section, a short circuit very likely exists in that section, because these tests are intended to compare one coil with another, and, if good, they should have approximately the same readings.

Note. If the indications obtained are less than .1 volt, the connection may be changed from the 3-volt range to the .1-volt range. This is the second special case where the .1-volt range can be used.

This method is applicable to the generator.

Testing the armature for grounds: Disconnect all intentional ground connections to the motor. Also disconnect the field from the armature. Lift the brushes off the commutator.

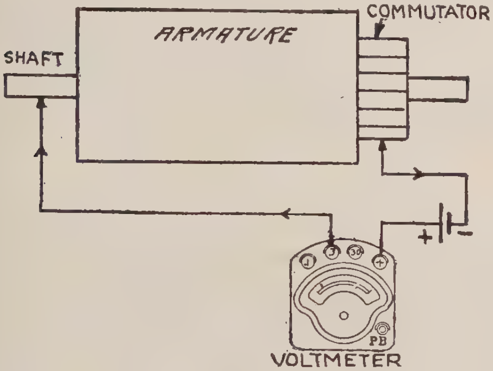

Fig. 8. Connections for testing for a ground in an armature. Use the 3-volt terminals and scale.

Connect the negative (−) terminal of a cell (Fig. 8) to a commutator segment, and the positive (+) terminal to the (+) binding post of the instrument. Complete the circuit from the 3-volt binding post to the armature shaft or motor frame.

If an indication is obtained, the armature is grounded. The cause of the ground is very likely due to damaged insulation on the armature conductors. The armature should be carefully examined for this.

On one-wire systems of the two-unit type, a grounded coil will result in slow cranking and a materially reduced charging rate.

In some starting and lighting outfits using motor-generators, two windings are placed on a single armature, each being brought out to a separate commutator. One winding is for the motor and the other for the generator. A ground may develop between these windings.

To test for such a ground the terminal of the instrument which was attached to the shaft or frame of the car should be transferred to the second commutator and the general directions followed. See also test-light test, page 497, Fig. 28.

Testing the fields for grounds: Transfer the connection from the commutator segment to one end of the field. **If an indication is obtained,** the field is grounded.

When the system is of the single-unit type, such as a motor-generator, both motor and generator fields are wound on the same field frame. It is possible for these windings to develop a ground to one another.

The method of testing for such a ground is to interpose the instrument and a cell between one end of each winding. If a ground exists an indication will be obtained.

Caution: Be certain that the ends of the field coil are not touching the motor frame.

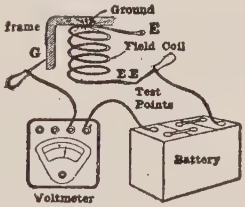

Fig. 9

When testing the field for a ground, be sure both field coil ends (E) and (EE) are disconnected from all terminals. Use the 30-volt connection as shown in Fig. 9. Place one test-point on (EE) and the other on the frame at (G). If deflection is shown, the coil is grounded and a new one must be supplied.

Testing grounded brush-holders: This test is made in the same manner as the test for a grounded armature, except that the connections should be made between the shaft of the armature or frame of the car and each brush-holder. Insert a piece of cardboard between the brushes and the commutator before making this test. If an indication is obtained, the brush-holder is grounded.

These tests are applicable to the generator.

EXAMPLE OF HOW A STARTING MOTOR IS TESTED ACCORDING TO DATA GIVEN IN THE SERVICE MANUALS[1]

In order to make certain facts clear to the reader, which are usually found in Service Manuals, we shall use some data from the Remy Service Manual on the test of a starting motor, model "118-A," as follows:

Speed, Torque, Current Data Table

Starting Motor. Model 118-A, with Bendix drive.

Torque (Pull with 6″ Pulley)	R.P.M.	Amperes	Volts
0 lbs.	3750–4250	32–40	6.0
6 lbs.	1500–1540	88–98	5.7–5.8
9 lbs.	1200–1400	110–120	5.5–5.7
12 lbs.	1020–1150	130–145	5.4–5.5
16 lbs.	800–1000	158–175	5.3–5.4

Torque of an armature is the momentum tending to turn it. In a generator, it is the momentum which must be applied to the armature to turn it in order to produce current. In a motor, it is the turning momentum which the armature gives to the pulley or gear. The torque is greatest when starting, and is in proportion to the load.

Observe that the **data given above are for a torque test of a starting motor.** Therefore we shall use a simplified torque test apparatus, consisting of parts shown in Fig. 10.

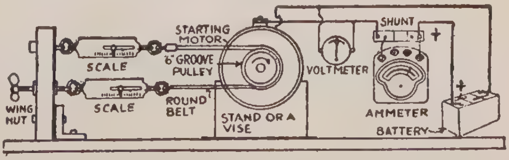

Fig. 10. Simplified illustration showing how a torque test of a starting motor is made.

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[1] See advertisements in the back of book for Service Manuals.

The starting motor is placed in the stand (Fig 10) with a 6″ pulley on it, and is first given a "free running test" and then connected with an adjustable belt and two spring scales for making the "torque test."

The starting motor is then connected with a fully charged battery known to be in good condition (a 6-volt battery in this instance), and an amperemeter with a 300-ampere shunt is connected in the circuit as shown. A voltmeter is placed across line.

19A. Speed Indicator.

A speed indicator is used to indicate the speed. On modern test stands, as shown on page 507, a tachometer indicates the speed, but in this instance a hand-type speed indicator (Fig. 10A) is used. The point of the speed indicator is placed in the end of the motor armature shaft, and the number of revolutions per minute is counted.

Motor Free Running Test

Note on the first line of the table, on page 489, that the torque is given as 0 lbs. at 3,750 to 4,250 r.p.m., and 32 to 40 amperes at 6 volts.

Procedure of test: The motor is placed on the stand with belt detached, that is, the motor is permitted to run "free." According to the second column of the table, the motor should develop 3,750 to 4,250 r.p.m.; according to the third column of the table, the ammeter should indicate 32 to 40 amperes under these conditions; according to the fourth column of the table, the voltmeter should indicate 6 volts.

Motor Torque Test

Note on the second line of the table (page 489), that the torque is given as 6 lbs. at 1,500 to 1,540 r.p.m., and at 88 to 98 amperes at 5.7 to 5.8 volts.

Procedure of test: The belt is now attached, the motor started, and the wing nut tightened until the **difference** between the readings of the two scales is 6 lbs. (that is, a pull of 6 lbs. is exerted by the motor). The speed should then be 1,500 to 1,540 r.p.m.; the ammeter should indicate 88 to 98 amperes, and the voltmeter should indicate 5.7 to 5.8 volts. The test should be continued, using the various values of torque as given in the table. Note that the "value of the torque" refers to the **difference** between the readings of the two scales.

An Explanation of Difference in Scale Readings

Suppose that the upper scale in Fig. 10 reads 26 lbs., and that the lower one reads 20 lbs. It seems at first that the motor is exerting a pull of 26 lbs. on the top scale; note, however, that the bottom scale is helping the motor by pulling with a force of 20 lbs., and that therefore the motor itself is only pulling 6 lbs., or the difference between 26 lbs. and 20 lbs.

Stalling or Locked Torque Test

Procedure of test: Tighten the wing nut until the motor comes to a dead stop: this is termed "stalling" or "locked." The difference in scale readings at this time gives the pull exerted by the motor. This pull should be very high, as it is the force which, when the motor first starts a cold engine, breaks the oil film. The amperage will also be very high.

Therefore, note that with a series-wound motor, the greater the load, the greater the amperage consumption and the less the speed. Also note that the greater the load, the greater the voltage drop.

Such data as these are given in the Service Manuals referred to in the advertisement in the back of this book.

EXAMPLE OF HOW A GENERATOR IS TESTED ACCORDING TO DATA GIVEN IN THE SERVICE MANUALS

The Remy generator (relay regulated type) model "16-A" is used as an example.

Speed, Current Data Table

Generator without ignition. Model 16-A, using relay regulator regulation.

Amperes	R.P.M.	Volt
0.	370	6.0
7.	490	6.5
14.2	2200	6.9

On **"battery test,"** field draws 3 to 3.5 amperes at 5.9 volts.

"Generator motoring," draws 4 to 4.5 amperes, 5.8 volts and runs at 430 R.P.M.

Note that in the table there are given **three methods of testing:**

1. **By driving the generator** on the test stand and connecting it to the battery through the cut-out, as if on the car (Fig. 11).
2. **By making a "battery test" of the amount of current drawn by the shunt-field windings,** by connecting a battery across the shunt-field circuit with armature disconnected (Fig. 12).
3. **By "motoring the generator,"** that is, by running the generator by the battery free, without a load, i.e., with no tight bearings or binding at any point (Fig. 13).

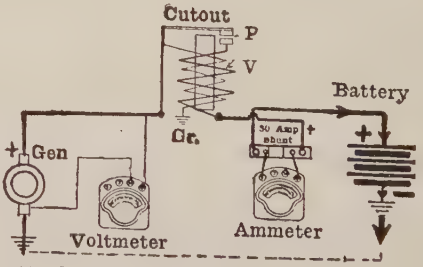


Fig. 11. Testing a generator by driving the generator.

Method 1: By driving the generator at a speed of 370 r.p.m., "0," or zero amperage, would be indicated (see table); but 6 volts is the voltage that should be indicated. The cut-out points (P) (Fig. 11) would be open, as the speed is not great enough to produce pressure sufficient to close contact-points (P). At 490 r.p.m., 7 amperes and 6.5 (6½) volts should be indicated. The cut-out points (P) should close, and the generator would charge the battery. At 2,200 r.p.m., 14.2 amperes (maximum) and 6.9 volts would be indicated. **The ampere-meter** is placed in series with the circuit indicated above, as in Fig. 11. **A voltmeter is placed across the circuit,** to indicate the voltage.

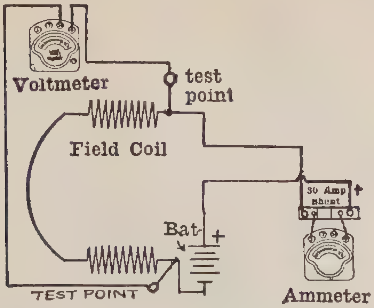


Fig. 12. Testing a generator by observing the amount of current taken by the shunt-field winding.

Method 2: By connecting a battery to the shunt-field winding terminals (Fig. 12) **with an ammeter in series with the circuit,** the ammeter should show 3 to 3.5 amperes. **With a voltmeter across the circuit,** as shown in Fig. 12, it should indicate 5.9 volts.

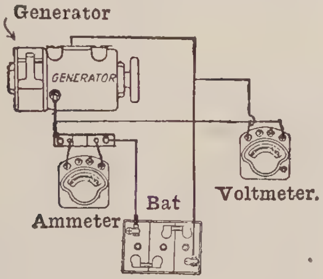


Fig. 13. Testing a generator by "motoring" it.

Method 3: By connecting this shunt-wound generator to a fully charged battery (Fig. 13) **with** the armature and all brush connections complete, and **with an ammeter in series** with the circuit and **a voltmeter across the circuit,** the generator running as a motor (termed "motoring-generator") should draw 4.0 to 4.5 amperes, and the voltmeter should indicate 5.8 volts; the generator operating as a motor should run at a speed of 430 r.p.m.

Generator Trouble Indications when "Motoring" a Generator on the Test Stand (Ford Generator as an Example)

The following tests and determinations may be made with an ammeter in the circuit and a generator connected with the 6-volt battery. Preferably one which has been in use is used, and the connections are made as shown in Fig. 14.

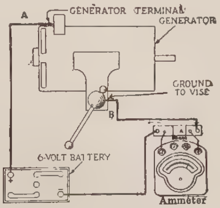


Fig. 14. Connections for motoring generator.

1. **The correct reading** is from 2 to 4 amperes, the generator running at a slow, steady speed, with no arcing at the brushes.

2. **A heavy discharge,** with the hands going beyond the limit of the instrument, indicates trouble in the head, such as the third brush not seated, fields open probably at the third brush or ground connection, the third or positive brush-holder or pigtail shorted. To prove an open field, raise the third brush and connect (A) to it. If open, no reading will be shown on the ammeter.

3. **No reading on the ammeter** indicates a dirty commutator or the brushes not seated upon it, because of the brushes sticking in the holders, or being worn too short to make proper contact, or sprung out of shape so one or both press against holder.

4. **The ammeter fluctuating between 18 and 20 amperes,** indicates short circuits in the armature.

5. **The ammeter reading 6,** with a higher r.p.m., indicates a shorted field.

6. **If the ammeter is normal,** but there is a decided flash at one point on the commutator, an open armature is indicated. Turn the armature over by hand, one segment at a time; if there is a point where the armature will not start to rotate, that coil is open.

COMMUTATOR TROUBLES AND TESTS

Commutator troubles can be classed under three headings: (1) those due to defective manufacture; (2) those due to surface wear or deterioration in service; (3) those due to a dirty or burned commutator.

Defective commutators may be grounded, may have a short circuit between the segments, or may have loose segments or high mica, or loose brush-holder springs.

Sparking at the brushes will be caused by any of the causes mentioned above, or by loose pigtails, or by loose connections of wires to the brushes, by sticking brushes, by overloading of the generator, and by short circuits in the armature windings.

If the commutator is dirty, and if grease and carbon dust have accumulated between the commutator segments, to such an extent that the bars are shorted, excessive sparking will be the result, and no current, or very weak current, will be allowed to pass.

Examine the Commutator

First, **examine the commutator** to see if it is dirty, and if it consequently prevents proper contact between the brushes and the commutator bars. If it is all blackened and covered with grease, no current, or a very small current only, will be allowed to pass.

Cleaning Commutator

If the trouble is due to grease and dirt only, it can easily be cleaned. Start the generator, and while it is running, hold a piece of cloth dampened with gasoline against the commutator bars to remove the grease.

Next, use a finely pointed tool and clean out any dirt or grease that may have accumulated between the commutator bars.

Sanding the Commutator

If the commutator is dirty, caused by excessive sparking, it will be necessary to sand it by the use of a very fine piece of sandpaper, not coarser than No. 00, held against the commutator (rough side down) while the generator is running. Never use emery cloth.

The strips of sandpaper should be a little wider than the brush (Fig. 15) and wrapped around the

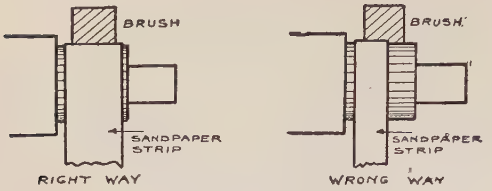


Fig. 15. Right and wrong way to sand a commutator.

commutator so as to make contact with at least half of its circumference. Fig. 15 shows the correct method on the left and the incorrect method on the right.

Worn Commutator Bars

The next source of trouble may be a very badly worn commutator, which would allow the mica between the bars to become flush with the surface of the bars. The mica should be kept slightly below the surface of the bar (which is done by undercutting the mica as explained farther on).

Mica Protruding

If the mica insulation between the commutator bars becomes flush with the bars, the brushes cannot make good contact, and this causes arcing or sparking, which burns away the bars until they are below the level of the mica which then protrudes. This not only prevents the brushes from making good contact, but the bars are pitted and become very rough. Fig. 16A shows the appearance of a commutator with protruding mica.

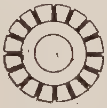


Fig. 16

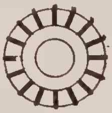


Fig. 16A

Fig. 16. Mica correctly undercut.
Fig. 16A. High mica before cutting.

This trouble is more common on generators. On starting motors, where brushes do not make contact, the commutator becomes rough and causes arcing. The mica is not undercut on a motor commutator, but if rough, it is put in the lathe and turned down with a very sharp lathe tool to take a very fine cut off the surface of the commutator.

Dressing Commutator Down and Undercutting the Mica

To remedy protruding mica: Remove the armature and very carefully true or dress it up on a lathe, as in Fig. 17. Then cut out the mica between the bars with a hack-saw blade, the sides of its teeth having been ground off so that it will cut a groove slightly wider than the mica insulation, as in Figs. 18A and 19. This will leave a rectangular groove free from mica; the depth should be about 1/32″. It is important that these spaces be free and clear of all foreign matter.

The edges of the slots should then be slightly beveled, using a three-cornered file (Fig. 18) in order to prevent any burrs remaining, which would cause excessive brush wear.

When properly finished, the commutator will have the appearance shown in the illustration (Figs. 16 and 19).

Note. The mica can also be cut by placing a special tool in the lathe and moving it laterally as a planer (Fig. 17).

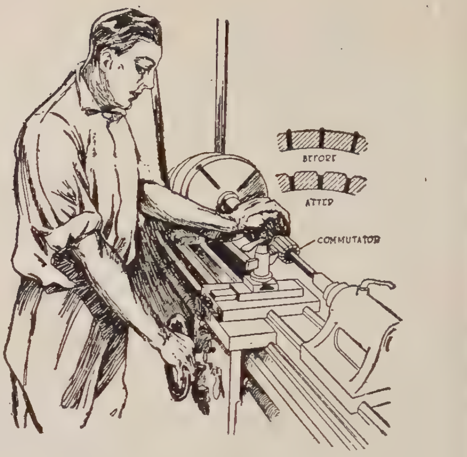
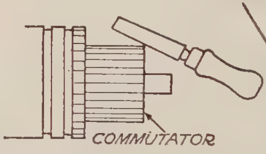
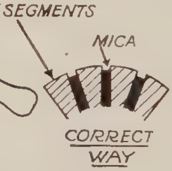


Fig. 17. Dressing down a commutator on a lathe when it is very rough, or when mica protrudes above the commutator bars.



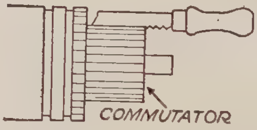
STARTING GROOVE IN MICA WITH 3-CORNERED FILE.

Fig. 18



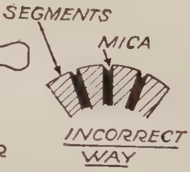
MICA MUST BE CUT AWAY CLEAN BETWEEN SEGMENTS

Fig. 19



SLOTTING MICA WITH PIECE OF HACKSAW BLADE.

Fig. 18A



MICA MUST NOT BE LEFT WITH A THIN EDGE NEXT TO SEGMENTS

Fig. 19A

The blackened and burned appearance of the commutator is not always caused by high mica. The same effect may be caused by having brushes of improper size or material, by an insufficient spring tension on the brushes, by an overload on the generator, and by an open or short circuit in the generator windings; or, where there are two windings on one armature with two commutators, by a short circuit between the motor and generator windings.

Commutator and Other Noises

Protruding mica and improperly seated brushes produce a noise which can easily be detected.

Noises are sometimes due to bent armature shafts, broken balls, or worn bearings. If an improperly seated brush causes the noise, it can sometimes be eliminated by setting the brush to one side with a small stick. Do not use a screwdriver.

Do Not Use Grease on the Commutator

It is unnecessary to lubricate either a generator or a motor commutator, as the grease or oil mixes with the carbon dust from the brushes. This will soon soak into the mica insulation and form a path between the bars, thus short-circuiting the commutator bars, and, consequently, the armature coils connected with them. This is common on old generators where the bearings wear and permit oil to pass into and on the commutator.

Loose Commutator Connections

One can tell if the generator is generating its proper output by observing the dash ammeter. One should learn just what the maximum output should be. If it generates a very low amperage, say about 2 amperes, and then at times none at all, the trouble may be due to a loose connection and sometimes that loose connection is at the point where the end of the armature coil is soldered to the segment of the commutator, which, although apparently securely soldered, may be loose. Furthermore, it may not be loose when stationary, but when it is revolving, the connection is thrown loose by centrifugal force.

One method of testing is to use a test light and test points. Place one test point on the commutator segment connected with the suspected loose armature coil and the other on the segment 180° apart, or on the extreme opposite side of the commutator, which is the other end. On passing the current through the armature coil in this manner, there will probably be a slight spark or arc at the point where loose. Test all segments in like manner, and resolder any that are loose.

Another Commutator Trouble

High segments in a commutator, the result of the commutator having been turned or dressed down eccentrically with the armature shaft (out of round), will cause the generator to produce weak current or none at all, especially at high speeds, owing to the brushes not making good contact.

The test for these two conditions is to press on each of the commutator segments at both ends with some blunt instrument. If there is the slightest movement at either end of a segment it is loose, and a new commutator will have to be installed.

To determine whether or not the commutator is running true with the armature shaft center, whittle a piece of crayon to a point and, with the generator running, bring it slowly up against the surface of the commutator. If it is out of round with the armature center the chalk will mark the high spot and leave the low side unmarked, provided the test is carefully made.

If the commutator is out of true, re-turning, using the correct size of ball bearings as supports, will be necessary.

Besides the foregoing a few other causes will give rise to the same effect. Among these are weak brush springs, sticking brush-holders or brushes, connections which are not tight enough and which, vibrating at certain critical engine speeds, introduce a resistance into the exterior line.

It may also be possible that the **armature windings are not secure in the slots,** and that, at high speeds, one of the coils moves a trifle and, coming in contact with the iron of the armature coil, forms a ground. As the armature slows down, the natural spring of the coil brings it back to a normal position in slot and causes the armature to show "clear" when tested.

Testing for a Dirty or Rough Commutator with a Voltmeter

Connect the voltmeter terminals so that the voltmeter will read 0 to 30 volts as shown in Fig. 20. (The construction of this Weston voltmeter is shown on page 468.)

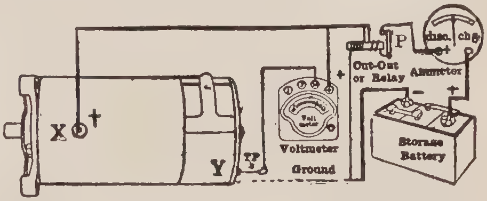


Fig. 20. Testing for a dirty or rough commutator with a voltmeter.

The positive (+) terminal of the voltmeter is connected to the positive (+) wire of the generator. The other terminal from the voltmeter which has a test point (TP) at its end, makes contact with the frame of the generator at (Y) (this being a grounded or return-wire system).

Then speed the engine up to a speed corresponding to a car speed of 10 to 15 miles per hour. **The voltmeter should show slightly over 6 volts** and the cut-out (V) should be closed, showing "charge" on the dash ammeter or indicator.

If the voltmeter does not show slightly more than 6 volts, this indicates a **dirty or rough commutator,** or else an **open circuit** in the shunt field. Press down lightly on the brushes while the generator is running, and if this causes the voltmeter to indicate and the cut-out to close, the trouble is due to **bad brush contact,** which can be remedied as just mentioned.

If the voltmeter cannot be made to indicate and the cut-out point (P) fails to close by cleaning the commutator and pressing on the brushes, the trouble is probably an open circuit in the shunt-field winding, which will have to be repaired locally or sent to the factory.

If the voltmeter does show 6 volts or more, by pressing down on the brushes, or by cleaning the commutator and brushes, but the cut-out will not close, it means that the cut-out is not in proper adjustment, and a new one should be provided if it is defective internally. The trouble may be due to loose connections on the cut-out, or to disarrangement of the contact-points, which can be examined and tested. See Index under "Testing cut-outs."

If the commutator is dirty then clean it. The probabilities are that the mica is protruding. This can be remedied as explained in preceding paragraphs.

BRUSH TROUBLES AND TESTS

Brush troubles are very common. Some of the troubles are: brushes sticking on their holders, brush springs not pressing on brushes with proper tension, loose brush-holders, loose connections to brushes, improperly seated brushes.

Brush and Brush Rigging

The open circuit is often caused by one of the brushes sticking in the brush-holder, from dirt. The remedy is obvious, that is, to clean the brush thoroughly and see that it moves easily in the brush-holder under the regular action of the spring.

No Spring Pressure

The brush spring may not have sufficient tension to hold the brush in contact with the commutator with sufficient force to give a good contact. This not only will show a partial or full open circuit, due to insufficient contact pressure, but it will be the cause of serious sparking between the commutator and the brush, and will soon burn and blacken the commutator so badly that a full open circuit will result, and no current will be generated at all.

A new spring with sufficient tension is the best way of repairing this trouble. The tension should be strong enough so that when the brush is pulled off the commutator by means of the pigtail, and then released, the spring pressure snaps it back freely on the commutator. **Too much spring pressure** has the effect of rapidly wearing out both commutator and brush, but is better than too little spring pressure.

The **approximate average brush-spring tension** on starting motors is 1 to 1¼ lbs., and from 12 to 18 oz. on generators.

Brushes Too Short

If the brushes are allowed to go too long without replacement, and are worn so short that the spring pressure is reduced very considerably, the same troubles will result. Be sure in replacing brushes to use only those of such a make as are recommended by the manufacturer; otherwise you are likely to have repeated troubles with both brush and commutator.

Broken Brush Connection

An open circuit will be caused by a poor or broken brush lead, or pigtail connection. In general, see that the brushes move smoothly in the brush-holders and that the springs press firmly and squarely on the top of the brush.

Fitting Brushes

The brush must always make good contact with the commutator; it should have sufficient spring tension to press the brush to the commutator, yet move freely.

Seating Brushes

When fitting new "generator" brushes, it may happen that they do not always fit the commutator perfectly, that is, they are not rounded to the curvature of the commutator surface.

This can be remedied by placing the rough side of a strip of No. 00 sandpaper under the brush, when it is in its brush-holder (each brush separately), and working the strip back and forth, holding the ends close together as in Fig. 21, so that it will conform with the curvature of the commutator. The entire surface of the brush must be treated, otherwise it will be uneven. The "pigtails," or brush connections must also be kept tightened.

When fitting "motor" brushes, the same method is applicable, but something harder than sandpaper must be used. A strip of carborundum cloth can be used on the "motor brushes," but sand-cloth should be used on the "motor commutator." It is seldom necessary to cut mica down on the motor commutator.

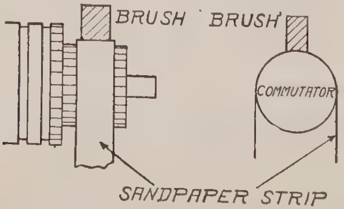


Fig. 21. Correct method of seating brushes. Place the sanded side of the sandpaper up. With the sandpaper held as shown above, a true arc is made on the brush for the entire length of contact on the commutator.

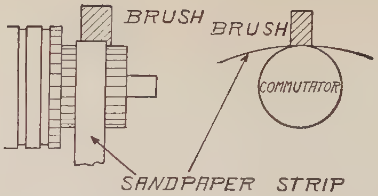


Fig. 22. Incorrect method. Note that only part of the brush is being seated. If held in position as above, the ends of the brushes are worn off, through the upward pull of the sandpaper; also the brush is subject to being pulled off the commutator while it is being sanded.

The motor brushes should be "sanded in," to avoid brush squeak which occurs sometimes as a result of a rough or irregular commutator surface, or grooves in the brushes. For this reason, if the motor commutator is rough, it is desirable to smooth it up, and then "sand in" the brushes at the same time that the mica on the generator commutator is undercut. If it is excessively rough, turn the commutator down in a lathe, being careful not to remove any more copper than is absolutely necessary.

On most of the Delco machines it will be found possible to "sand in" the upper and lower brushes by this method separately; but in a number of cases, on account of the construction of the machine, it is advisable to "sand in" both motor brushes, as well as both generator brushes, at the same time.

Spotting in Brushes

On some generators **it is not possible to "sand in" the brushes** in the manner explained above, **because the brush arm is too short.** In this case, the brush should be placed in a brush-holder and let down firmly on the commutator. Then "motor" the generator by running it from the battery as a motor. Then disconnect battery and remove brushes, leaving the "high spots." These can be scraped down.

Seating the Delco Flexible Brush

The design of the flexible generator brush arms and the third brush carrying a thermostat, used on many Delco four-pole round types of motor-generators and generators is shown in Fig. 23 (a later design is shown in Figs. 23B and 23C). Instead of the brush arm being rigid, it is made quite flexible by the use of a thin piece of phosphor bronze between the body of the brush arm and the carbon brush. Damage to the commutator is prevented, in case of brush breakage, by the insulating safety plate on the end of the brush arm, this plate being loosely mounted by the special heads of the screws securing the brush to the brush arm.

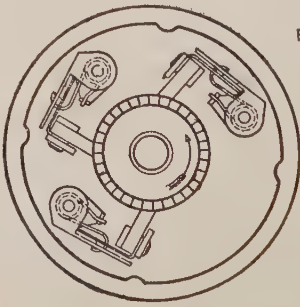


Fig. 23

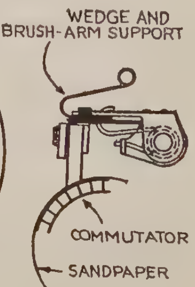


Fig. 23A

Fig. 23. Front, or commutator end view of Delco generator showing the flexible brush arms.

Fig. 23A. A side view showing brush seated on commutator. This model is now replaced by those shown on the next page.

It is very important to have this type of brush fully seated on the commutator. The brush cannot be properly sanded in by the usual methods of sanding brushes. It is necessary to place wedges between the brush arm body and the phosphor bronze, as shown in Fig. 23A, to prevent the flexible action of the brush arm during sanding. These wedges should be just thick enough to fit in place without falling out, approximately .075″. A strip of fine sandpaper or sand-cloth may then be used to seat properly one brush at a time.

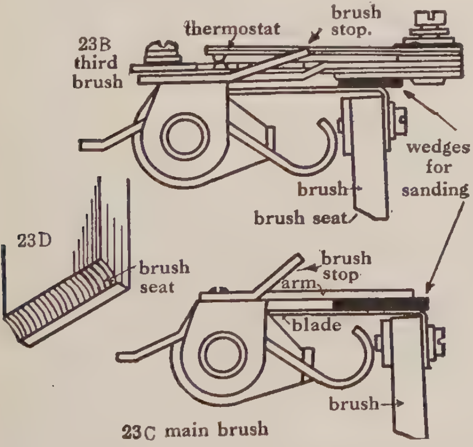
Another very successful method is to remove the end housing carrying the brush arms, so that a strip of fine sandpaper may be wrapped snugly once or twice around the commutator, gluing the overlapping edges of the sandpaper to secure it. The end housing may then be replaced and all three brushes properly sanded at the same time. This operation should cause the brushes to have a full seat on the commutator.

Remove the wedges in the brush arms and the sandpaper after the operation is completed.

The Delco Later Design of Flexible Brush Arms with Stops

A later design of Delco flexible brush arm with stops is shown in Figs. 23B and 23C.

The brush should always be assembled on the inside of the arm as shown.



Figs. 23B, 23C. Later design of Delco flexible brush arms with stops.

Fig. 23D. Showing how the brush should be seated.

Always replace all three brushes whenever inspection shows that the grounded brush has worn so short that its brush stop, coming into action, may soon keep the brush from contact with the commutator. This is the brush (on the Cadillac using No. 162 Delco motor-generator) which is on the right side of the commutator viewed from the front of the car.

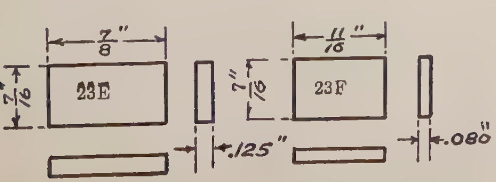


Fig. 23E. Dimensions of wedge for the third-brush arm.

Fig. 23F. Dimensions of wedge for the main-brush arms.

It is very important to have this type of brush seated on the commutator, at least to the extent shown in Fig. 23D. The brush cannot be properly "sanded in" by the usual method of sanding brushes.

It is necessary to place wedges between the brush arm body and the bronze blade to which is attached the brush. Two sizes of wedges are necessary, one size for the main-brush arms, and the other for the third-brush arm, owing to the difference in space between the body of the arm and the bronze blade.

These wedges are shown in Figs. 23E and 23F. Figs 23B and 23C show their application to the brush arms. These wedges prevent the flexible action of the brush arms during the sanding operation, keeping them rigid, and giving a seat more nearly over the entire brush.

These wedges should be just thick enough to fit in place without falling out, approximately .080″ for the main-brush arms (23F), and .125″ for the third-brush arm (23E). It will be found that the distance between the body of the arm and the bronze blade varies in some assemblies. It will be necessary in these cases to make the thickness of the wedges a little less by filing, or a little more than specified above by wrapping a couple of turns of paper around the wedges.

To sand the brushes after the wedges are properly fitted to the brush arms, wrap a 1″ strip of sandpaper, or sand cloth, snugly once or twice around the commutator, glueing the overlapping end to secure it. A drop or two of glue should be put on the commutator previous to putting on the sandpaper to hold the paper in place and prevent it from slipping during the sanding operation. The sandpaper should be wrapped around the commutator in a counter-clockwise direction, looking at the armature from the generator-commutator end.

After the glue has dried a few minutes, place the end housing carrying the generator brushes on the armature shaft and lower the brushes down on the sandpaper which is around the commutator. To prevent chipping of the edges, do not snap the brushes down on the commutator. Hold the armature in a vertical position with the housing at the top and revolve the housing in a counter-clockwise direction. This will sand all three brushes at the same time. When proper seating is accomplished, raise the brushes, remove the housing from the armature shaft and the sandpaper from the commutator. Avoid waste of brush material by being careful with this operation. Remove all glue from the commutator by sanding and remove the wedges from each of the brush arms.

To determine the seating of the brushes, mount the housing on the armature again as was done in sanding; revolve the housing several times with the brushes on the commutator. Then remove the housing as after the sanding operation, and inspect each brush seat, which is shown by a polished surface.

If at least a 75 per cent brush seat is not obtained, the wedges should be inserted again and the brushes reseated until a good seat is obtained. It may be necessary to make the wedges slightly thinner, or thicker, according to whether the seat is on the heel or toe of the brush.

It is very important that good brush seats be obtained before installing the generator on the car. If good seats are not obtained, a change in the charging rate will result as soon as the brushes become thoroughly seated.

Setting Motor Brushes

Motor brushes should be set at the position of **least sparking** when the machine is carrying **full load.** This position will be located a short distance back (in the direction opposite to rotation, instead of with direction, as on a generator) from the neutral plane.

To set motor brushes in the correct position, place the machine on a block test and apply a load approximately equal to that which it is normally required to carry. (This load will be about 40 lbs., on a pulley of 6″ diameter, or 10 ft. lbs. for starting motors.)

The speed of a motor is greatest when the brushes are at the neutral plane, and decreases as they are moved away from that position. The voltage of a generator and speed of a motor can be changed considerably by moving the brushes, providing the machine is not too heavily loaded so that it will not spark badly.

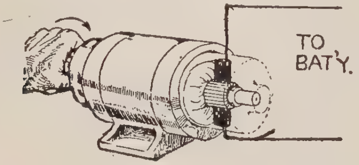


Fig. 24

In the absence of a torque-testing device, **a good method for setting brushes on a starting motor** is to place the motor on a "free running" test, no load (connected with battery), and to hold the shaft by hand, with a rag (Fig. 24), so as to offer more or less resistance; then shift the brushes to a point where they do not spark.

Setting Generator Brushes

If the generator will not come up to voltage, and the trouble is not due to improperly seated brushes, and the third brush is properly adjusted, set the brushes on "neutral" and then shift to the best position. See page 360, relative to neutral position.

Note. Use only brushes recommended by the manufacturer.

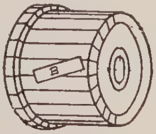


Fig. 25. Showing incorrect setting of brush on commutator.

Brushes should be set parallel to the commutator segments. Improperly seated brushes will act like a cut-out which is not working properly.

Brush Care

Once or twice a season the springs holding the brushes against the commutator should be raised and the brushes examined, to see that they operate freely in their holders. Oil or dirt should be removed with a stiff bristle brush and gasoline.

To Clean the Brushes

It is not necessary to remove them from the holders. Lift the brushes and wipe off the surface with a piece of cloth dampened with gasoline.

If the brush surface is apparently rough, then use sandpaper to fit them to the commutator, as shown in Fig. 21.

No lubricant is to be used on commutators, as the brushes are usually self-lubricating. Application of vaseline or grease is harmful, as all forms of grease possess insulating qualities to a greater or less extent.

Miscellaneous Brush Troubles

When spring tension fails, the brushes are worn too short, the tension is not adjusted or has been thrown out, through heat, or the springs themselves may be broken.

When the brushes stick, it may be due to binding or to dirt and grease. A little gasoline may tend to loosen them. When the brushes do not fit the brush-holders it is a matter of manufacture.

Overheating of brush-holders is caused by the sparking due to ill-fitting brushes or to the absence of brush lead connection and to lack of sufficient pressure on the brush.

Sparking at the brushes: If there is any sparking, or if the commutator becomes dull, it may be that the brush-holder springs are too loose, or there is excessive vibration, which may be due to a bent shaft, an unbalanced gear pinion, or to defective mounting. Brushes should be kept in perfect contact with the commutator, and it is advisable to use only the kind recommended by the manufacturer.

It may be found that where the generator is also used as a starting motor (on motor-generators), **sparking will in time develop at the commutator.** This is due to the arcing of the heavy starting current at the trailing edges of the brushes, and the trouble may be eliminated by filing down their contact surfaces.

Carbon dust (providing carbon brushes are used) may be worn from brushes by the commutator and deposited in the lower part of the generator. **This ought to be blown out with air,** otherwise it might cause a ground.

ARMATURE TROUBLES AND TESTS

In the preceding pages, the subject of **"commutators and brushes"** was treated. This is usually the first place to look for generator troubles.

Other troubles are:

Evidence of trouble: In all probability, trouble in the generator will be clearly shown by failure to generate a terminal voltage. The first warning of such a trouble would be the absence of an indication on the ammeter or indicator on the dash of the automobile, provided one is furnished with the automobile.

Causes: The causes of failure to generate a voltage may be due to (1) open circuits, short circuits and grounds in the field or armature of the generator; (2) the commutator may be dirty, or the brushes may not bear on the commutator, or the commutator may be worn; (3) the brushes may be grounded.

Locating Armature Troubles

Armature windings may be burned out or grounded. When burned out, the trouble may be due to a current overload, caused by improper regulation, a soaked winding, or a steady and prolonged return flow from the battery, due to failure of the cut-out contact points to open. A grounded armature winding is due to defective insulation.

Armature troubles are sometimes found in the attaching leads at the commutator segments. The solder attaching them may be thrown off in revolving. They can be soldered back to the segment by an electrician.

Dim lamps, low voltage, and undercharged battery might be the result of armature trouble. One of the armature coils might be short-circuited, or burned out, or a connection might be loose or broken.

Any defect in the armature will be indicated by an uneven torque, if it is operated as a motor. In the case of the generator, this may be very easily tested by disconnecting the driving mechanism, holding the cut-out points closed, and allowing the generator to operate as a motor. If everything is all right the armature will rotate evenly and in the same direction as when it operates as a generator.

Whether the torque is even or not may be determined by holding the end of the armature shaft in the hand, and noting whether the pull is steady in a manner similar to that described in Fig 24. An uneven pull means that one or more of the coils is not working; it is just like an engine with a missing cylinder. See also Index under "Motoring generator."

If an armature coil is burned out or there is a broken connection, the armature will invariably stop at a certain point; if this is the case, the commutator segments between the two ends of the coil will also be burned. Sometimes the broken connection occurs at the junction between the commutator bar and the coil, in which case the remedy is to resolder. All other armature defects should be left for the factory to remedy.

No current in the generator may be due to an open fuse in the field circuit, the third brush not being properly seated, or to the main brushes not making good contact, or to a broken connection, to a short circuit, or to broken driving mechanism. The last trouble should be looked for first. This simply means that the generator driving shaft should be tested to determine whether it is solidly connected to the engine or not. It is possible that one of the driving keys has sheared off, or that the driving gear, chain, or belt, as the case may be, has failed. See also "Digest of Troubles," page 454.

Loss of Residual Magnetism

The magnetism that remains in the steel or iron field poles and frame after the field current is cut off is called **"residual magnetism"** (see also Index). Sometimes the generator loses its residual magnetism.

When a **repaired generator** has been installed, and possibly with the **field coils reversed,** the residual magnetism left in the field poles would not correspond with the magnetism in the field coils; or when the generator has been in operation for some time with the field fuse out of the clips; or if the generator has been operated with the **battery disconnected,** and the generator terminal grounded, according to the usual instructions, it may be necessary to **excite the field** before the generator will show charge. This is accomplished by momentarily closing the cut-out points so that the battery will discharge through the generator, thus exciting the fields.

On some generators, the field can be excited by momentarily connecting the lower fuse clip to a metal part of the generator. Best results will be obtained with the engine running slightly above an idling speed, and if the operation is continued for several minutes after charging begins.

Submerged Motor-Generator

The generator must be kept free from excessive moisture. Ordinary moisture will not affect it, but it should not be allowed to become thoroughly wet, such as would be the case if the generator were to become submerged under water. This is likely to happen while fording a stream. If the generator is wet, it should not be operated until it is thoroughly dried out. This can be done by removing it from the car and baking 24 hours in an oven whose temperature does not exceed 220° Fahr. A higher temperature in the baking oven would damage the insulation.

Testing Armatures for Grounds and Short Circuits with Test-Light

There are several methods for testing armatures. They can be tested with test-lights and test-points, with a meter, or with a growler.

In this example we shall make use of **the high-voltage test-light** and employ the Delco motor-generator armature, in which there are two commutators and two windings on armature. These tests will also apply to other armatures, or where there is but one winding and one commutator, with the exception of the test in Fig. 28, which is a short-circuit test between two windings on the Delco armature.

When making tests for grounds in armature windings, or short circuits between them, or short circuits between generator and motor armature winding, raise the brushes and insulate them from the commutator with pieces of cardboard.

A grounded generator armature coil will result in slow cranking and materially reduce the charging rate. (Note that the motor and generator winding is on one armature in this Delco armature, which is used as an example).

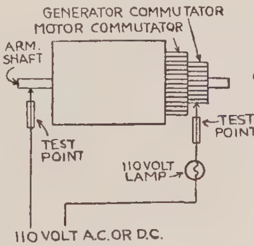


Fig. 26

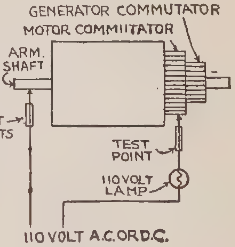


Fig. 27

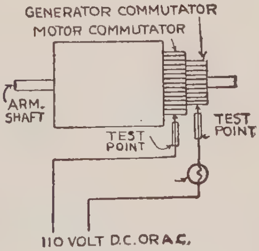


Fig. 28

Figs. 26, 27, 28. Tests with a test-light for grounds in armature. Delco motor-generator armature with two commutators used as an example. Tests apply to any other type of motor or generator armature.

To test whether the armature coil is grounded with the armature core or shaft, see Fig. 26. If the lamp lights, a ground is indicated.

A grounded motor armature coil will cause an excessive amount of current to be drawn from the battery while cranking, or prevent cranking entirely.

To test whether motor armature coil is grounded, see Fig. 27. Place the test-point on the motor commutator instead of on the generator commutator. If the lamp lights, a ground is indicated.

Short circuits between motor and generator armature coils will decrease the speed of cranking and also cause the armature to continue to run after the engine is shut down.

To test, see Fig. 28. If the lamp lights, a short circuit between motor and generator armature coil exists.

Note. The word **"cranking"** refers to the starting motor cranking the engine.

Meaning of Open and Shorted Armature Coils

The diagrams **A, B,** and **C,** Fig. 29, will explain **what is meant by an open and short-circuited armature coil. A** shows diagram of commutator with brushes which make contact with segments and carry the current during the test. It will be seen that the current **divides equally** from the upper brush, passing down each side of the armature coils, or winding circuits, and out at the lower brush, and **if in good condition, the voltage between two commutator segments will be the same.**

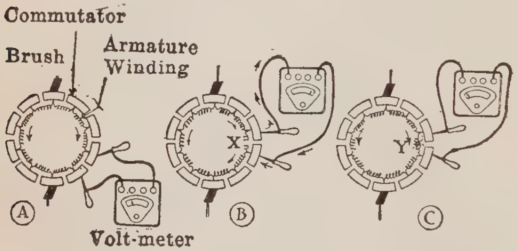


Fig. 29. Diagrams explaining open and short-circuited armature coils.

If an open circuit is in one of the coils, as at (**X**) in diagram **B,** there will be an interruption of current flow on that side, and if test-points of a voltmeter are placed on the two segments shown there will be a big **increase** of the needle, since the meter will carry all of the current flowing down that side. If points are placed on other adjacent segments on that side, there will be nearly a zero reading.

If a coil is short-circuited, as at (**Y**) in diagram **C,** the voltmeter, if placed on the segments shown, will be **nearly zero,** the short circuit having the effect of a shunt across the meter.

Armature Tests with the Volt-Ammeter for Open-Circuited and Short-Circuited Armature Coils[1]

Before proceeding, turn to pages 464, 468, and study the construction of the Weston model "280" volt-ammeter, which is used in the following test.

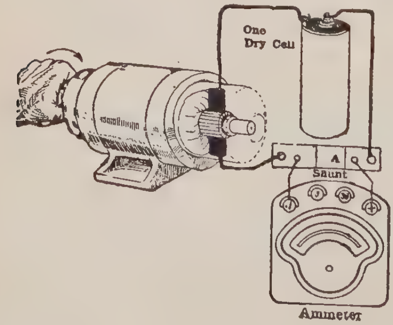


Fig. 30. Testing armature coils with one dry cell and an ammeter.

Open or short-circuited generator armature coils: When testing for open or short circuits in a generator armature, the generator brushes should be left on contact with the commutator; but disconnect the storage battery from the system. Then disconnect the shunt-field from the brushes and connect up two or three dry cells. Use an ammeter having about a 30-ampere scale and also a 30-ampere shunt and connect to the brushes, as shown in Fig. 30.

To test, turn the armature slowly by hand. If the commutator is in good order and the brushes are making good contact, the ampere reading should be the same in all armature coils when the brushes make contact with the different coils through the commutator segments, but if a very noticeable change in the ammeter reading takes place while turning, this will indicate an open or short-circuited armature coil.

It will be observed that this is what would be termed a **"comparative test,"** or where one armature coil is compared with another.

To tell if the generator armature coil is open-circuited or short-circuited, proceed as follows:

To test for open-circuited coil, connect the brushes on the commutator to a dry cell as in Fig. 31, so that about 10 amperes will flow through the brushes. The field winding should be entirely disconnected. Then connect test-points to the 3-volt scale of the meter and measure the voltage across two adjacent commutator segments. The readings should be the same all around the commutator, as the test is made on all commutator segments. But if there is a **material increase in the reading on any two segments,** then there is an open-circuited coil. This test is termed a "comparative test," that is, each armature coil is compared with the others.

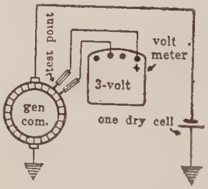


Fig. 31

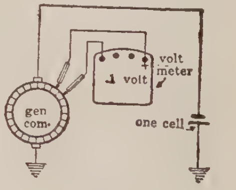


Fig. 32

If there are no open-circuited armature coils, but the test shown in Fig. 31 shows there is some armature trouble, then test for a short-circuited coil. This, however, should only be done after making the test as in Fig. 31, as we shall now use the .1-volt scale of meter, and if there was an open-circuited coil, the voltmeter might be burned out if this test was made first.

To test for a short-circuited armature coil, see Fig. 32. Connect test-points on the meter with the one-tenth volt (0.1) terminal and the (+) terminal. The voltage drop between each two adjacent commutator bars is then tested, and this test is termed a "millivolt drop test." Turn the armature slowly by hand, and test each adjacent commutator segment as shown in Fig. 32. If on testing any of these coils, **the reading drops nearly to zero,** it will indicate that one or more of the armature coils are short-circuited. The reason is stated above. See illustration **C** at **Y** (Fig. 29).

In making these tests, **care should be taken to keep the points on adjacent bars,** otherwise the voltage drop may be sufficient to injure the voltmeter.

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[1] It is advisable to use a small amount of resistance in the circuit, as explained on page 488.

Example of a Millivolt Test of an Armature

By referring to page 465, an explanation of what is meant by a millivolt drop will be found. Also read matter in connection with Fig. 29, explaining why the voltmeter will read less when there is a short circuit than when there is an open circuit in the armature.

This explanation is one of a test used in many service stations where there are many armatures to test.

Procedure: Sand off the commutator with fine sandpaper, and solder on two segments of the commutator 180° apart, two small wires, each about 3 ft. long, No. 18 or 20 gauge (see Fig. 33). Place a 6-volt storage battery and light in series with these connections. In soldering on these wires, it is not necessary to smear the solder all over the commutator. Just enough to make the wires give a good contact will suffice. The solder will not injure the commutator, for it can be removed easily with a knife and a little sandpaper.

Use a voltmeter which will read in millivolts. A millivolt is a one-thousandth part of a volt.

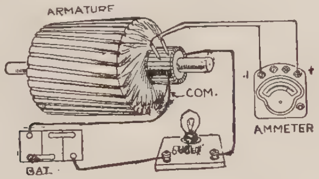

Fig. 33. A millivolt test of armature coils.

Place one of the meter contacts on the segment connected to one of the current wires, and the other contact on an adjacent segment, one immediately adjoining. If the reading of the milli-voltmeter is reversed, reverse the contacts and the reading then will be positive.

The reading the meter gives is the **millivolt drop** through the armature coils connecting these segments together. If the armature is a new one and everything is in good condition, these readings between every adjacent pair of segments will be the same. But if one coil is shorted out, or one turn of the coil is shorted out, this method will tell.

As an example, take an armature with twelve commutator segments connected up according to these instructions. The readings between every adjacent pair of segments are taken and are:

Between Segments	Millivolt Drop
1-2	2.54
2-3	2.50
3-4	2.51
4-5	0.31
5-6	0.01
6-7	2.50
7-8	2.52
8-9	2.54
9-10	2.51
10-11	2.53
11-12	2.50
12-1	2.52

It is seen that the average reading is about 2.52, which is the general result that should be expected for all pairs of segments.

Between 4 and 5 the reading decreases to 0.31. Upon examination of the armature coil we find that there are eight turns per coil. This immediately explains that seven turns of this coil are shorted out and the current is flowing through but one turn, giving an eighth of the drop in the other coil.

Between segments 5 and 6, the reading is just a flutter of the needle. This explains that the whole coil connecting these two segments is burned out and the connections probably have fused together, so that the current flows from one segment to the other commutator segment almost directly.

Note. The needle of the Weston "280" instrument (page 464) will deflect from 0 to right of scale, if 100 millivolts (1/10th of a volt) pass through the coil of the meter, if connections are made with the 100-millivolt terminal marked .1. The scale, however, is not calibrated for millivolts. Therefore in using this instrument a reading of an **armature coil should be made which is known to be good,** and the reading noted. The other armature coils should then read or compare with it.

The light in this example, just given, takes the place of the resistance unit (see Fig. 6, page 488, and explanation, page 488). It puts resistance into the circuit in order to prevent too much current from flowing through the meter.

A GROWLER FOR TESTING ARMATURES

This device (Figs. 34 and 34A) consists of **two laminated cores** (C) around which are wrapped two coils of wire (W). The upper ends of these cores (C) are shaped so that an armature can be placed between them.

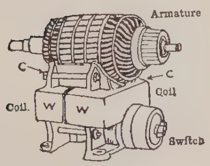

Fig. 34

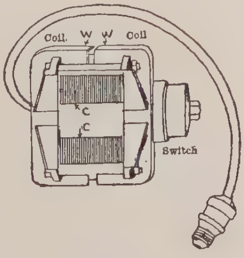

Fig. 34A

Fig. 34. View of growler with armature in place to be tested.

Fig. 34A. Top view of growler.

The principle of this device is very similar to the action of a high-tension coil. See Index under "Principle of a high-tension coil."

By referring to the action of a high-tension coil, it will be seen that when current is passed through the primary winding of the high-tension coil, magnetic-lines-of-force are produced around the wire, and these magnetic whirls cut the secondary winding and thus produce an induced current in the secondary winding.

The principle of the growler is very much the same. The iron cores (C) of the growler would represent the iron core of the spark coil, and they collect magnetic-lines-of-force. The winding (W) around these cores would represent the primary winding of a spark coil. When current is passed through the winding of the coils (W), the action that takes place is the same as sending current through the primary winding of a spark coil.

The current in the primary circuit induces a current in the secondary circuit of the armature coils, and it is by means of these secondary, or induced currents in the armature coils that open and short circuits are located.

The rapid alternations of the current through the coils on the laminated core of the "growler" cause rapid magnetic reversals, and set up a vibration in the core which produces a decided hum or growl, thus giving use to the popular name of "growler" for this device.

When the armature is placed in between the cores (C), the armature winding represents practically the same as the secondary winding on a spark coil. Consequently, if the armature under test is free from short circuits, its coils act simply as an open-circuited secondary winding on a spark coil, and no current is generated in them.

Whenever a short circuit does exist in the armature coils, the circuit thus formed operates as a closed secondary winding, and a heavy secondary current is set up in them, and thus it makes the presence of the short circuit known, as explained later.

The North-East growler (Figs. 34 and 34A) **for testing armatures** is so constructed that it may, without any change in the instrument, be operated either from a 110-volt or 220-volt circuit (Figs. 35 and 35A), and it can test any ordinary armature from 2″ to 4″ in diameter. **It must, however, be supplied with alternating current**—never with direct current—because its operation depends essentially upon the fluctuating character of the magnetic field produced by the alternating current. The growler is designed especially for operation on a 60-cycle circuit, but it can be used with reasonably good results on circuits of other frequencies.

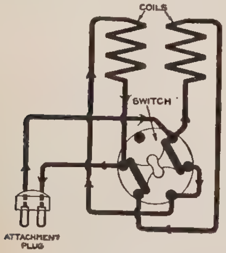

Fig. 35

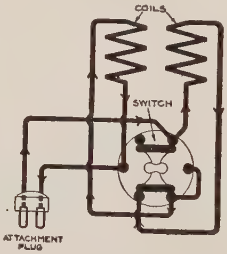

Fig. 35A

Fig. 35. Diagram of N.E. growler circuit with switch in position for 110-volt operation; coils connected in parallel.

Fig. 35A. Diagram of N.E. growler circuit with switch in position for 220-volt operation; coils connected in series.

Internal wiring and connections of the North-East growler is shown in Figs. 35 and 35A. The instrument is equipped with a standard attachment plug for connection to the line, like a lamp or a small motor. The circuit in which the growler is connected should be protected by fuses of not less than 30-ampere capacity, because the current drawn by the growler might exceed 25 amperes if a completely short-circuited armature should be tested in it, or if the growler switch should be accidentally turned on with no armature in position between the pole-pieces.

Note. **Many armatures will test clear on the growler when they are cold,** and show a decided ground after they have become heated up. When an armature is suspected, it is well to leave it on the growler, covered up tightly until it becomes warm.

Of course, reason must be used when doing this, and the armature must not be allowed to heat to the point where the leads will be loosened in the commutator.

Another armature fault, which is very difficult of detection, is grounding while the part is in motion and clearing when it comes to rest. The reason for this peculiarity is that the coils have a slight movement in the slots, and, when the armature gets to spinning, they have a tendency to fly outward.

The F.B. Armature Tester or "Growler" as an Example Showing how Armature Tests Are Made[1]

The parts of this outfit are shown in the illustration (Fig. 36).

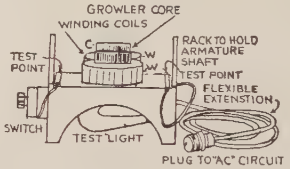

Fig. 36. The F.B. armature tester or growler.

The F.B. armature tester is connected with a 110-volt alternating light circuit. It will test an armature for short-circuited coils (Fig. 37), or for open-circuited coils (Fig. 38), and in connection with the test-light supplied with the F.B. armature tester, armatures can be tested for grounds (Fig. 39).

To Test for Short Circuits in Armature Coils

Place the armature on the core of the tester. Turn on the switch. Hold the "feeler" just above the top of the armature coils (Fig. 37), but not touching, and slowly turn the armature by hand.

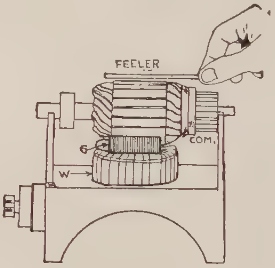

Fig. 37. Testing an armature for short-circuited coils.

If there are no shorts in the armature windings, there will be no magnetizing force in any of the coils, and consequently the "feeler" will not be attracted or pulled toward the coils.

If, however, there is a short between the windings of one coil or between the windings of separate coils, a closed circuit will be formed which will permit of a strong secondary current being induced in the shorted coil or coils.

This induced current will produce two distinct effects: It will heat the wires forming the closed coils, because of the heavy current passing through these wires, and it will also cause the shorted coils to exert a very strong magnetic pull on the "feeler." The magnetic pull on the "feeler" is very strong, and it is a positive indicator of shorted coils.

The heating of the shorted coils may show up almost instantly, or may take a minute or two, depending upon the number of turns of wire included in the closed circuit, and consequently determining the resistance of the closed circuit. The less the resistance of this circuit, the heavier the induced current, and the quicker the coil will heat.

Short circuits in armatures may exist from **three** causes:

1. A short circuit between commutator bars, generally caused by copper dust or particles of brush material collecting in the undercut spaces between the bars.

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[1] Courtesy of the Service Station Equipment Co., Chicago, Ill. Copyrighted.

2. A short circuit caused by defective insulation between the wires of an individual coil.
3. A short circuit caused by defective insulation between wires in separate coils.

Short circuits from any of these causes will be indicated by the action of the "feeler" as described. If the "feeler" is attracted by only one coil, it indicates a short between the turns of that individual coil. If, however, the "feeler" is actuated by more than one coil, that is by coils situated in different slots in the armature, it indicates that the short is caused either from a commutator short or a short between the windings of different coils.

Always clean the space between the bars if any shorts are found, in an effort to eliminate troubles from this source.

To Test for Open Circuits in Armature

Open circuits in either the generator armature or the motor armature may be caused from two sources:

1. A broken wire in the coil windings.
2. A broken connection between the end of the coil and the commutator riser.

A poor soldering job or a dirty wire at the point where the coil end is connected to the commutator riser will also cause an open circuit and it is from this source that most open circuits result. Defective workmanship at this point can be detected by careful inspection after the particular coil or coils that are open have been located with the tester. Troubles from this source can easily be repaired and do not necessitate returning the armature to the factory for rewinding.

The condition of the commutator is also a good indicator of open circuits. Wherever an open circuit occurs the commutator bar or bars to which the coil is attached will generally be found badly burned and with a flat spot, caused by the continual arcing between the brush and the commutator every time the bar, to which the open coil is attached, passes under the brush.

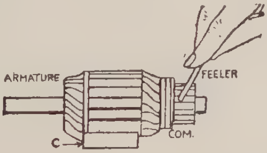

Fig. 38. Testing an armature for open-circuited coils.

To test for open-circuited coils, put the armature in the tester in the same way as described for making tests for "shorts." Then with the "feeler" make a connection between two adjacent commutator bars, as shown in Fig. 38, and then break this connection. A decided spark should occur if the coil is not open.

When contact is made by the "feeler" between two commutator bars, it forms a short circuit in the coil whose ends are connected to the bars, and a secondary current is induced in the coil.

When this current is broken by breaking the connection between the bars, a spark is produced. **If the coil is open,** through a poor contact between the coil end and the commutator, or because of a broken wire in the coil, no current will be induced in the coil and consequently no spark can occur when the contact made with the "feeler" is broken.

Make this test all the way around the commutator between each bar, and the open circuits, if any, will be clearly indicated by the absence of a spark.

To Test for Grounds in Armature

The "test-points" provided with the F.B. armature tester[1] are for use in locating either grounds or open circuits on the armatures that are being tested, or on any electrical device.

The ends of the test-points are connected to the source of current, with the indicator lamp in series. When the two points are touched together, the circuit is completed and the lamp is lighted.

In the same manner, by holding one test-point each on different parts of an electrical device, the lamp will indicate a complete circuit if it lights, and no circuit or an open circuit if it fails to light.

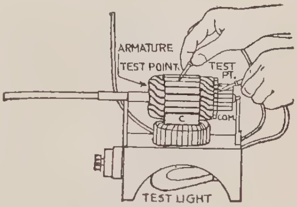

Fig. 39. Testing armature for grounded armature coils.

To test the armature for grounds, hold one test-point on the commutator and the other point on the armature core, as shown in Fig. 39. This circuit should show open and the lamp should not burn. If it shows closed, by the lighting of the lamp, it indicates that the armature is grounded.

Grounded armatures are caused by defective insulation in the armature slots or by a grounded commutator.

Grounded commutators are generally caused by defective insulation between the commutator bars and the armature shaft, and in such cases must be returned to the factory for repairs.

If the ground is caused by copper dust or brush material collecting on the end of the commutator and forming contact between bars and shaft, it can easily be cleared up by removing dust or dirt.

FIELD WINDING TROUBLES AND TESTS

The troubles occurring in a field winding are usually: open circuits, short circuits, or grounds.

An open circuit in a motor-series field winding renders the motor inoperative, because any break in a series circuit opens the circuit.

An open circuit in a generator shunt winding will prevent the generator from generating current.

The shunt-field windings, usually used on generators, are of finer wire than a series-field winding. The shunt-field winding forms a bypath or shunt for the armature current. Being of finer wire, it is of high resistance, so that it will take but a small part of the armature current. The shunt-field windings are subjected to the full voltage of the generator, as shown in Fig. 40.

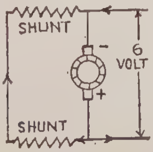

Fig. 40

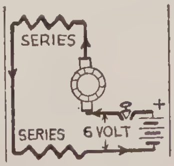

Fig. 41

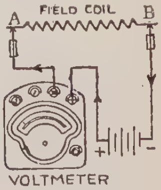

Fig. 42

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[1] Can be secured of A. L. Dyke, Electrical Dept., Granite Bldg., St. Louis, Mo., price $24.00.

The series-field windings generally used on motors and motor-generators are of coarse heavy wire, are in series with the armature, and must carry all the current that passes through the armature (Fig. 41). The series-field windings are of very low resistance; hence they consume as little as possible of the voltage supplied to the machine.

By referring to Fig. 42, the connections to a voltmeter are made clear. If the free ends of these wires are touched together, the voltmeter will indicate the terminal voltage of the storage battery. This reading should be kept in mind.

Now, if instead of touching the ends together, they were placed on the terminals of a rather high resistance, the voltmeter would give a much **lower reading,** the value of this reading depending directly upon the amount of resistance between the ends. If there is no circuit at all, as for instance, when the ends are held apart in the hands, the voltmeter needle will stand at zero.

An open-circuited coil will be indicated by a zero reading of the voltmeter, when the two free ends or "points" are placed upon the terminals of the field coil at (A) (B) (Fig. 42), which represents a certain amount of resistance. If, on the other hand, the reading is very nearly that of the battery voltage, the field coil is in good condition.

Therefore if a voltmeter is placed on the ends of a **shunt winding,** which is of a higher resistance than a series winding, the meter would read less on a shunt winding than on a series winding, because, the wire of the shunt winding is smaller than the series winding and the resistance offered to the passage of current would be greater, with a consequently greater voltage drop, whereas, if the meter was placed on the ends of a series winding, the meter reading would be greater, or nearer the battery voltage, because the resistance offered to the passage of current in the large wire would be less.

Right here is the difference between a voltage reading and a millivolt reading. If we were making a test of the **millivolt drop** in the shunt and series field coil, then current would be passing through the coils instead of the coil being in series with the meter. We should then be measuring the **voltage drop,** which would be greater in a fine-wire shunt field than in a coarse-wire series field.

If an armature or field is short-circuited or grounded, the machine may not necessarily be inoperative altogether. This will depend upon the nature of the short or ground, but it will cause a generator to generate less output, and will cause a motor to draw more current and produce sparking.

Testing Field Windings with a Meter

Meter tests for an open-circuited, short-circuited or grounded armature and for short-circuited or grounded field-coils are the same in principle as described under the tests for a motor, and explained on pages 487, 488.

A meter test for a generator-field open circuit (Fig. 43), is different from the test of a motor-field open circuit (Fig. 4, page 487).

Disconnect the field terminals from the other parts of the generator, including the field regulating devices. Connect the negative (−) terminal of one cell of a battery to one end of the field, and the positive (+) terminal to the (+) binding post of the instrument. Complete the circuit between the 3-volt binding post and other end of field. **If an indication is obtained,** the coil is not open-circuited, but if **no indication is obtained,** the coil is open-circuited.

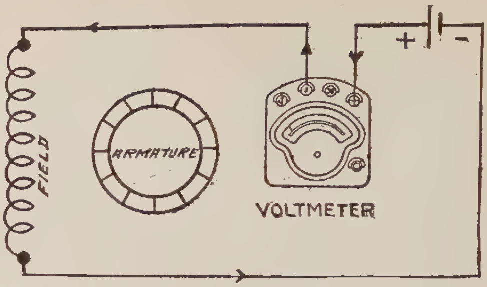

Fig. 43. Connections of voltmeter for testing for open-circuited generator fields.

Testing the Delco Motor-Generator Field-Coils with a Test-Light

To test for grounds in the field-coils of a motor-generator, place one point on the frame of the motor-generator at (F), and the other on the terminal of the field-coil at (B) (Fig. 44). Be sure that all grounds which are regularly connected to these terminals are first removed.

If the lamp lights, a ground is indicated. **If it fails to light,** the coil circuit is in good shape.

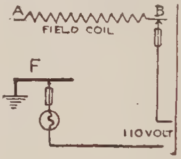

Fig. 44

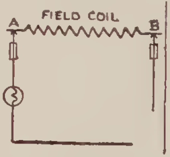

Fig. 45

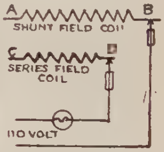

Fig. 46

To test for open circuits in the field-coil, place test-points, as shown, on each terminal of the winding, at (A) and (B) (Fig. 45).

If the lamp fails to light, the circuit is open. The coil should be replaced or repaired.

To test for short circuits between motor-generator windings: The test here is between the "shunt" and "series" field winding.

Place one of the test-points on the terminal of the shunt-field winding (B) (Fig. 46), and the other test-point on the terminal of the series winding at (D).

If the lamp lights, a short circuit is indicated between the windings.

Replacing Field-Coils

When replacing field-coils on a generator, it is not always possible to tell which way they are wound in order to make one field-pole North and one South.

Each field-pole must have opposite polarity, that is one must be South and the next North, the next must be South and the next North. The practice is to place the field-coils on the pole pieces, and then to connect them together temporarily and connect with a battery, as shown in Fig. 49. A compass then placed on the outside of the field-frame will show if each pole has a different polarity, that is if one is N and next S, and so on. Field-coils on a 6-volt generator will draw about 3 to 5 amperes. Each adjoining pole should show opposite polarity.

Most generators have field-poles which can be removed by loosening a screw which holds the pole in place. The pole-tip or flange end next to the armature holds the field-coil tight to the frame. It is very important that these field-coils be punch marked and that the frame be punch marked, so that both can be put back exactly correct, otherwise the field-coil may not fit properly and the air-gap clearance between the armature and the field-pole tip may not be as it was originally.

On a starting motor the wire in the field-coils is much larger and of less resistance than on generator field-coils, and while the same test can be made, it is only possible merely to touch battery terminals for a fraction of a second, otherwise it is practically a dead short circuit on the battery. Most starting motor coils come in pairs, and two will have the same appearance and can easily be distinguished. The idea is to alternate them on the poles.

When the polarity is correct, solder the connections and tape with cotton tape, as the ordinary friction tape will soon become oil-soaked and loosened. This tape is white and is called English twilled tape.

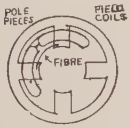

Fig. 47

Fig. 48

Fig. 47. Illustrating how field-coils are held in place on the field-poles by a strip of fiber. This method is generally used where field-poles are **not detachable** from the outside of the frame by means of a screw.

Fig. 48. Illustrating the appearance of a field-coil winding ready to apply on the field-pole.

On pole-tips which are cast to the frame and not detachable, the pole-tip is usually small at the end next to the armature. The field-coils can be slipped over the pole-tips on to the pole-piece or core. A fiber strip about ⅛″ thick (Fig. 47) is then placed under the coil in a groove, from one pole-tip to the other, and will thus hold the coils in place.

Remy Instructions on Field Polarity

Reversed field-coils: Field-coils are not likely to be connected wrong when the machine leaves the factory, and cannot possibly become reversed when in operation. This trouble, therefore, is very unlikely to be encountered unless the machine has been disconnected for repairs and is then connected up wrong.

To locate a reversed field-coil: With the field excited (connected to the battery), and the armature out of circuit, approach each field-pole with a compass, taking them in succession. If connected properly, each pole will attract the end of the compass needle opposite to that which the preceding or following pole attracts.

Care should be exercised, in making this test, to approach each pole with care, and not to slide from one pole to the next without taking the compass well away from the machine, as the polarity of the compass needle is very likely to be reversed and incorrect results to be obtained.

Finding the Polarity of Field-Poles (Ford Generator as an Example)

Care should be taken that the leads on the generator yoke are connected to the proper brush terminals. The earlier fields were wound opposite to the later, and it is therefore necessary to cross the leads on the latter. To determine how they should be connected, test the field with a battery and compass as follows (refer to Fig. 49):

The generator is placed on its end with the commutator end up and the terminal to the left as shown. A 6-volt battery is connected to the field-coil leads. Current will then flow through the field-windings or coils, and in doing so, the field-poles will become an electromagnet.

One end of a field-pole will be North (N) and the other end South (S) of each field pole, of which there are four.

Therefore, by placing a compass, say, at the frame end of field-pole No. 1, the N pole end of the compass needle (the dark or arrow-point end of a compass needle is the N pole end) will point toward the field-pole, and the end of the field-pole next to the generator frame will be the S pole and the inner end will be the N pole.

By placing the compass needle at the frame end of the next field-pole (No. 2), the S pole end of the compass needle will point to the field-pole, and the end of the field-pole next to the generator frame will be the N pole and the inner end will be the S pole.

The outer end of field-pole No. 3 will be S and the inner end N; the outer end of field-pole No. 4 will be N and inner end S. Thus it will be observed that the polarity of the field-poles alternate and those field-poles which are opposite each other are of the same polarity.

If the poles do not indicate with reference to the terminals as shown in the diagram, reverse the leads of the field-coils to the battery wires and test with the compass again. If they indicate properly now, the lead attached to the positive (+) wire from the battery is the one to be attached to the **third brush,** and the other is attached to the grounded brush.

The reason why the N pole of the compass needle points to the S pole of a magnet or field-pole is the fact that the magnetic lines-of-force flow from N to S (see Fig. 1, page 179), and the N pole end of the compass needle will always point **with** the direction of flow of a magnetic circuit. For example, the magnetic lines-of-force flow out of the N pole end of field-pole No. 1, into the S pole end of field-pole No. 4, out the N pole end of No. 4, through the frame **into** the S pole end of No. 1, thus completing a magnetic circuit; and the N pole end of the compass needle, will point **with** this direction of flow.

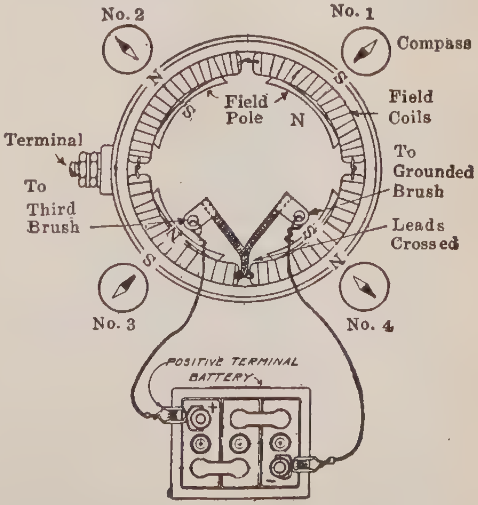

Fig. 49. Testing the polarity of field poles with a compass after placing the field coils on the field poles.

Therefore when a compass is placed over No. 4 field-pole, the outer end is the N pole and the magnetic lines-of-force will be coming out instead of going in, as at the S of No. 1; consequently the N pole end of the compass needle will point with the direction of flow, and thus the S pole end of the compass needle will be toward the N pole end of field-pole No. 4, as shown. The same action takes place in No. 3 and No. 2 field-poles. See also Index under "Magnetic circuits of field-poles."

Another Method of Determining Proper Connection of Field Terminals to Brushes

When the generator is assembled, **operate it as a motor** from the battery. If it runs in the wrong direction, the field terminals should be reversed. If it does not run at all, the field coils are mounted wrong. The proper direction of the generator when motoring is counter-clockwise when looking from the commutator end, or, in other words, **the same direction in which the engine drives it as a generator.**

CUT-OUT TROUBLES, TESTS, AND ADJUSTMENTS

Although the construction may vary, **the principle of all cut-outs is very much the same.** See also Index under "Testing the cut-out."

Sometimes, due to the cut-out points (P) (Fig. 50) sticking and not opening when the engine stops, the battery discharges for a long period of time through the cut-out at about 20 amperes, which will often burn out[1] the voltage winding (V). The result is that if the points (P) are still stuck when the generator is started again, it will charge the battery, but the battery will again discharge instantly, the moment the engine stops.

If the points (P) should be open, with a burned-out cut-out voltage winding (V), the core will not become magnetized sufficiently to draw the points together. Thus the generator will not charge the battery, or the cut-out armature may intermittently cut in and cut out in a feeble effort to close, and the ammeter will fluctuate back and forth as it cuts in and cuts out.

Function of the Cut-Out

The function of the cut-out is fully explained on pages 332, 519, and should be studied carefully.

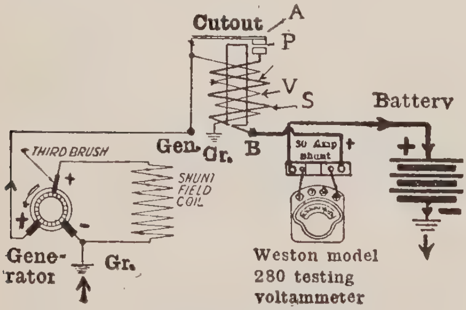

Fig. 50. Method of testing a cut-out.

There are two windings on the cut-out, a fine-wire voltage winding (V) (Fig. 50), and a coarse series winding (S).

The fine-wire voltage winding (V) is always connected across the generator main circuit, but takes very little current.

The series or winding (S) is in series with the circuit to the battery from the generator.

On the Delco some of the very old models had cut-outs, but later on the cut-out was dispensed with entirely (see page 387). On the late two-unit Delco systems the cut-out is used.

See discussion of Remy cut-out adjustment on page 351; Delco, page 409, and North East (Dodge), page 372.

Cut-Out Troubles and Adjustments

If the cut-out points stick and fail to open, the battery will discharge back through the generator.

It is well to mention here that it is **permissible for the battery to discharge from 0 to 3 amperes back through the cut-out** at low generator speed. This is usually the case, as explained on page 333, as the series coil (S) which opens the points is thus demagnetized. If, however, the points fail to open, then as high as 15 to 20 amperes will discharge through the generator, and thus will run the battery down.

If the cut-out points fail to close, the generator will not charge the battery.

Failure of the cut-out points to open may be due to:

1. **Not sufficient air-gap space** between contact arm blade (A) (Fig. 52), and the iron core of the cut-out coil (G). This can be remedied by slightly increasing the spring tension controlling the pull of the blade.

Note. The spring is not shown in this illustration. See pages 333, 351, 373. The **air-gap space** between (A) and the armature core (C) (Fig. 52) is usually .010" to .015" clearance.

If the cut-out is slow to cut in, then this air-gap should be slightly decreased by bending the contact blade, which moves the blade or armature (A) closer to the core (C). On some of the Westinghouse cut-outs, there is a screw for this purpose. Poor brush contact will also cause the cut-out to cut in late.

If the cut-out cuts in too quickly, increase the spring tension which holds the contact-arm, or increase the air-gap.

2. **Pitted points are also the cause of failure to open.** This may be caused by: (a) long usage; (b) excessively high current output of the generator; (c) insufficient spring tension; (d) improper operation of the generator.
3. **Defective windings,** such as a short circuit, may also be the cause of failure to open.

Failure of cut-out points to close may be due to:

1. Air-gap clearance (G) (Fig. 52) too great.
2. Spring tension too strong.
3. Open cut-out windings.

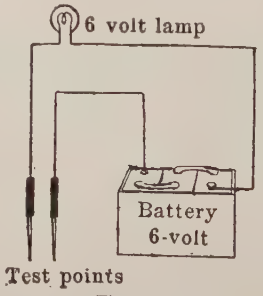

Fig. 51

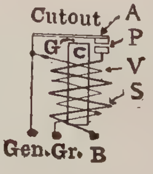

Fig. 52

Fig. 51. Test points, battery and lamp used for cut-out tests.

Fig. 52. Cut-out winding terminals.

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[1] Burned-out cut-out voltage coils are also sometimes occasioned by running a car with the charging circuit opened without grounding the generator, or by a loose ground connection.

To Test the Cut-Out Windings

To test the cut-out voltage winding (V) (Fig. 52): Use four cells (8 volts) of a 12-volt storage battery. Disconnect the cut-out from all circuits. Place one lead from the battery on (Gen.) and the other lead on (Gr.). The cut-out points (P) will close quickly if the voltage winding is in good order.

To test the cut-out voltage winding for a ground. (Fig. 52): Place one test-point (Fig. 51) on (Gen.) and the other on (Gr.). If the lamp lights, but the cut-out points (P) when tested as in the preceding paragraph, fail to close, this indicates a ground, or too great an air-gap at (G), or too much spring tension.

To test for an open in voltage winding (V), make the same test. If the lamp fails to light dimly, winding (V) is open.

To test the cut-out series winding (S) (Fig. 52): Place one test-point on (B), which is the end of the series winding (S) leading to the battery. Place the other test-point on (Gen.). The lamp should fail to light, as the cut-out points are open at (P), but the lamp should light when the cut-out points are held closed by the hand.

To test series winding (S) for a ground (Fig. 52), place one test-point on (B), the other on (G). The lamp should fail to light.

After testing the cut-out windings, proceed as follows:

Method of Testing the Cut-In and Cut-Out Speeds of Cut-Out

1. **Connect cut-out between generator and battery,** as shown in Fig. 50, as if on the car. Use the 30-ampere shunt with testing ammeter. We shall assume the driving method is as shown in Figs. 15 and 16, page 477.
2. **Use the pulleys for the 675 speed.** Permit the belt to slip when first starting, and gain speed gradually. The cut-out should cut in, or close at about 650 to 675 r.p.m. It will be heard to click when it closes, and about 1 ampere will show on the meter.[1]

   Permit the belt to slip, and thus slow down the speed of generator, or use the pulleys for the 450 r.p.m., and see if the cut-out cuts out below 600 r.p.m.

   The cut-out, with most generators, cuts out when the generator speed is low enough to permit the battery to discharge slightly back through the series winding (S) of the cut-out, which demagnetizes the series coil, releasing the points. This discharge varies from 0 to 3 amperes.

   The foregoing refers to testing the cut-in and cut-out speeds of the generator. We will proceed with the **complete generator-driven test,** using a Ford generator as an example.
3. **Use the pulleys for the 1,425 speed.** At about 1,400 to 1,500 r.p.m. the generator should deliver 10 amperes.
4. **Use the pulleys for the 1,800 speed.** At about 1,800 r.p.m. the generator should deliver its maximum of 12 amperes. The generator is, however, capable of giving a higher amperage, but 12 amperes is the maximum according to the manufacturers' instructions. About 15 amperes is really necessary, however, to keep the battery charged. If more is attempted, the generator will heat.
5. **Use the pulleys for the 2,400 speed.** At speeds over 1,800 the amperage should not increase over 12 or 15 and should drop off at high speeds, or over 1,800 r.p.m.

If the amperage is more at the speeds mentioned above, the rate can be decreased by moving the third brush in the opposite direction to the rotation of the armature.

If the amperage is less, the rate can be **increased** by moving the third brush with the direction of rotation.

If an "external regulator" is used, adjust the regulator. See page 350 for the Remy. See also Index under "Adjusting third-brush regulated generators."

If, after adjusting the third brush, this does not give the desired readings, then operate the generator at 1,400 to 1,800 r.p.m., and note if there is a flashing at commutator and if there is a smell of burned insulation; if so, **the armature coil is probably short-circuited** and a separate test of the armature for a short-circuited coil should be made. See pages 497, 498, 499, 516. Be sure, however, that the flashing is not due to loose brushes, protruding mica, etc., as previously explained.

A short-circuited field-coil will also cause sparking, but not so much heat, because the other field-coils will take the load which is cut out of the shorted coil, and they will probably heat.

Other tests of armature coils and field-coils are shown on pages 497 to 499 and 513 to 519.

Example of Locating Cut-Out Trouble ("Overland 4" as an Example)

Trouble: We will assume that the battery cut-out fails to close and that after closing it by hand, will find that it remains closed and the generator charges the battery until the engine stops, when the points open as they should, but will not close when starting the engine again. We will assume that a new cut-out was installed, and the result remained the same. The generator makes a grinding noise when the points are closed.

Causes: The initial current from the generator flows through the binding-post of the cut-out marked "To + Gen.," through the metal framework of the cut-out and through the cut-out core.

The fine winding (V) of the cut-out core, termed the voltage or shunt coil, is connected to the core at one end and to the binding-post marked (2) at the other (see Fig. 53).

Binding-post (2) is grounded, that is to say, to be attached to some part of the metal of the chassis.

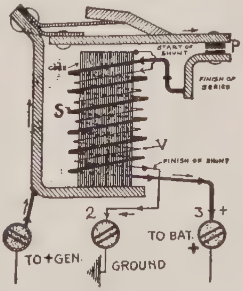

Fig. 53. Overland "4" cut-out.

As the opposite side of the generator is also grounded, it is apparent that so long as there is no break in the circuit the initial current will flow through the shunt winding of the cut-out and, energizing the core, cause the points (P) to be closed.

Next, examine the other circuit. From the binding post to the left, the current flows through the iron frame of the cut-out, through the movable arm—called the armature—which carries one of the cut-out points. When these are brought together, the path of the current is through the lower, stationary cut-out point, through the heavy winding of the cut-out, called the series or current winding (S), to binding-post (3), and thence to the battery.

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[1] The Service Manuals, advertised in the back of this book, give the cut-in and cut-out speeds, voltages, etc., of different models of generators of all makes.

As the cut-out remains closed after having been closed by hand, it is apparent that this circuit as well as the generator is normal, providing the ammeter indicates "charge" with the points closed.

It is likely there is either a break in the fine winding of the cut-out or that the ground connection between binding-post (2) and the chassis is either broken or dirty.

The winding (S) can be tested with a 110-volt test-line wired in series with a 110-volt bulb. Do not attempt to make the test without using the bulb.

Apply one test-point on the binding post to the left, and the other on binding-post (2). The lamp should light, although not up to full candle power. Should it light and burn up to full brilliancy, the probability is that the fine winding is short-circuited or in contact with the iron of the core somewhere with its coils. On the other hand, if the lamp should fail to light at all, a break in the winding is indicated.

The remainder of the test had best be made with a 6-volt battery, as the high-voltage current is quite likely to overcome the resistance of a dirty connection and give a clear indication.

With two wires connected to a test battery—not the one on the car—test between terminals (2) and any clean part of the chassis. There should be a flash. If there is not, the proof is conclusive that the ground connection between terminal (2) and the chassis is at fault.

To corroborate this, attach a wire to terminal (2), fastening the other end underneath the head of an engine bolt or nut. Start the engine and bring it up to speed. If the generator is operative and the cut-out has tested normally, current should flow. The points should close and everything should operate satisfactorily.

The fact that a new cut-out is installed would indicate that the trouble will be found in the ground connection.

The noise of the armature is caused by one of three things: (1) the generator is not charging, and when the points are brought together by hand the battery current discharging back through the apparatus causes it to drag, knock, and growl; (2) the new armature is short-circuited in one or more coils; (3) the bearings are not all that they should be. So long as the generator is not delivering current, it simply runs idle, absorbing very little power, but as soon as it begins to generate, an extra load is thrown upon the bearings; and if these are not in good condition and in perfect alignment, the noise will result. (*Motor Age.*

CONNECTING CUT-OUT WHEN TERMINALS ARE NOT MARKED

Every cut-out has three terminals: One of these terminals may be invisible, as it is connected to the ground of the cut-out case (see Fig. 50, page 504, and Fig. 54 below).

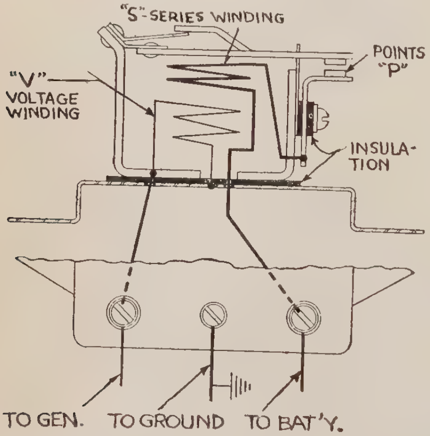

Fig. 54. Internal wiring of a typical form of cut-out (see also Fig. 24, page 520). The core on which the two windings (V and S) are wound, and which becomes magnetized and draws the armature blade (blade at top with upper point P) to it is not shown. The core is shown in Fig. 50, page 504, and page 333.

The lower part of the illustration shows the connections to the base of the cut-out. These terminals are not always marked.

To locate terminals of voltage coil (V): Use a 110-volt **A.C.** test light. Connect terminals of test light to various combinations of two terminals on the cut-out. When those two terminals are touched, which give a dim light and a buzzing of the cut-out points, the test points are across the voltage coil.

The reason **why the light dims** is that there is great resistance in the fine-wire voltage winding (V). The reason of the buzzing is the magnetization of the current flowing through the voltage coil (V), which causes the cut-out points (P) to close, but owing to the alternation of the current the cut-out core is rapidly magnetized and demagnetized, as the current flows alternately in opposite directions. Thus the points are closed and released rapidly, causing the buzzing effect.

To locate terminals of current or series coil (S): Use the 110-volt test light. Close cut-out points by hand. Place test light on terminals, and test as above. Those two terminals which give a bright light with the cut-out points closed, and no light with the cut-out points open, are connected to the current coil.

This is **due to** the low resistance of the heavy winding of the current coil (S). The lamp goes out when the cut-out points are open because the circuit is then open.

Determination of terminals: The one terminal which was used in both tests above should be connected to the generator. The other terminal of the voltage coil should be grounded. The other terminal of the current coil should be connected to the ammeter and battery (see Fig. 50, page 504).

The **reason why** the one terminal which was used during both tests above should be connected with the generator is that this terminal is connected to both the current coil (S) and voltage coil (V) (see Fig. 50, page 504).

ADJUSTING OUTPUT OF DIFFERENT GENERATORS

The third-brush type of generator is the type used most, and the adjustments of the different makes of third-brush regulated generators are shown on pages as follows:

Delco third-brush regulated generator	pages 407-409
Remy third-brush regulated generator	page 363
North East third-brush regulated generator	pages 374, 375
Bijur third-brush regulated generator	page 364
Ford third-brush regulated generator	page 516

Adjusting the charging rate of generators using an electro-magnetic vibrator regulator instead of a third brush to increase or decrease the output is usually by means of an adjusting screw which increases or decreases the spring tension of the regulator. Some of these regulators control the voltage output of the generator and some control the current output, and some makes control both the current and voltage, as explained on pages 346-348. See also page 350.

The average amperage charge of the generator to the battery, with lights off for winter use, is approximately 18 amperes, and in summer 12 to 14 amperes. In some instances the generator is set to give 1 ampere for each plate, that is, if the battery has 13 plates, the rate is set for 13 or 14 amperes with all lights off.

Too high a charging rate will produce sparking at the brushes, which will pit and burn the commutator and will also necessitate taking up on the chain tension which often produces a singing noise. The bearings will also feel the effects in time of a higher charging rate, owing to the increased tension of drive chain.

When increasing the charging rate, be sure it is not enough to produce sparking. If sparking is produced, see if brushes and commutator are in proper condition, and if so, and sparking continues, then the charging rate should be set back.

The main point is to keep the battery charged without over-charging, and this can be determined by testing the battery which should show around 1280 s.g.; the temperature of the solution should not rise above 105° F. (see page 572).

To tell when a battery needs charging and when to increase the generator output, see page 563.

INSTRUCTION No. 45

EXAMPLE OF A MODERN METHOD OF MAKING ELECTRICAL TESTS

(Ford Generator, Motor and Cut-Out as an Example)[1]

The F.B. Test Stand, designed for testing the Ford starting motor and third-brush regulated generator and the cut-out, as described, will be used as an example in the following discussion.

Most all generators of the present day are of the third-brush type. Tests of other makes of generators would, therefore, be similar in principle to the test of the one selected as an example. They differ however in the amperage generated and in the speed at which the cut-out cuts in and cuts out.

It is impossible in this book to give data for the test of all generators. We recommend therefore that the repairman purchase the Service Manuals which give data concerning the speed, amperage, and voltage to test different makes of generators, cut-outs, starting motors, etc. See also the advertisements in the back of this book, describing these data books. The Wiring Manual as mentioned in the advertisements is also very necessary for general automobile electrical work.

MODERN ELECTRIC TESTING EQUIPMENT

Testing equipment is divided into two distinct classes: (1) equipment for testing and repairing the starting and lighting system **while it is installed on the car;** (2) equipment for testing and repairing the various units of the system after they have been **removed from the car.**

The first tests are made with a combination voltmeter and ammeter, such as the F.B. test set (or the Weston, described on page 464, or other makes of instruments).

The second tests are made with a testing stand, an example of which will now be given.

The F. B. Test Stand[2]

This stand is designed solely for use with the F.A. starting and lighting systems used on the Ford car. The illustration (Fig. 1) and parts will give an idea of how a modern testing stand is constructed.

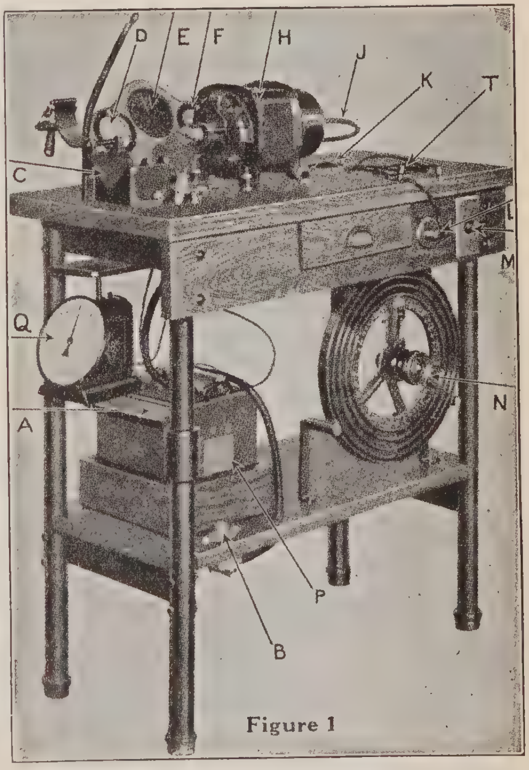

Figure 1

Parts for Testing Starting Motor

B is the **starting switch** connected between **battery** **(P)** and the wires leading to the top of the stand for testing the starting motor on a "free-running" test.

D is the **motor ammeter** connected in the circuit just mentioned, and shows the amperes of current used in the test. It reads 0 to 1,000 amperes.

A is a **swinging shelf** for the **scale** (Q) which is used for the "torque" or "kick" test of the starting motor. When a torque test is made, the motor is placed in **stand** (C) and connected with the battery.

A **brake-arm,** one foot long, is attached to a sleeve which slides over the motor shaft. The swinging shelf with scale is pulled out and an **extension** from the brake arm rests on the scale.

The **starting-switch** (B) is pressed, and when the motor stalls or cannot turn because of the resistance to rotation by the scale, the pound pull on the scale indicates the **torque** of the motor armature shaft.

If the motor is in good condition, the scale (Q) should read 12 to 14 pounds and the ampere-meter should show a current draw of 600 to 750 amperes.

As the gear ratio between the Bendix gear on the motor and the gear on the flywheel on the engine is 12 to 1 (Ford starting motor), this means that the motor under these conditions is exerting a turning effort of 168 pounds on the end of the starting crank 1 foot long (12 [gear ratio] x 14 pounds = 168 pounds).

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[1] We are indebted to the Service Station Equipment Co., Chicago, Ill., for data and information concerning the Ford tests given in the pages following.

[2] The later model of this test stand is now equipped with a bench lathe, attached to the front of the stand, and driven by the universal motor and a jack shaft on the stand. The lathe has a swing of 7". Extreme distance between centers, 12". It is furnished with slide rest, slotted face plate, arbor clamp dog, ¼" drill chuck, and saw arbor. Both head and tail stock are provided with centers. The lathe can be used for turning, sanding, and under-cutting mica of armature commutators and for many other jobs which are necessary to do around a service station. Price $241. Can be secured of A. L. Dyke, Electrical Dept., Granite Building, St. Louis, Mo.

Parts for Testing Generator

C is a **stand** for holding the motor or generator. If the generator is given a "free running" or "motoring" test as a motor, it is connected with a battery in the same manner as a starting motor.

H is a **universal motor,** so called because it will operate on any 110-volt lighting circuit, either alternating or direct current.

When the generator is given a "driven" test, it is placed in stand (C) and connected to the universal motor which drives it, by means of a flexible coupling.

M is the **toggle-switch** which connects with the lighting circuit (110-volt) and the universal motor.

N is the **rheostat** connected with the universal motor which varies the speed of the latter. The generator is driven at the same speed as the universal motor which drives it.

E is the **tachometer,** connected by a **flexible shaft** (J) with the universal motor and indicates the speed in revolutions per minute of the generator which is being driven. The tachometer readings are from 0 to 2,500 rev.

F is the **ammeter** used in connection with the generator tests, and reads from 0 to 30 on the "charge" and "discharge" sides.

T are **test-points** connected with the 110-volt lighting circuit, and using a "tell-tale" red light (**K**) mounted flush with the test-stand.

L is the **switch** connecting the test-light (**K**) with the test-points (T) and the lighting circuit.

All instruments are protected by 10-ampere fuses mounted under the test table.

A cut-out is provided and mounted on the test stand so that the generator can be connected up and tested as if on the car.

GENERAL INSPECTION OF GENERATOR AND MOTOR TROUBLES

Before going into the details of the location of the various faults of the generator and motor, which are the two main units of the starting and lighting system, and the ones that generally cause ninety per cent of the trouble, we will explain the general effects of the more common troubles on the various parts of the machine. A careful inspection of the machine, having in mind these effects, will often instantly locate the trouble so that no electrical tests are necessary.

Ninety per cent of generator and motor troubles are indicated by the condition of the commutator. If the commutator is burned and blackened uniformly over its entire circumference, it is due, as a rule, to dirt and grease which have collected on the commutator, or to carbon or copper dust from the commutator itself, or from the brushes, which cause sparking and burning of the commutator.

The collection of carbon or copper dust on the commutator is generally due to the commutator becoming roughened and starting to cut, or by the use of a brush which is not of the proper composition and which acts more or less like a file against the commutator.

Poor contact between the brushes and the commutator, due to insufficient spring pressure or sticking brushes, will cause the commutator to burn pretty uniformly, due to the constant arcing between the brushes and the commutator. The same effect of a burned commutator will also be caused by a loose connection somewhere in the circuit which is constantly making and breaking the circuit. The flame of the arc resulting from the causes named above is generally of a reddish color, and is very distinct from the bluish tinge in the arc resulting from other causes.

An open circuit in the armature is nearly always detected by a **"flat" on the commutator,** because every time the brush comes in contact with the commutator bar which has an open coil attached to it, an intense blue spark is made as a result of the breakage of the circuit at this point under the brush and the segment is burned away, causing what is commonly known as a "flat."

The burned bar as well as the "flat" indicates the nature of the trouble, namely, an open circuit, and immediately locates the coil in which the trouble exists.

Short circuits in armature coils are indicated by flashing at the commutator and also by the smell of burning insulation.

A short-circuited field-coil is also liable to cause sparking, but not undue heating of the armature. However, the particular field-coil that is shorted will become much hotter than the other field-coils.

The windings of the generator, both on the armature and field, consist of many turns of fine wire as compared with the motor windings which have only a few turns of heavy wire in both armature coils and field coils.

The result of this construction is such as to give rise to many more sources of trouble in the generator than in the motor.

In addition, the troubles of the generator are further influenced by open circuits or grounds in the wiring system, including the cut-out, which connects it to the battery. All of these affect the behavior of the generator and are the immediate cause of generator troubles.

On the motor side, a ground or short in the wiring has no bad effect on the motor proper. The conclusion is that the majority of troubles experienced will be with the generator, as it is so vitally affected by the proper operation of a number of other things, while motor troubles should be very few, and in general confined to mechanical troubles, and on the electrical side almost solely to commutator and brush troubles.

No repairs should be attempted on armatures on which grounded, shorted, or open windings have been located, but the complete armature should be returned to the factory for repairs or replacement. If the trouble is such that it can be easily located and repaired, such as an open circuit due to poor contact between the ends of the coil and the commutator bar, or a short due to copper dust between bars, there is no need of returning the armature to the factory. Any troubles, however, that involve rewinding of the armature should be remedied by returning the armature to the factory.

Most of the troubles experienced with the cut-out will be caused by the contact points becoming corroded and pitted so that the cut-out points will fail to make a contact, thus leaving an "open" in the generator circuit, or else they will stick and fail to open, causing the battery to discharge back through the generator. This trouble is easily taken care of, as explained under "cut-out troubles," by cleaning the contact points.

If, on making a test of the cut-out, it is found that there are open or shorted or grounded coils in it, the instrument should be returned to the factory for repairs or replacement, and under no circumstances should the service man attempt to rewind the coils.

When the cut-out is installed on the car when it leaves the factory it is in perfect condition, and if it fails to operate from causes other than dirty contact points, as just described, the chances are that the trouble lies in a defective magnet winding. Any attempts to increase or decrease the spring tension on the cut-out points or adjust the opening between them will only make matters worse.

No attention other than cleaning the contact points should be required for the cut-out, and if it will not work properly under these conditions return it to the factory for repairs.

USE OF TEST-POINTS

The F.B. Test Stand is equipped with a set of test-points consisting of two brass points insulated with fiber handles attached to a flexible cord which is fitted with a Hubble plug.

On the front of the stand is a Hubble socket into which this plug is inserted, and when this is done it connects into the circuit the standard 110-volt lamp which is attached to the under side of the table and which lights the red "tell-tale" glass whenever the circuit is completed through the test-points.

Whenever these points are touched together, or whenever a circuit is completed by holding the points on any electrical circuit that is complete or continuous, a circuit is established allowing the current to pass through the lamp, in this way indicating that there is a continuous and complete circuit. This principle is utilized to locate open circuits, grounds, and shorts.

For example, **if it is desired to test an open circuit in the field-windings,** hold one of the test-points on either terminal of the field. If the field-winding is not open, that is, if there is not a broken wire or connection in it, the circuit will be complete, and it will be indicated by the lighting of the bulb.

For testing for grounded field-coil, hold one test-point on one terminal of the field-coil and the other terminal on the frame of the machine.

If there is no ground, that is, if there is no contact between the field-coil and the frame of the machine, there can be no circuit. Consequently the indicator will not light. On the other hand, if there is a ground, the circuit will be completed to the lamp and it will indicate the ground by the lighting of the bulb.

Test points with a high-voltage lamp are shown in Fig. 2 and with a low-voltage lamp in Fig. 3.

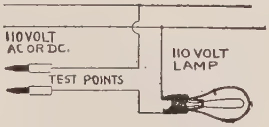

Fig. 2. Test-points and lamp for use with a 110-volt circuit.

The test-points furnished with the F.B. equipment are designed for use on 100-volt circuit, either A.C. or D.C., and the advantage of this higher voltage over a lower voltage is very considerable. For example, if there is a partial ground due to copper or brush dust which has settled between the commutator bars, the higher voltage tends to show it up more clearly and often burns out the foreign substance which is causing a ground and thus clears up the trouble. Fig. 2 shows the test-point circuit using 110 volts.

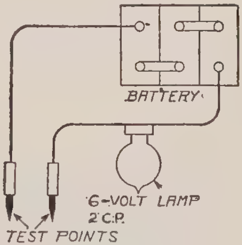

Fig. 3. Test-point and lamp for use with a 6-volt storage battery.

The same principle of using test-points can be utilized with a 6-volt battery, using a standard 6-volt bulb in the place of 110-volt lamp. Such a set as this is often very convenient, especially in making tests around the car where it is not always possible or convenient to utilize a 110-volt set. Fig. 3 shows the method of connecting up the test-point set with a 6-volt battery.

MOTORING TEST OF GENERATOR

A considerable number of the first installations of the F. A. Starting and Lighting Equipments on Ford cars were assembled with the Ward-Leonard automatic cut-out assembled on the dash, while in the later systems the cut-out is assembled on top of the generator.

If the generator to be tested is from one of the systems where the cut-out is mounted on the dash, the generator lead is connected directly to the generator terminal marked (T) (Fig. 4).

If, however, the generator has a cut-out mounted on it, the terminal lead is connected to the terminal on the cut-out (Fig. 5).

Do not put the flexible coupling on the generator shaft for making the "motoring" test. This is a "free running" test, and the generator must not pull any load while making it. The coupling is used for driving the generator and is not needed for this test.

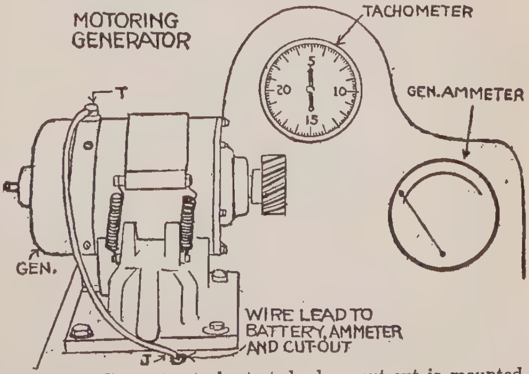

Fig. 4. Generator to be tested where cut-out is mounted on dash of car.

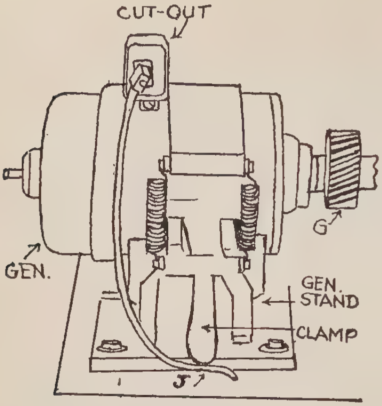

Fig. 5. Generator to be tested where cut-out is mounted on generator.

By this connection the generator is connected to battery and meter and cut-out on the F. B. Test Stand in the same way that it is wired up on the car.

The generator is now ready for the motoring test, that is, to send the current through it as a motor and to note its performance. The results will indicate whether the generator is in good condition, and if not, it will to a great extent indicate the troubles that may be looked for in it.

The generator motoring test can be conducted under two different conditions, namely: when the generator is not equipped with a cut-out mounted on top of it, and when it has a cut-out mounted on it.

Motoring Test Without Cut-Out on Generator

After the generator has been set up as described for the motoring test, it is necessary only to press the starting-motor switch, clearly indicated in Fig. 1, which action short-circuits or cuts out the Ward-Leonard cut-out on the Test Stand so that the current from the battery passes directly through the generator and causes it to run as a motor.

The generator ammeter mounted on the right-hand side of the instrument board will indicate the amount of current being taken to motor the generator, and is indicated by the needle on this instrument reading to the left of the zero center. The amount of current taken should be about 4 amperes, and the generator should turn in a clockwise direction, looking at it from the drive end, without any undue noise or sparking at the brushes.

Motoring Test With Cut-Out Mounted on Generator

For making the motoring test when the cut-out is mounted on the generator the same procedure is followed and the same results should obtain, but it is first necessary to short or cut out of the circuit the cut-out which is mounted on the generator. This is done by using the special wire jumper which has a snap connector on either end, and is provided with the outfit. One of the connectors is snapped on the main terminal of the generator marked (A), and the other connector is snapped on the terminal marked (C) in Fig. 6. By attaching this jumper in this way it has the effect of taking the cut-out out of the system.

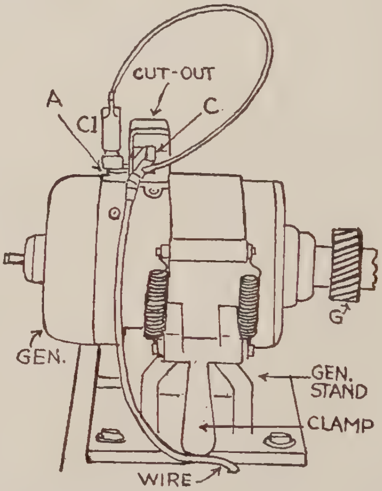

Fig. 6. Method of shorting or cutting out the cut-out on the generator when making the motoring test of the generator.

The starting-motor switch is then pressed, as in making the test without the cut-out mounted on the generator, and the same readings on the ammeter will apply to this method of installation.

GENERATOR TESTS

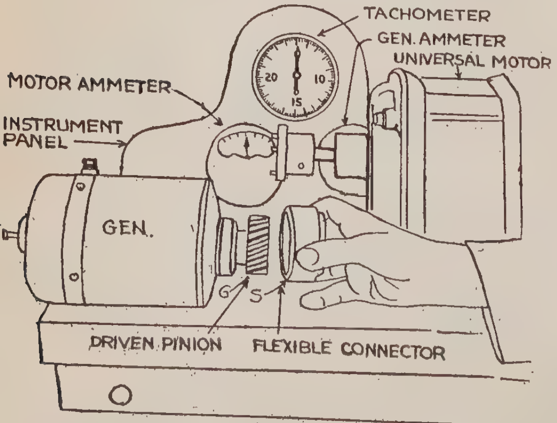

Fig. 7. Hooking up the generator with the drive motor for the generator driven test.

The next hook-up is for making the complete generator test. The first thing that is necessary is to make a connection between the generator and the universal motor, so that it can be driven at the desired speeds.

When the generator is taken off the car for test, it has a gear keyed to its shaft on the driving end. It is not necessary to take this gear off to make the test, but rather this gear is used as part of a flexible connector to hook the generator to the universal motor. The generator half of the flexible connector shown in Fig. 7 is slipped over this gear and locked to it by tightening the screw (S) shown in Fig. 7.

The flexible coupling is of the conventional type, driving through a leather washer. The other half of the coupling is attached permanently to the universal motor shaft. Put the generator in the generator stand, as previously described, turning the flexible connection until the three driving pins on the motor half of the connector fit into the leather washer and then lock the generator in position.

If the generator has no cut-out mounted on it, the generator lead is connected directly to the main generator terminal, as shown in Fig. 4. If there is a cut-out on the generator, the generator lead is connected to the main terminal on the cut-out, as shown in Fig. 5.

The generator will then be connected into the system electrically, the same as it would be in the car, except that the motive power will be furnished by the universal motor instead of the Ford engine.

The first test to make on the generator is to determine whether it is cutting in at the proper speed; that is, whether or not it starts to generate sufficient voltage and current to operate the cut-out, which action connects it to the battery. This is done by starting the universal motor by throwing in the starting switch and then slowly increasing the speed until the cut-out operates. The operation of the cut-out can be noted in two ways: first, a distinct click will be heard when it closes and also the generator ammeter will show a reading of about 1 ampere which will be indicated by the needle of the ammeter to the right of the zero center the instant that it operates. This is probably the best way of noting the action of the cut-out.

If the generator is in good condition, the cut-out should close at about 650 r.p.m., which speed will be shown by the tachometer.

It may be that in the case where the cut-out is mounted on the generator **the cut-out is defective** and will not close the circuit, so that no reading will show in the ammeter. If this happens, the cut-out can be cut out of the circuit by putting the jumper across the two terminals (C) and (A) (Fig. 6), as described under "Motoring Test." The generator tests can then be completed as described, and the cut-out tested independently, as described under "Test for cut-outs."

The next test is to see if the generator is delivering 10 amperes at a speed of 1,400 r.p.m. This test is made by slowly increasing the speed of the generator and noting its output on the ammeter at this speed.

Next, **the test for regulation** is made to see that the third-brush type of regulation with which the generator is equipped is controlling the output of the generator properly at high speeds. This test is made by moving the controlling handle on the rheostat to the right until a speed of from 1,700 to 1,800 r.p.m. is reached. At this speed the generator should not be delivering more than 12 amperes, as will be indicated by the ammeter, as this is the maximum current that the generator is supposed to give. It should be held constant at this rate by means of the third-brush regulation.

STARTING-MOTOR TESTS

First take off the Bendix gear, and place the motor in the generator holder, locking it in place by following the same methods as were used with the generator. See that the heavy terminal again comes on top, and that the motor shaft now extends to the left instead of to the right.

It will be noted that the motor has a square flange on the drive end, and one of these four sides should be placed flush against the upright projection on the back and left-hand side of the generator stand. This actually prevents the motor frame from turning in the stand when the torque test is being made.

Then connect the heavy motor lead to the motor terminal, being sure to make a good connection. The motor is now attached electrically to the storage battery under the same conditions as on the car, and connection is made by pushing the starting switch on the front of the table, allowing current from the storage battery to pass through the motor.

Motor "Free-Running Test"

The motor mounted for the free-running test is shown in Fig. 8. Press the starting-switch lever and the motor will spin rapidly, making what is known as a "free-running" test. The behavior of the motor under this test will, as explained later, indicate clearly any trouble which may exist in it.

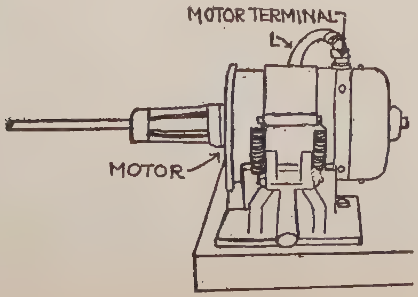

Fig. 8. Free running test of starting motor.

If the motor is in good condition, it should spin over without any undue sparking at the commutator and should draw about 75 amperes, as indicated by the motor ammeter on the left-hand side of the instrument board.

Torque or "Kick" Test of Motor

Attach the brake arm to the motor shaft by simply sliding it on until the inner end of the brake arm enters the bearing housing on the end of the motor housing. This will bring the thumb screw on the other end of the brake arm in the same plane as the counter bore in the end of the motor shaft used for holding the Bendix gear on it. Then turn the brake arm until the thumb screw fits this counter bore and tightens snugly, as shown in Fig. 9.

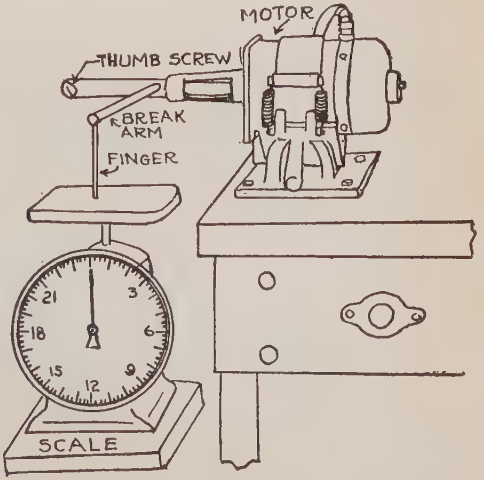

Fig. 9. Method of making a torque or "kick" test of the motor. (Note that the word "break arm" in the drawing should read "brake arm.")

Next pull the swinging shelf out into its extreme position, as shown in Fig. 9, and attach the scale to the shelf by sliding it on the scale holding clip mounted on top of the shelf. Now when the brake arm is placed on the scale it will bring the finger on the end of the brake arm approximately in the center of the scale. If the scale needle does not point exactly to the zero mark, it can be adjusted by the adjusting thumb screw on the upper part of the scale. We are now ready to measure the torque or "kick" of the motor in foot pounds.

How to Make Motor Torque Test

Press the starting switch, which will send the full current from the battery through the motor, causing it to try to rotate. Resistance to rotation is furnished by the scale, and the motor can make only a very small part of a turn when it will stall, which also gives a name to this test known as the "stalling test." Note the reading on the scale, and then quickly note the reading on the motor ammeter.

If the motor is in good condition, the scale should read 12 to 14 pounds, and the ammeter should show a current draw of between 600 to 750 amperes.

As the gear ratio between the Bendix gear on the motor and the gear on the fly wheel on the engine is 12 to 1, this means that the motor under these conditions is exerting a turning effort of 168 pounds on the end of a starting crank one foot long, which is sufficient to turn over any Ford engine under extreme conditions of stiffness.

In making this motor test do not hold the starting switch closed any longer than is necessary to take the readings, otherwise the battery will be unduly run down. It might be well to add at this point that in making a test on both the generator and motor, it is taken for granted that the battery is fully charged. The best method of determining this is by the use of a hydrometer.

In making the generator tests, and especially the final running test, sufficient charging will be given the battery to keep it in proper shape for all the motor tests that are made, but if it should run down it should be fully recharged before making the test.

LOCATING AND REPAIRING GENERATOR TROUBLES (MECHANICAL)[1]

The results of the generator tests given under this heading are those that should be expected when the machine is right in every detail. It is taken for granted that the generator is removed from the car because it is defective and will not successfully pass the generator tests, and it is now necessary to locate and repair the trouble within it.

All troubles with the system can be classed under two headings: "mechanical troubles," and "electrical troubles."

We will take up the **mechanical troubles first,** as it is not only necessary to correct them to get the proper results in the generator, but furthermore, the generator could not be run properly to make the electrical tests unless it is right mechanically. The mechanical troubles experienced are as a rule confined to the following:

1. Loose driving gear.
2. Broken bearing.
3. Armature off center.
4. Shaft bent.
5. Commutator burst.

It is very apparent that a visual inspection and examination will locate any of these troubles. **First take hold of the gear by hand;** see that it is properly and firmly keyed to the shaft. Turn the armature by hand and see that it runs freely and noiselessly. If it sticks or turns hard, examine the machine to see, first, if there is a **broken bearing.** The only remedy for this is, of course, a new bearing.

If the armature is off center, and the bearings are all right, it may be due to a loose pole-piece, and this can be caused by the heavy screws (S) (Fig. 10) which hold the individual pole-pieces to the generator frame having become loosened. Under either conditions the magnetic pull on the pole-pieces will cause them to be drawn toward the armature and will have the same effect as if the armature was off center. **The remedy** for such trouble is to pull the field-piece back into its proper position by tightening up on the screws which hold it in place.

A bent shaft will be a rather unusual source of trouble. **The remedy** is a new armature, it being impossible to straighten for an alignment of bearings.

The final trouble, namely, a **burst commutator,** can be repaired only by putting in a new one. It has been our experience, however, that when a commutator bursts or throws the pieces, a great deal of other damage is done, such as broken brushes or brush-holders, and very considerable damage as a rule to the armature windings. Our recommendation in a case of this nature is the installation of a **complete new armature,** instead of attempting to put on a new commutator and to do the work of connecting up the armature leads to it.

In making the mechanical inspection, it will be necessary to get at the various parts of the generator to do so. The brushes are located at the rear end of the generator and can be inspected by removing the rear-end cover band. This is done by taking out two screws which hold this housing to the generator frame, shown in Fig. 10, marked (A).

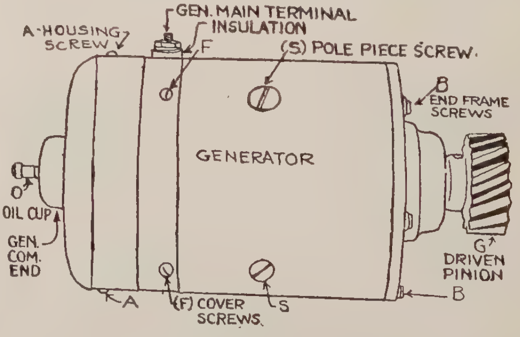

Fig. 10. Illustration of generator, showing pole-piece screws, frame screws, etc.

In order further to disassemble the generator, lift the brushes clear from the commutator by pulling them up in the holders by means of the brush pigtails. They will be held in this position free from the commutator by the pressure of the springs against the side of the brushes.

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[1] See also "Digest of Troubles," page 454.

Next take out the screws (B), which attach the front end-cover to the generator frame, and pull this cover free from the frame. The front end-cover and armature will then disassemble completely from the frame.

At this point we are in position to **examine the generator completely for all mechanical troubles,** but if it is necessary further to disassemble the generator to get at the brush rigging in the rear end-cover, this can be done by taking out the four screws (F) which hold it in place and then loosening the cover from the frame. It will be noted, however, that the cover can be moved away a short distance only as governed by the length of the wires which are attached to the brushes. **If it is desired to remove it completely,** wires can be disconnected.

Figs. 11 and 12 show **the detail construction of the F.A. generator** with all parts clearly marked. A study of this drawing will assist the service man to understand the complete construction and enable him to disassemble and rebuild the machine properly.

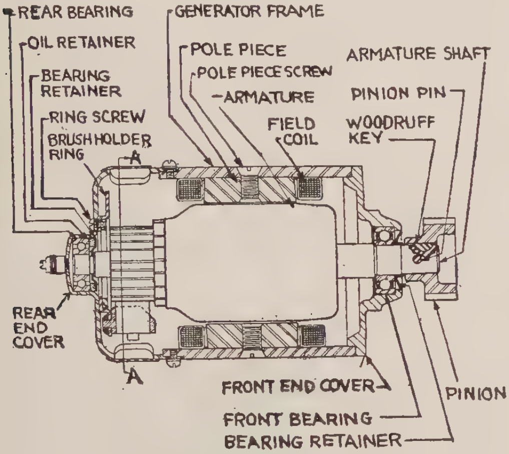

Fig. 11. Longitudinal section of generator.

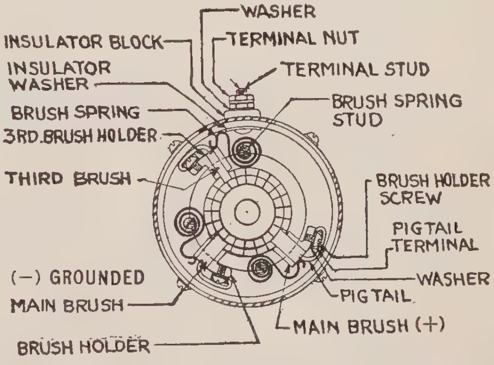

Fig. 12. Cross-sectional view of commutator end of generator. The (−) grounded brush is on the left, and insulated (+) brush on the right.

LOCATING AND REPAIRING GENERATOR TROUBLES (ELECTRICAL);[1] OPEN CIRCUITS

Open Circuits

Having inspected and repaired the generator for mechanical troubles, we then **locate the electrical defects,** which are nearly always the cause of our troubles. All electrical troubles are the result of:

1. An open circuit or partially open circuit.
2. A ground or short circuit.

In case of an open circuit, or partially open circuit, which is generally caused by poor contact, the more common sources of trouble are as follows:

1. A dirty commutator.
2. Worn commutator.
3. Brushes stuck.
4. No spring pressure on brushes.
5. Brushes too short or broken.
6. Broken brush connection.

The more uncommon sources of trouble in open circuits are caused by:

1. An open field.
2. Open armature.
3. A broken connection between commutator and armature winding.

To locate the electrical troubles in the generator, we first make use of the motor test which gives us a good indication of where to look for our difficulty.

If the generator fails to motor and there is no current passed through it, as indicated by no reading on the generator ammeter, we know immediately that we have an open circuit.

If the generator motors very slowly and we have a reading of less than 4 amperes on the scale, it shows that there is a partial open circuit or a poor connection in the generator, which does not allow the proper amount of current to pass through it. This, then, puts our trouble in the open-circuit class, and we go after the locating and localizing of this trouble in the following manner:

Locating Open Circuits

Using the test-points, first test for an open circuit between the main generator terminal marked (T), (Fig. 13), and the insulated brush marked (B). This will test the connection between these two points.

Then test between the insulated brush (B) and the commutator (C).

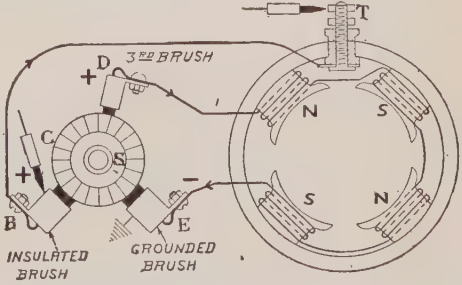

Fig. 13. Testing generator for open circuits with test-points and lamp. The test-lamp and points (Fig. 2, page 509) are used for making the tests. (The brush holder is shown removed and turned over.)

Next disconnect the lead from the grounded brush (E). Then by following out the same line of test as can be clearly seen in Fig. 13, we test between the commutator (C) and the third brush (D) and then between the commutator and the grounded brush.

If the open circuit is in any one of these connections or between any of the brushes and the commutator, it can be localized in this way.

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[1] See also "Digest of Troubles," page 454.

Commutator and Brush Troubles

Commutator troubles, such as dirty or burned commutators, high mica, etc., are fully treated on pages 491 to 493.

Brush troubles are treated on pages 493 to 496.

Open Field

This test is for testing the shunt field of the generator, by holding one of the test-points on the third brush at (D) (Fig. 14), and the other on the end of the connection (1) which has been taken off the grounded brush-holder (E). This will show us whether the shunt field is all right.

If the test indicates an open circuit, first inspect the joints (2, 3, 4) between the field-coils to see that they are not broken, and then test each field separately by holding the test-points on the ends of each coil. In this way the open circuit can be located in one particular field-coil.

To repair, it will be necessary to disconnect this coil from the other coil and take it out of the machine for further examination. To do this, the pole-piece will have to be removed by taking out the two screws which clamp it to the generator frame.

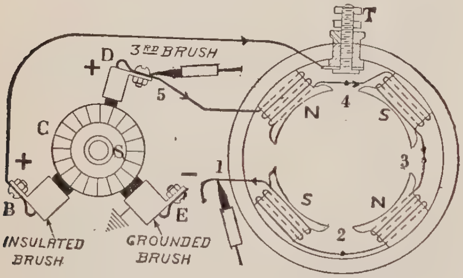

Fig. 14. Testing generator for open field-coils.

It will then be necessary to locate the exact point of the break by unwinding the coil until the rupture is located. Carefully make a good connection at this point, and rewind the field and replace, and reconnect, and then repeat very carefully the test to see that the open circuit has been properly taken care of.

Open Circuit in Armature Coil

There are a number of methods of testing for open circuits in armatures. We particularly recommend the use of the F.B. Testing Set which consists of a very high-grade ammeter and a voltmeter substantially mounted in a walnut case with self-contained shunts for giving three ranges of readings on each instrument and special leads and connectors adapted exclusively for Ford work.

With this instrument are given very careful instructions for easily and accurately locating armature and field troubles on various units of the F. A. starting and lighting system, as well as locating grounds and other troubles in the wiring and battery system.

The following is a simple method for locating open circuits in the armature, requiring the use of an ammeter and one cell of any storage battery, which must be in first-class condition. An ammeter with a range 15 to 25 amperes best answers the purpose for this test.

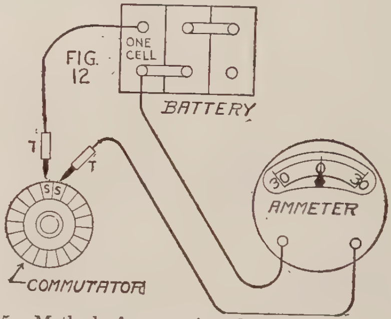

Fig. 15. Method of connecting the ammeter and battery for locating open circuits in armature coils.

The method of using the ammeter and battery and how to wire them up is shown in Fig. 15. The two wires which come with the meter with test-points (T) are preferable, similar to those furnished with the F. B. Test Stand, but any No. 14 or 16 wire with contact-points attached to the end to act as test-points will answer the purpose.

The theory of the test is to send a current through each of the armature coils, one at a time, by holding one each of the test-points on adjacent commutator bars (SS). The current from the battery will pass through the armature windings, and the ammeter will indicate the amount of this current. **If the armature winding is not open in any case,** all of the readings will be approximately the same.

If, however, the ammeter should show very much less on one set of bars than on the others, it indicates that the circuit in that coil is open, caused either by the burning out of that coil or by a broken connection in the wire or a broken connection or poor contact between the commutator bar and the armature coil.

Readings are taken on adjacent commutator bars all the way around the commutator, and if they all read the same there is neither an open circuit nor any other trouble with the armature.

If one or more, however, show a low reading, the cause of an open circuit resulting from one of the causes just mentioned must be located.

If the trouble is a poor connection between the commutator bar and the armature winding, it can easily be repaired by a proper job of soldering, but if the trouble exists in a broken or burned-out armature coil, the complete armature must be returned to the factory for repairs.

LOCATING AND REPAIRING GENERATOR TROUBLES (ELECTRICAL); SHORT CIRCUITS AND GROUNDS

Short Circuits and Grounds

If, when the motoring test is made, taking it for granted that all mechanical troubles have been eliminated as instructed, the generator does not run as a motor and shows more than four or five amperes reading on the ammeter, or if it runs very slowly and still shows a larger current draw than it should for proper running, it indicates that the current from the battery is not passing through the windings of the field and the armature in the proper way, but that all or part of it is being lost or shunted through some grounded connection or some short circuit, and in this way is not doing any effective work.

Again the common sources of this trouble are:

1. Grounded brush rigging.
2. Grounded main generator terminal.

And the more uncommon troubles are:

1. Grounded commutator.
2. Grounded armature coil.
3. Grounded field.
4. Short-circuited armature.
5. Short-circuited field.

Brush Rigging Grounded

To test insulated brush rigging, either lift the brush clear of the commutator, holding it in this position by allowing the brush spring to press against the side of the brush, or place a piece of paper under the brush to insulate it from commutator (Fig. 16).

Then test between the brush-holder and the frame. If this shows a ground, the trouble is in poor insulation between this brush-holder and the cover to which it is attached. It can be found only by proper inspection, and must be repaired by replacement with proper insulating parts.

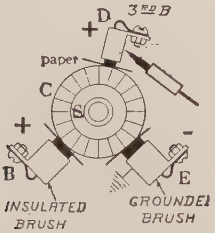

Fig. 16. Insulating the brushes from the commutator with paper preparatory to testing for grounded brush rigging.

Main Terminal Grounded

To make the test for the main terminal, disconnect the lead from it (T) (Fig. 17) to the insulated brush-holder (B), holding one of the test-points (7) on the end of this lead; the other on the frame of the generator (6).

If this shows a ground, carefully examine the insulation on the lead which has just been disconnected and also the insulating bushings and washers that insulate the generator terminal (T) from the frame.

The test on the third brush is made in the same manner, by first disconnecting the field-lead to it, insulating it from the commutator by the paper method or raising it free from the commutator, and then making the test. The grounded brush-holder, of course, is grounded permanently, and this test does not apply to it

Grounded Field

Disconnect the field-lead to the grounded brush (E) (Fig. 17), as well as the lead to the third brush (D), as shown. This then leaves the field with no electrical contact with the rest of the system, and one test-point placed on either one of these terminals and the other on the frame of the generator should show clear.

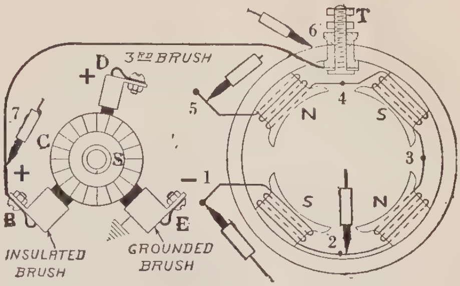

Fig. 17. Tests for grounds in the field-coils and in the commutator.

If it shows a ground, follow the same method of testing for an open field, that is, disconnect the fields from each other where they are soldered together (2, 3, and 4), and test each field-coil separately for a ground. When it has been located, take the pole-piece out and endeavor to locate by inspection just where the wire is touching the frame. After it has been located, insulate it properly with tape, and replace. Be sure to make test after replacing, first on the individual coil and then on the entire field-system before permanently connecting up.

Grounded Commutator

The commutator (C) is entirely insulated from the armature shaft (S) to which it is permanently attached by mica or other suitable insulating material, and there should be no electrical contact between it and the shaft.

The test for a grounded commutator can be made while the armature is in place in the generator frame, or preferably while it is disassembled completely from the machine.

In order to make the test while the armature is in place in the generator, it is first necessary to lift the brushes free and clear of the commutator and to hold them in this position, or else to place pieces of paper between the brushes and the commutator so as to insulate them from it, as in Fig. 16.

Then hold one test-point on the commutator (C) and the other on the armature shaft (S), and if the commutator is free from grounds no current will pass, as indicated by the lamp not lighting.

This test will show whether the commutator as well as the armature windings are free from grounds; but if this test shows a ground, it may be a ground between the commutator and the shaft or between the armature windings and the armature core. If the ground cannot be located and easily repaired by a careful examination, the complete armature should be returned to the factory for repairs or replacement.

Grounded Armature Coils

In addition to a grounded commutator, **one or more of the armature coils may be grounded to the armature core.** If the ground cannot be detected by visual examination the test-points can again be brought into use for localizing the grounded coil.

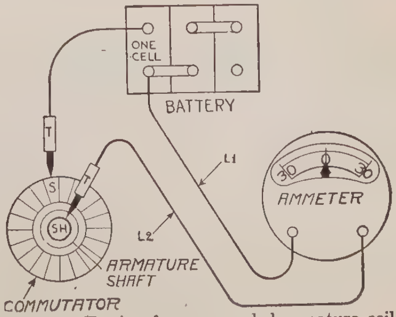

Fig. 18. Testing for a grounded armature coil.

The proper connection for making these tests is by using **one cell only** of any storage battery connected to a set of test-points with the 30-ampere scale ammeter in circuit, as shown in Fig. 18.

Hold one test-point on the armature shaft and the other on one bar of the commutator. The ammeter will give approximately **equal readings** on all commutator bars successively, if there are no grounded coils in the armature.

If there is a grounded coil, the ammeter will show a larger reading when the test-point is touched to the bar to which the grounded coil is connected. In this way any grounded coil is quickly detached and located.

The ground may be between the individual commutator bar (S) and the shaft (SH), or between the armature coil and the armature core. If the ground is in the commutator, it can usually be detected by a visual examination, and often it can also be located in the coil in the same way. Unless it can be easily repaired, the complete armature must be returned to the factory for repairs or replacement.

If the ground is not in the windings, but is in the commutator, it will have to be repaired, as instructed under "Grounded Commutator."

Short-Circuited Armature Coils

The same method for locating a short circuit in the armature windings in the generator is followed as was used for locating open circuits in armature windings. Fig. 15 shows the method of connecting up for this test. The test-points are held on adjacent bars and current from the cell passes through the armature coils, and the amount is indicated by the ammeter.

If all the readings between the adjacent bars are approximately equal, it indicates that the coils are all in good shape, but if one or more of the readings show higher than the average, it indicates that this coil is short-circuited.

The trouble is caused by defective insulation on the coils, allowing the different sections or layers of the coil to come in contact, thus cutting out more or less of the turns in the coil and rendering them useless. The effect is an increase of current through the shorted coil due to the reduced resistance and constant heating of the coil and sparking at the commutator bar connected to the defective coil.

Do not attempt to repair a shorted armature, but return it to the factory for repairs.

Short-Circuited Field

It is possible that one or more of the field-windings may be shorted, resulting from defective insulation, so that the full effect of the field-turns are not being utilized.

A diagram of the field-windings and means for sending a current through the coils by the use of test-points attached to any standard 6-volt storage battery with an ammeter in circuit is shown in Fig. 19. The ammeter preferably should read up to 30 amperes.

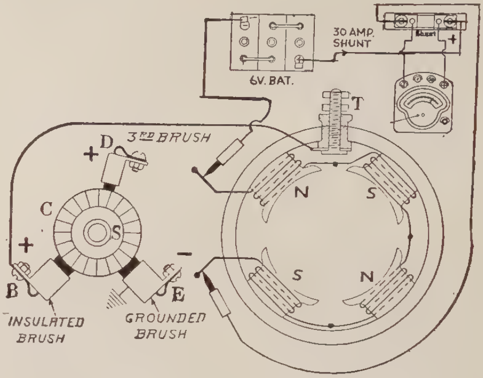

Fig. 19. Testing field-coils by sending current through them from a battery.

First, as will be noted from the illustration, the field-winding connection has been disconnected from the grounded brush (**E**) and also from the third brush (**D**). Test-points are then held on the two winding connections that were just disconnected and the current from the 6-volt storage battery passes through the fields and is indicated on the ammeter.

The normal resistance of the field windings on the F. A. generator varies from $2\frac{7}{10}$ to $3\frac{3}{10}$ ohms, depending on whether they are wound with single cotton enameled wire, in which case the resistance is about $2\frac{7}{10}$ ohms, while if it is wound with double cotton-covered wire, the resistance is about 3 ohms.

With a standard 6-volt storage battery in good condition the ammeter should show from $2\frac{2}{10}$ to $1\frac{8}{10}$ amperes passing through the fields when the test is made. **If the reading is noticeably higher** than this, it indicates that some of the windings on the field-coils are cut out of circuit by being shorted, and it is then necessary to determine in which coil the short occurs.

To do this, take off the insulating tape at the point where the join is made between the individual field-coils, and then measure each coil separately in the same way as above.

The amount of current shown on the ammeter by this test should be four times as great when measuring a single coil instead of four of them in series. Consequently, for a good coil the reading on the ammeter should show from $8\frac{8}{10}$ to $7\frac{2}{10}$ amperes. If any of the coils show a decidedly **higher reading** than this or than any of the other coils, it indicates that it is shorted.

Having located the shorted coil, it will be necessary to take it out of the machine, unwind it until the defective spot in the insulation has been located, then insulate it properly and rewind. Be sure and retest after the coil has been reinstalled in the generator.

THIRD-BRUSH SETTING

The current generated by the F. A. generator should be 10 amperes at a generator speed of about 1,400 to 1,500 r.p.m. Any increase in the speed of the generator beyond this point would tend to increase the current very rapidly, if it were not for some system of regulation for holding this current down to a maximum.

Third-Brush Regulation

On the F. A. generator the system of regulation used is known as the "third-brush" system, so called because a third brush is used in this system.

Just how this third brush is connected to the generator field so that the voltage across the field erminals is equal to the voltage generated between he generator brush and the third brush, is shown n Fig. 13, also Fig. 12.

As the current generated in the machine increases, due to the increase of speed, the magnetic ield becomes distorted or twisted out of line, so that he voltage between the third brush and the generaor brush is decreased. Consequently the field trength is decreased approximately in proportion o the increase of speed, and the current is held by his method to a maximum value of approximately 12 amperes.

The output or the current developed by the generator may be varied by shifting the third brush which s held in place by a bolt in a slotted opening in the brush-holder ring. The bolt is held permanently in position by a hexagonal nut, which is turned with a special wrench furnished with the F. B. equipment.

To increase the output of the generator, loosen the hexagonal nut and move the third brush in the direction of rotation of the armature by tapping the brush-holder, then tighten firmly in this position.

To reduce output of generator, move brush-holder in direction opposite to rotation of armature.

After any adjustment of the third brush, the brush should be sanded. Follow the same instructions and methods given for sanding the regular brushes (page 494). It is very important that the contact between the third brush and the commutator be pretty nearly perfect in order to get proper regulation. After the adjustment and sanding in of the brushes have been made, the generator should then be run through the regular generator test, and a readjustment of the brush should be made if it does not come up to the generator test specifications.

LOCATING AND REPAIRING MOTOR TROUBLES (MECHANICAL)[1]

Motor troubles are classified the same as generator troubles, namely: "mechanical" and "electrical."

Before proceeding with the location of any electrical troubles in the motor, it is first necessary to be sure that all mechanical difficulties are taken care of. Practically the same mechanical troubles can exist in the motor as are possible in the generator, namely:

1. Broken or worn bearing.
2. Armature off center.
3. Shaft bent.
4. Commutator burst.

Bearing Trouble

The motor, unlike the generator, is equipped with **solid bearings,** the front one of a high grade of bronze bushing and the rear bearing of a soft composition bearing metal. As the motor is actually run only a few hours during the course of the year, there is no occasion for these bearings showing any great amount of wear, especially if no dirt is allowed to get in them whenever they are taken down.

If, however, either one or both become badly worn they should be **replaced with new bushings.**

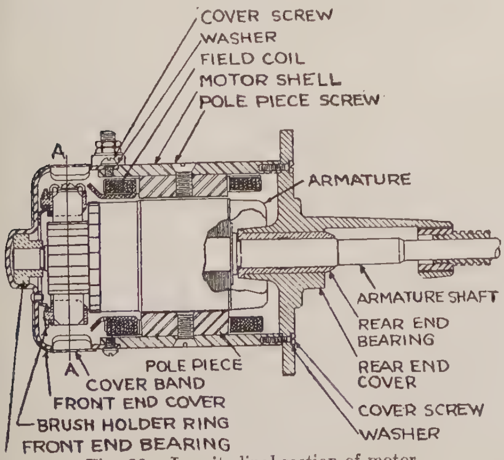

Fig. 20. Longitudinal section of motor.

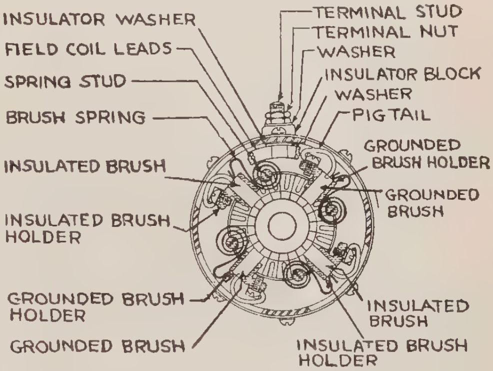

Fig. 20A. Cross-sectional view of front of motor.

Armature Off Center

A broken or worn bearing will allow the armature to locate itself in an off-center position in respect to the pole-pieces to such an extent that it is possible that the armature will rub against the pole-pieces. The **remedy is new bearings** to center up the armature, or it is possible that one or more of the pole-pieces may become loosened, having the same effect as placing the armature off center. The remedy is to pull this pole-piece sungly back into place by tightening screws which hold it to motor frame.

Shaft Bent

There is likely to be more trouble from a **bent shaft** in the motor than in the generator, especially if the operator is careless when starting his car and gets a "kick back" from having his spark lever advance too far, or from the engine being in bad condition. A severe back-kick is liable to bend the shaft. As a general rule, the shaft **cannot be properly straightened** and the complete armature should be returned to the factory.

Commutator Burst

This trouble is a very unlikely one, but if the commutator should burst it always does considerable damage, especially to the brushes and brush rigging. Our suggestion is the same as on the generator, namely, the return of the complete armature to the factory for repairs and substitution of a new armature.

The assembly of the F. A. motor is shown in Fig. 21. Figs. 20 and 20A show the details of its construction. A careful study of these will enable the operator to understand its construction and the proper method of assembling and reconstructing.

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[1] See also "Digest of Troubles," page 454.

LOCATING AND REPAIRING MOTOR TROUBLES (ELECTRICAL)

Electrical troubles on the motor are classified as on the generator:

1. Open circuits.
2. A ground or short circuit.

An open circuit may be caused by:

1. Dirty commutator.
2. Worn commutator
3. Brushes stuck.
4. Insufficient spring pressure.
5. Brushes too short or broken.
6. Broken brush connections.
7. Open field.
8. Open armature.
9. Broken connection between commutator and armature windings.

Open Circuits

To locate the electrical troubles in the motor, we first determine whether there are any open-circuit troubles. To do this make a free-running test on the motor as previously described.

If the motor fails to run and there is no reading shown on the motor ammeter, it indicates that there is no current passing; consequently the circuit is open.

Or, if the motor runs very slowly and takes considerably less than 75 amperes, it indicates that there is a partial open circuit or poor connection or contact at some place in the motor circuit.

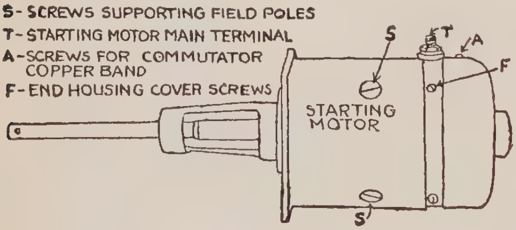
S- SCREWS SUPPORTING FIELD POLES
T- STARTING MOTOR MAIN TERMINAL
A- SCREWS FOR COMMUTATOR COPPER BAND
F- END HOUSING COVER SCREWS
S
T
A
F
STARTING MOTOR
S

Fig. 21. Assembly of starting motor.

Take off the motor cover band by taking out the two screws (A) which hold it to the frame so that the brushes and commutator can be examined and tested, as shown in Fig. 21. Using the test-points, the open circuit can be localized by the same method as was used with the generator.

Diagrammatic connections of the motor are shown in Fig. 22. First, either raise all the brushes free from the commutator, or else insulate them by putting paper between them and the commutator.

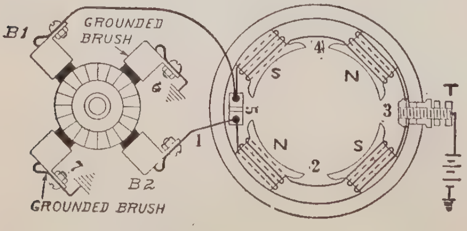

Fig. 22. Connections of the motor showing where to make tests.

Hold one test-point on (T) and the other test-point on the brush pigtail at (B1), which will test one-half of the motor field-circuit from the main terminal (T) up to the brush (B1).

Still holding the test-point on (T), put the other test-point on (B2). This will test the other half of the motor field-circuit.

If either one or both show an open circuit, it is either in the lead to the brushes or in the field-windings, which is easily localized by narrowing the test down.

Using the test-points, proceed in the same way to test between (B1) and the commutator, first lifting the brush (B2) off the commutator and seeing that brush (B1) makes a good contact on the commutator. Then make the same test on (B2).

The open circuits in the fields, brushes, brush rigging, etc., are all taken care of in the same manner as has previously been described for generator troubles. The commutator should be cleaned and repaired, as should the brushes and brush rigging according to these same instructions.

Short Circuits or Grounds

If, when making the free-running test, the motor fails to turn or turns very slowly and a much larger current than 75 amperes is shown by the ammeter, it indicates that there is a ground or short circuit in the motor connections. These troubles are the result of the same causes as in the case of the generator, namely:

1. Grounded brush rigging.
2. Grounded main motor terminal.
3. Grounded armature.
4. Grounded fields.
5. Short-circuited armature.
6. Short-circuited field.

Test for Motor Grounds

First make a combination test for a ground in the main terminal, the field coils, the two insulated brush-holders, and the connections between the coils and brush-holders.

To do this first insulate the two grounded brushes shown in Fig. 22, by placing paper between the brushes and the commutator, or by raising them in the brush-holders so that they will be held free from the commutator.

Then hold one test-point on the main terminal (T) and the other test-point on the frame of the motor. **If no ground is indicated,** it will show that all of the parts are clear. **If a ground is indicated,** it will then be necessary to localize it.

Disconnect the two leads that are attached to the insulated brush-holders (B1 and B2), and hold them clear of the motor frame. Then test for a ground with one point on the main terminal (T) and the other on the motor frame. **If a ground is still indicated,** it is in the field coils or the main terminal.

In order further to localize the ground, the fields must be disconnected from the main terminal (5) and the field and the terminal must be tested separately for a ground.

A ground in the main terminal will be due to defective insulating bushings, which bushings must be replaced with new ones.

A ground in the field-coils is more likely to be due to the field connectors which connect the various coils together (2, 3, and 4) touching the motor frame, as they are not insulated at the point where the connection is made between each coil. All of the wire used in the motor construction is very heavy, and when once bent or pushed in place clear of the frame and metal parts of the motor, there is practically no danger of a ground.

The remedy for a ground in any of the various parts of the motor is the proper insulation of the grounded part. The field-coils are taken out of the frame and handled in the same way as described for the generator coils. Be sure to make a good job of reconnecting the coils when replacing, as they carry a very large current when cranking the motor, and a defective joint would offer a high resistance and cut down the efficiency of the motor.

Brush Rigging Grounded

On the motor two of the brush-holders marked (B1) and (B2) are insulated from the motor frame as shown in Fig. 22, while the other two brushes marked (6) and (7) are grounded to the frame. (B1) and (B2) can be tested for grounds by holding the brushes off the commutator and using the test-points.

Grounded Commutator or Grounded Armature Coil

The test for a grounded motor commutator is made in the same manner as a test for a grounded commutator on the generator, namely, by using the test-points and holding one point on the commutator segments and the other on the armature shaft.

If a ground is indicated on this test, it may be either in the commutator or in the armature coils. Usually it can be located by visual inspection, as the motor windings consist of only a few turns of bare wire to a coil and are well exposed for examination.

If the ground cannot be easily located and repaired, the armature should be returned to the factory for repairs.

Short Circuits in Armature Coils

On account of the very low resistance of the motor armature coils, **it is not practical to locate a shorted armature by the same methods as are suggested for the generator armature.** In fact, if the trouble cannot be located visually, as indicated by burned or flattened commutator bars, the only practical method is the use of a specially designed instrument commonly known as a "growler."

The F.B. growler is specially designed for use with the F.A. motor and the F.A. generator, and a grounded or shorted coil is instantly detected and located in either the generator or motor armature with it. See page 500.

Open Circuits in Motor Armature

The motor armature, being wound with only a few turns of heavy copper wire, **has a very low resistance,** and consequently the methods used for testing for open circuits in the generator armature cannot be used satisfactorily for the motor armature.

On account of the few turns in the motor armature coils and the very large size of wire used, there is practically no trouble experienced from "open coils." The only point at which there is danger of an open is at the point of connection between the ends of the coils and the commutator bar. An open at this point can always be detected by visual examination. **It is generally caused by defective soldering. The remedy** is to pull the leads out of the slot in the commutator riser, clean them thoroughly, and resolder properly.

An open motor armature coil can also easily and quickly be detected by a "flat" on the commutator, caused by the constant arcing due to an open coil. Such arcing burns the commutator continuously at one point until it has made a flat spot. A flat further increases the trouble by causing **the brushes to jump at each turn of the armature** when they come in contact with the defective spot on the commutator.

In all cases of armature trouble due to shorts, grounds, or open circuits, the complete armature should be returned to the factory for repairs.

LOCATING AND REPAIRING CUT-OUT TROUBLES

Automatic Cut-Out

The function of the cut-out is automatically to connect the generator to the battery when the generator has attained sufficient voltage to charge the battery, and to disconnect the two when the voltage of the generator falls below that of the battery so as to prevent the battery discharging through it.

This action is accomplished by the circuit being made and broken by the two contact points of special metal. Normally these points are open or separated. The points are brought in contact by the action of the magnet which has two windings on it, one very fine winding called the voltage coil and connected across the generator terminal, and the other a heavy winding called a series coil and connected in the main line between the generator and the battery. These connections and the details of the cut-out are shown in Figs. 23, 24, and 25.

Action of the Cut-Out

When the generator has attained sufficient voltage it will send a current through the voltage coil (Fig. 23) which will energize the electromagnet and draw the contact points together. This action will close the main circuit between the generator and the battery, through the heavy winding or series coil.

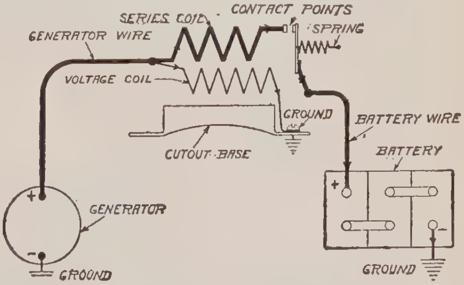

Fig. 23. Circuit of cut-out.

When the voltage in the generator decreases to a point lower than the voltage of the battery, the current from the battery will flow backward through the series coil, but the current through the voltage coil will still be in the same direction. The result is that the two opposing currents will demagnetize the electromagnet and the spring pull on the contact-point lever will separate the points and break the circuit.

The cut-out is one of the most important units in connection with the starting and lighting systems, since its failure to operate either in closing the circuit or not opening it at the proper time can easily put the entire system out of commission.

Two types of cut-outs are in use on Ford cars. The first is known as the **dash type,** because it is mounted on the inside of the dash. This type has now been discontinued permanently.

The second type is known as the **generator type** and is mounted permanently on top of the generator. It is the standard cut-out now being installed on all jobs equipped with F. A. starting and lighting systems.

Both cut-outs are identically the same in action, but slightly different in construction. Fig. 24 shows the dash type, and Fig. 25 shows the generator type.

Cut-Out Troubles

Troubles due to cut-outs are caused, first, by **failure to close** and, second, by **failure to open.**

Failure to close may be caused, first, by an open circuit in the voltage coil, or a shorted voltage coil, and, second, by failure of the contacts to make a connection due to dirty or corroded points.

The cut-out fails to open because the points become welded together, and this welding action is caused, first, by continual opening and closing of the contact points and excessive sparking due to imperfect operation of the generator, and, secondly, fails to open by the sudden breaking of the circuit in the voltage coil, thus killing the demagnetizing effect of it and allowing the current through the series coil to energize the magnet and keep the contact points together.

How to Locate Troubles

First take the cover off the cut-out for inspection; see that the contact points are open, and that they are bright and clean. If they are dirty or corroded they can be cleaned with very fine emery cloth or with a very fine jeweler's file.

Generator Type

With the test-points, first try out the voltage coil to see that it is not open, by holding one point on the ground at (G) (Fig. 25), and the other on terminal (**M**). The lamp should light and the cut-out points should close with a decided click if the voltage coil is in good shape. If it is shorted or grounded, the light will still indicate a closed circuit, but the cut-out points will not close.

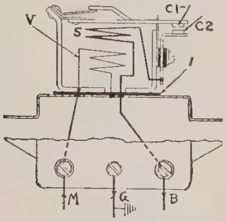

Fig. 24

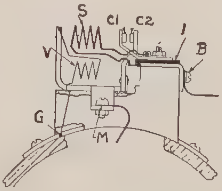

Fig. 25

Fig. 24. Dash type of cut-out; placed on the inside of dash of the car.

Fig. 25. Generator type of cut-out; placed on top of the generator.

Then test the series coil, by holding one test-point on terminal (**M**) and the other at point (**B**). No current should pass between these two points, as the circuit is broken by the fact that the cut-out points are separated. Then test for a ground in the series coil by holding one test-point at (**B**) and the other test-point on the base of the cut-out.

If the open circuits or grounds cannot be readily located and easily fixed by a visual inspection of the cut-out, we recommend the substitution of a new instrument instead of any attempts to rewind the cut-out.

Dash Cut-Out

The same inspection and tests are made on this type of instrument (Fig. 24), except that the test-points are held at the points (**M**) and (**G**) for making the voltage coil test, and on (**M**) and (**B**) for making the open-circuit test on the series coil, and at (**G**) and (**B**) for making the grounded test on the series coil.

To test the generator type it is not necessary to dismount it from the generator, but the battery lead should be disconnected from it until after the tests have been made and the instrument repaired, because if the cut-out is accidentally or intentionally closed the battery will discharge through the generator.

After the tests on the generator type have been made and the trouble eliminated if possible, the battery connection should be made for the regular generator test, and the cut-out should be tested to see that it cuts in at the proper speed and opens properly when the speed of the generator falls too low.

On the dash-type instrument after inspection and repairs have been made, or to test a new instrument, provision is made for this test on the F. B. Test Stand.

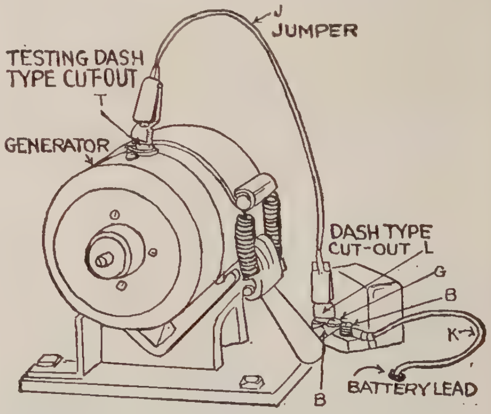

Fig. 26. Method of connecting the dash type of cut-out with the generator for testing the cut-in and cut-out speeds when driving the generator on test.

How to connect the dash-type cut-out to the system on the stand is shown in Fig. 26. The middle or ground terminal is attached to the copper strip fastened to the generator base (G) (Fig. 26). The battery lead is then connected to the battery terminal on the cut-out and, using the jumper, the generator terminal on the cut-out is connected to the main terminal on the generator. This hook-up then puts the cut-out in the circuit, identically the same as if it were attached to the dash of the car, and it can then be tested for the cutting-in speed and for proper opening at low generator speeds.

INSTRUCTION No. 46

THE STORAGE BATTERY; GENERAL DESCRIPTION: Connections; Care

GENERAL DESCRIPTION AND DATA

Storage batteries are described as being devices for storing electrical energy, which may be used for various purposes. They do not store the current, however, but generate electricity chemically, as will be explained farther on.

Storage batteries are also called "accumulators," and, under certain conditions, they are called "secondary" batteries.

The storage battery is used on automobiles for starting, ignition, lighting, operating the electric horn, and for various other purposes. The storage battery is used for starting the gasoline engine, by supplying current to an electric motor which causes the crank shaft of the engine to revolve.

Storage battery for ignition: Where a storage battery is used for ignition purposes alone, it is usually smaller; its capacity being from 40 to 60 ampere-hours. Its rate of discharge is about 2 to 5 amperes.

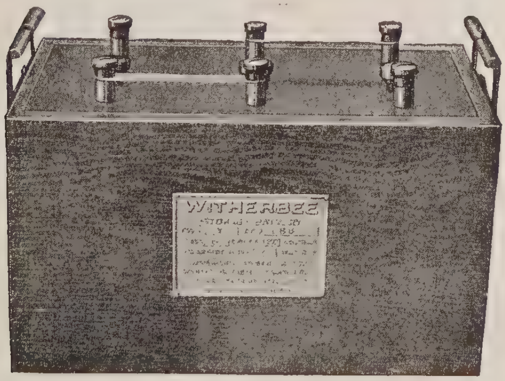

Fig. 1. A storage battery designed for **ignition and lighting.**

Storage battery for ignition and lighting: Where used for ignition and lighting, and not for starting purposes, the capacity ranges from 40 to 120 ampere-hours. The sizes in general use are of 40, 60, 80, 100, and 120-ampere-hours capacity.

The lighting and ignition battery is never subjected to a greater discharge than 5 to 15 amperes. For this reason, the connectors which connect one cell with another are of lighter construction than those of a battery used for lighting, ignition, and starting.

Lighting-battery plates are heavier and thicker in construction, being designed for service of low-discharge rates.

Storage battery designed for ignition, lighting, and starting: The usual capacity of a battery used for this combined purpose is from 90 to 100 ampere-hours. A generator operated from the engine keeps the battery charged, otherwise it would have to be recharged from an outside source.

The connectors on a battery of this type are very heavy, as the discharge, when operating a starting motor, sometimes runs as high as 450 amperes; the usual rate being from 150 to 200 amperes.

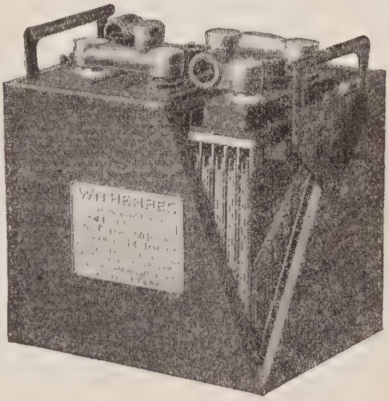

Fig. 2. A storage battery designed for **starting, lighting, and ignition.** Note the heavy construction of the connectors. One end is opened in order to show the plates of one cell.

The more plates per cell, or the greater the plate area, the greater is the batteries' capacity. Therefore, where batteries are designed for starting, lighting, and ignition, there are several thin plates; but a large plate area is used. Hence the large capacity that is essential where a high discharge is required.

Meaning of Amperes and Volts and Ampere-Hour Capacity

The meaning of "amperes" and "volts" is explained on page 175. The standard measure of the energy put into a battery is in terms of ampere-hours.

A volt is the unit of pressure which is necessary to cause electric current to flow.

A coulomb is the unit of electrical quantity: such a quantity of electricity as would pass in one second in a circuit whose resistance is one ohm, under an electromotive force of one volt.

An ampere is the practical unit of electric current—such a rate-of-flow of electricity as transmits one coulomb per second. The current rate-of-flow of 10 coulombs per second is 10 amperes; 50 coulombs per second is 50 amperes, etc. The amount of electricity is not of so much interest as the rate-of-flow—the ampere. Therefore this term is the one more generally used.

A higher electrical pressure (voltage) is required to force the same current through a small wire than through a larger one or through one of increased diameter. A higher voltage is required to force the same current through a long wire than through a shorter one.

The capacity of a battery is measured in ampere-hours. The volume of current flow is measured in amperes. A current of one ampere, flowing for one hour, is the unit by which capacity is measured, and is called "ampere-hour."

The ampere-hour capacity obtainable from a battery depends upon the amount of current consumed by the ignition, starting, or lighting system, and the capacity or quantity of electricity the battery is made to deliver. Lowering the consumption and increasing the capacity of the battery increases the ampere-hour capacity. The capacity of a battery is independent of its electrical pressure. Thus, a flow of 10 amperes, maintained for 8 hours, amounts to 80 ampere-hours.

The ampere-hour capacity of a battery, as stated, is dependent upon the rate of discharge. The lower the rate, the greater will be the capacity.

The same battery that has a capacity of 100 ampere-hours, at the 10-ampere discharge rate per hour, will have a capacity in excess of 100 ampere-hours if discharged at a lower rate, say of 5 amperes per hour.

An example: A certain battery will develop the following ampere-hour capacities at the indicated rates:

50.4 ampere-hours at a 3-ampere discharge rate for16.8 hours.
42.5 ampere-hours at a 5-ampere discharge rate for 8.5 hours.
36. ampere-hours at a 7½-ampere discharge rate for 4.8 hours.
30.0 ampere-hours at a 10-ampere discharge rate for 3.0 hours.

Ampere-Hour Discharge Rate of Battery for a Starting Motor

Let us take as an example a starting motor which requires 200 amperes for 3 seconds to crank the average engine. This means that 600 ampere-seconds (200 x 3) are taken from the battery. This is one-sixth of an ampere-hour.

If, when running the car, the generator delivers 6 amperes to the battery, it will require 2 minutes of running to replace the current taken out.

The voltage per cell of a fully charged battery during discharge at the 200-ampere rate will drop to 1.8 to 1.6, depending on the kind of plates and separators used.

If a battery has thick, **heavy plates and rubber separators instead of wood,** the acid cannot act as readily on the plates as it can when there are more plates but thinner. Acid cannot circulate as readily through the hard rubber as through porous wood. Furthermore, if the active material on the plates is hard, then the acid cannot act as readily as when it is soft.

For these reasons, the plates and separators used for the starting battery, which has a very heavy discharge, are **not as thick,** and the **separators are more porous,** and the active material is somewhat softer. The life of the starting battery of course is not as great as with a battery designed for a very low rate of discharge.

Voltage of Battery Cells

The voltage of a storage battery is determined by the number of cells. Each cell gives, on open circuit, from 2.1 to 2.2 volts when charged, no matter how many plates or what the size of the plates. If there are 3 cells to a battery, then the voltage would be 6.6 volts; that is, on open circuit, immediately after charging.

On a discharge, a charged battery will drop to 2 volts per cell, and if, say, an 80-ampere-hour battery is discharged for 8 hours at a rate of 10 amperes per hour, the voltage would gradually drop from 2 volts per cell to 1.7 volts at the end of the 8 hours, at which time it is discharged.

After this period, the voltage rapidly drops to zero voltage, in a manner similar to that in which the pressure of compressed air in a tank dies down if the air is drawn off.

The usual practice in determining the voltage of a storage battery is to count the number of cells. If there are three cells connected **in series,** which they usually are, each cell is considered as 2 volts, no matter how large or how small they may be.

A 3-cell battery would therefore be termed a "6-volt battery," a 6-cell battery would be termed a "12-volt battery," and so on. The 3-cell, or 6-volt battery represents the number of cells in general use on most cars. The Dodge uses 6 cells, or a 12-volt battery.

Capacity of a battery: The length of time a battery will maintain a certain current output, or ampere-hour discharge, depends upon the capacity of the battery, and the capacity depends upon the plate area exposed to the electrolyte. For instance, an ordinary jump-spark coil requires approximately 2 amperes. Therefore a 60-ampere-hour-capacity battery would operate the coil for approximately 30 hours, as the discharge rate is low. If the discharge rate was high, the ampere-hour capacity would be less.

Battery rating: It is customary for battery manufacturers to rate the battery as a "60-ampere-hour battery," or as a "100-ampere-hour battery," etc. This means that the battery is capable of giving 1 ampere for 60 or 100 hours respectively, if fully charged, and is discharged at a rate of 1 ampere.

The voltage of a battery does not entirely depend upon the size of the cell or the plate area of the cell. A battery is usually rated at 2 volts per cell, but the voltage varies slightly under certain conditions. We are of course considering a fully charged cell. The internal resistance of a cell is what governs the voltage.

If the battery is discharged, the internal resistance is greater, because the electrolyte, being less dense, offers resistance, and consequently less voltage. The higher the gravity up to a certain point, the less is the resistance. Too high a gravity (too much acid) is detrimental to the plates. When a very high discharge is made upon a cell, this calls for rapid circulation of the acid. Therefore, if separators are not porous, the internal resistance would be affected.

The capacity of a battery is usually rated in ampere-hours, meaning that a fully charged battery will discharge at a certain rate a constant current for a certain time until the voltage drops to a certain value (1.8). The rate of discharge is found by dividing the ampere-hour capacity by the hours, as, for example, 8 hours: 90÷8=11¼ amperes for 8 hours.

The capacity depends upon the plate area exposed to the electrolyte. If a square foot of positive plate surface is exposed to the electrolyte, the capacity is usually rated at from 40 to 60 ampere-hours, that is, at an 8-hour rate. This, however, varies. Temperature, as well as free circulation of the electrolyte, also affects the capacity of a battery.

Determining What Capacity of Battery to Use

Suppose a battery is to be selected for lighting purposes alone:

The first step in determining the proper size of battery for "lighting duty" is to decide upon the voltage of the lamps. Tungsten lamps, which consume about one-third the current required by carbon lamps, should invariably be used.

The second step is to determine the amount of current that the battery will be required to deliver. Do this by ascertaining, first, the number of lamps to be used, the voltage of each, and then determine the quantity of current each will take. Then add the total, which will give the total amperage required.

In some cases not all the lamps will be operated at the same time, and this should be taken into consideration. Allowance should also be made for any other current-consuming devices that may be used.

Knowing the amount of current that the battery will be required to deliver, you can select a battery of the proper capacity by referring to the table (Fig. 3).

How to Determine Number of Cells and Plates to a Cell by Number on Battery

In the U.S.L. battery lists, the first letter stands for a certain general type or construction.

For example, in type C-607, the letter "C" indicates the use of "C" plates, "C" jars, "C" covers, etc. The last two figures signify the number of plates per cell, and the first figure signifies the number of cells in the battery. Thus, battery type C-607 has 6 cells of 7 plates each; type A-317 has 3 cells of 17 plates each.

The suffix, or right-hand letter, indicates a particular assembly or arrangement of the jars in the battery box. For example, the letter "B" in type C-607-B indicates that the 6 jars are assembled side by side in the battery box.

Exide starting, lighting and ignition batteries: Take, for instance, the 3-XC-13-1 battery. The number "3" signifies that the battery is made up of 3 cells; the letters "XC" signify that the plates, separators, jars, covers, etc., which go to make up the battery, are of the type known as "XC"; the number "13" signifies that there are thirteen plates in each cell; the figure "1" signifies that the cells are assembled in the wood case side to side, this being known as No. 1 assembly.

When the cells are assembled end to end, the assembly is known as No. 2.

The same method of designation is followed out in the LX and SX batteries, also listed in the table of "Exide" batteries.

Types of Batteries (Exide as an Example)

Types JX, LX, LXR, LXRV, MHA, PHA, PHC, SX, and XC have been designed and built to meet the particular requirements of starting, lighting, and ignition service for passenger automobiles and power boats.

Types KXD, LXRE, and XE have been especially developed to meet the requirements of the exacting starting, lighting, and ignition service on motor trucks and tractors.

Types KZ and ZA have been produced particularly for motorcycle lighting and ignition service.

Capacity of Exide Batteries

The ampere-hours obtainable from a battery are greater for a **long low-rate** or intermittent discharge than for a **short high-rate** discharge. By an intermittent discharge is meant discharges of a few hours each spread over a period of three days or more.

The following table shows the **capacities at different discharge rates** for the various Exide types of batteries.

TYPE AND SIZE OF CELL	CRANKING CAPACITY	LIGHTING CAPACITY (IN AMPERE-HOURS)						IGNITION CAPACITY IN AMPERE-HOURS
	AMPERES FOR 20 MIN.	DISCH'G'D INTERMITTENTLY	1 AMPERE RATE	3 AMPERE RATE	5 AMPERE RATE	7½ AMPERE RATE	10 AMPERE RATE	
XC-9	63	60	.....	57	52	47	44	
JX-11 XC-11 XE-11	81½	75	.....	74	67	62	58	
JX 13 XC-13 XE-13	98	90	.....	90	84	77	72	
JX-15 XC-15 XE-15	114	105	.....	105	100	93	88	
XC-17	130	120	.....	120	117	109	103	
JX-19 XC-19 XE-19	116	135	.....	135	135	125	118	
XC-21 XE-21	163	150	.....	150	130	142	134	
XC-23	179	165	.....	165	165	158	150	
XC-25	195	180	.....	180	180	176	167	
KXD-5	.....	56	51	42	36	32	30	60
KXD-7	.....	84	81	68	61	55	51	90
KXD-9	.....	112	112	96	86	79	73	120
KXD-11	.....	140	140	124	113	104	97	150
KZ-3	.....	11	7½	5¾	4¾			
LX-5 LXR-5 LXRE-5	.....	40	39	32	28	25	23	50
LX-9 LXR-9 LXRE-9	78	80	86½	73	66	60½	56	100
LX-13 LXR-13 LXRE-13	117	120	136	118	108	100	94	150
LXRV15 LXR-15 LXRE-15	136	140	.....	140	130	120	112	
LX-17 LXR-17 LXRE-17	156	160	186	164	151	141	133	200
MHA-11 PHA-13 PHC-13	152	160	.....	160	150	140	132	
SX-9	.....	64	68	57	51	46	43	80
SX-13	.....	96	109	91	84	77	73	120
ZA-5	.....	13¼	10½	8	6¾			
ZA-7	.....	20	17	13½	11¾			

Fig. 3. Capacity of Exide batteries.

Age of Batteries

The age of batteries can be told by repairmen, as many of the manufacturers have codes which give the date from which time-adjustment can be made. These codes are letters or figures stamped on the connector, the name plate, or the battery box.

Some of the codes as supplied to us by the manufacturers are:

EXIDE AGE OR DATING CODE

Month	Stamp	Month	Stamp
Oct., 1917	Y	Nov., 1918	K
Nov., 1917	Z	Dec., 1918	L
Dec., 1917	&	Jan., 1919	M
Jan., 1918	A	Feb., 1919	O
Feb., 1918	B	Mar., 1919	Q
Mar., 1918	C	April, 1919	R
April, 1918	D	May, 1919	S
May, 1918	E	June, 1919	T
June, 1918	F	July, 1919	U
July, 1918	G	Aug., 1919	V
Aug., 1918	H	Sept., 1919	W
Sept., 1918	I	Oct., 1919	Y
Oct., 1918	J	Nov., 1919	Z

EXIDE AGE OR DATING CODE—*Continued*

Month	Stamp	Month	Stamp
Dec., 1919	&	Jan., 1921	M-1
Jan., 1920	A-1	Feb., 1921	O-1
Feb., 1920	B-1	Mar., 1921	Q-1
Mar., 1920	C-1	April, 1921	R-1
April, 1920	D-1	May, 1921	S-1
May, 1920	E-1	June, 1921	T-1
June, 1920	F-1	July, 1921	U-1
July, 1920	G-1	Aug., 1921	V-1
Aug., 1920	H-1	Sept., 1921	W-1
Sept., 1920	I-1	Oct., 1921	Y-1
Oct., 1920	J-1	Nov., 1921	Z-1
Nov., 1920	K-1	Dec., 1921	&-1
Dec., 1920	L-1		

Note. Since October, 1917, the date of shipment from the Exide factory has been stamped on the top of the first inter-cell connector link from the negative end of the battery and not on the nameplate.

VESTA AGE CODE

	1918	1919	1920	1921
Jan.	AV	AU	AT	AS
Feb.	BV	BU	BT	BS
Mar.	CV	CU	CT	CS
April	DV	DU	DT	DS
May	EV	EU	ET	ES
June	FV	FU	FT	FS
July	GV	GU	GT	GS
Aug.	HV	HU	HT	HS
Sept.	IV	IU	IT	IS
Oct.	JV	JU	JT	JS
Nov.	KV	KU	KT	KS
Dec.	LV	LU	LT	LS

Willard

When batteries are put into service, the date is shown in plain figures for the month and year on top of the connector. The customer can have his battery registered at the Willard service stations.

The Willard code uses the first letter as the year since 1916, using A for 1916, and so on alphabetically. The second letter indicates the month in alphabetical order except that I has been dropped.

Prest-O-Lite

Wet storage batteries shipped from the factory are branded with numerals, for example: "9-21," which is September, 1921.

Green seal or bone-dry batteries, when shipped to distributors, are not branded. Distributors are supplied with plates, with a space on them for inscribing the battery's date of service. This is on the side of the battery, and is usually inscribed by the distributor by means of a set of dies.

How to Tell if a Battery Has Been Repaired or Rebuilt

A rebuilt or repaired battery can usually be determined by noticing if the connectors have been removed. When these have been replaced and burned, a bright spot will appear in the end of each connector, and usually the numbers which were moulded on the connector will have been taken off.

Standard Size of a Starting and Lighting Battery as Determined by the S. A. E.[1]

Overall width, from side to side of case, not to exceed 7½".

Overall height, from bottom to top of handles, not to exceed 9½".

Overall length, measured from end to end of case, including handles, shall vary according to capacity and details of design. Handles shall, as standard, be placed at the ends of the battery. The space occupied by the handles, hold-down devices, shall be in the direction of width of battery. Terminals and connections shall not extend above handles.

ASSEMBLY OF STORAGE-BATTERY CELLS

The arrangement of the cells in the battery box can be across the battery box, termed "side assembly," or lengthwise with the battery box, termed "end assembly."

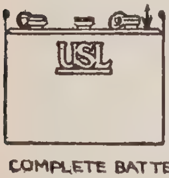

Fig. 4

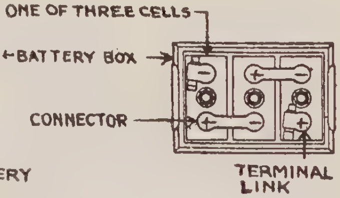

Fig. 5

Fig. 4. Side view of a complete storage battery.

Fig. 5. Top view of a 3-cell battery (6 volts) with one row of cells arranged as a "side assembly."

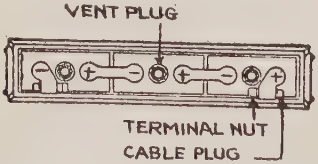

Fig. 6. Top view of a 3-cell battery (6 volts) with one row of cells arranged as an "end assembly."

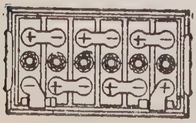

Fig. 7

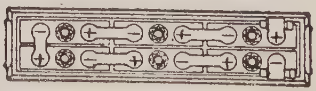

Fig. 8

Fig. 7. Top view of a 6-cell battery (12 volts) with one row of cells arranged as a "side assembly."

Fig. 8. Top view of a 6-cell battery (12 volts) with two rows of cells arranged as an "end assembly."

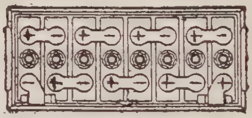

Fig. 9. Top view of an 8-cell battery (16 volts) with one row of cells arranged as a "side assembly."

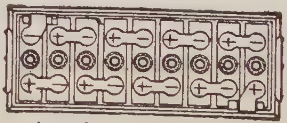

Fig. 10. Top view of a 9-cell battery (18 volts) with one row of cells arranged as a "side assembly."

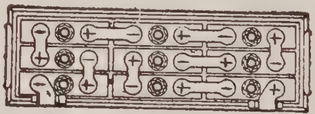

Fig. 11. Top view of a 9-cell battery (18 volts) with three rows of cells arranged as an "end assembly."

Cell Connections

The battery voltage is determined by the number of cells it contains, each cell being of a 2-volt capacity.

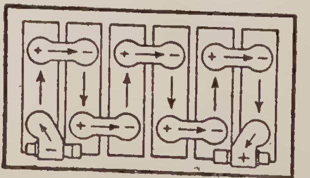

Fig. 12. Arrows show direction of current flow from cell to cell during discharge on a 6-cell, 12-volt battery, where the cells are side by side. Current would flow out from the (+) terminal to the circuit, then back to the (—) battery terminal. All cells are connected in series.

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[1] Society of Automotive Engineers.

Cells are usually connected in series, that is, the (−) terminal of one cell is connected with the (+) terminal of the next cell, and so on, as shown in Fig. 12. It is possible to connect cells so that a lower-voltage lamp or ignition circuit can be used on a higher-voltage battery.

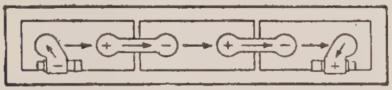

Fig. 13. Arrows show path of current from cell to cell on a battery during **discharge,** on a 3-cell, 6-volt battery. All cells are connected in series.

When a battery is discharging into a circuit, the current flows from the (+) terminal of the battery to the circuit, back to the (−) terminal of the battery. The arrow points in Fig. 12 show the path of the current when discharging.

When a battery is being charged by a generator, the current path through the battery is in the opposite direction.

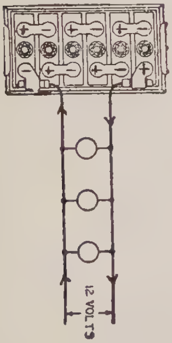

Fig. 14

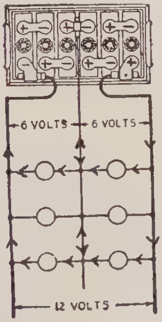

Fig. 15

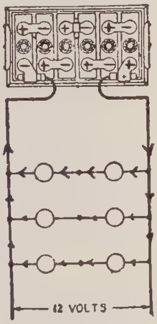

Fig. 16

Fig. 14. A 6-cell (12-volt battery) supplying current for one circuit of 12-volt lamps. Lamps are connected **parallel** across the circuit or line. If each lamp takes 1 ampere, the **discharge** of the battery would be **3 amperes.**

Fig. 15. A 6-cell (12-volt) battery supplying current for two lamp circuits of 6 volts each circuit. The third wire is the **neutral wire,** and connects with a neutral link or connection of the battery. Thus a neutral wire divides the battery circuit into three cells on each side.

The lamps are connected **parallel** across the line. If each lamp takes 1 ampere, then 3 amperes would be taken from the three cells on the right and 3 amperes from the three cells on the left, or **3 amperes from the six cells.** Therefore it is plain that the load on each side should be divided equally, so as not to discharge one side more quickly than the other.

This battery would be charged by connecting the end terminals (+) and (−) with a 12-volt charging circuit.

If one lamp burns out, it would not affect the other lamps.

The circuit of 3 lamps on the right would be from the (+) terminal of the battery to the lamps on the right, to the neutral wire, to the (−) terminal of the third cell in the center (right).

The circuit of 3 lamps on the left would be from the (+) terminal (top center cell at the left), to the neutral wire, through the lamps, to the (−) terminal of the battery.

Fig. 16. A 6-cell (12-volt) battery supplying current for one circuit of 12 volts. Two lamps are connected **in series** and then **parallel** across the line. Each lamp is 6 volts and two in series would operate on 12 volts.

If each lamp required 1 ampere, each of the two lamps across the line would draw 1 ampere; thus **3 amperes** would be the **battery discharge.** If one of the two lamps across the line should burn out, the other lamp would go out, as its circuit would be open. The other lamps, however, would not be affected.

Amperes do not express quantity. It will no doubt appear to the reader that the battery in Fig. 15 or Fig. 16 would be discharging 6 amperes. This is the result of considering amperage in terms of **quantity** of electricity; whereas it should be considered as expressing **rate of flow, or speed** of current.

In order to produce **light,** it is necessary to have **power,** and in Figs. 15 and 16, we have assumed that each 6-volt lamp draws **1** ampere. Therefore, the **power** required to light **each lamp** is 6 volts×1 ampere=6 watts per lamp.

In Fig. 15, we have six lamps, each requiring 6 watts power, or a total of 6×6=36 watts are necessary to cause the six lamps to burn. The battery supplies power at a pressure of 12 volts; consequently the **current discharging** from the battery would be 36 watts÷12 volts=**3 amperes.** For the same reasons, the current in Fig. 16 would also be **3 amperes.**

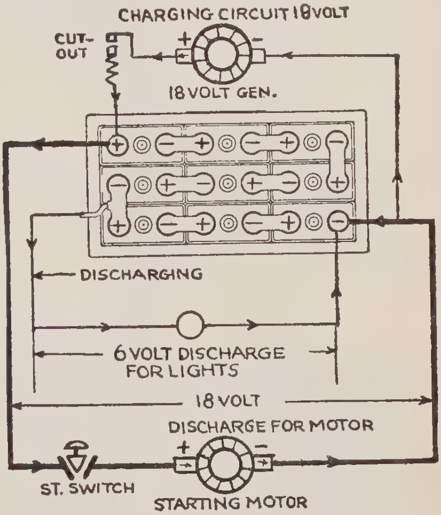

Fig. 16B. A 9-cell (18-volt) battery connected so that it **will discharge** at 18 volts for a starting motor and at 6 volts for a lighting circuit. The **battery is charged** by an 18-volt generator.

The charging circuit is from the (+) brush of the generator, through the cut-out points when closed, to the (+) terminal of the battery, through the nine cells connected in series, to the (−) terminal of the battery, to the (−) brush of the generator.

The discharging circuit of the starting motor is from the (+) terminal of the battery, to the starting switch, to the motor brush, through the motor field and armature, to the (−) brush, to the (−) terminal of the battery. This circuit is never on when the generator is charging the battery.

The discharging circuit for 6-volt lights: The lead wire for the lighting circuit is tapped on to the connector which connects with the lower cell at the left. Thus (+) current is derived from this lower left cell. The circuit is then through the lamp to the (−) terminal of the cell on the lower right. Note that there are 3 cells, or 6 volts used for the lighting circuit.

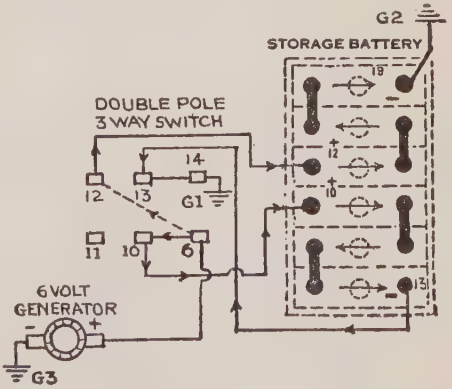

Fig. 17. A 6-volt generator **charging** a 6-cell (12-volt) battery.

Circuit of generator charging battery: We shall assume that we have a double-pole switch and that it is thrown to the right, so that 10 and 6 and 13 and 14 are connected.

The circuit for the three lower cells would then be from the (+) brush of the generator to (6), to (10), to the (+10) terminal of the battery, then through the three lower cells to the (−13) battery terminal, to (13) on the switch, to (14) which is grounded (G1), to the (−) grounded brush of the generator (G3).

The circuit for the three upper cells would be from the (+) brush of the generator to (6), through a permanent connection to (12), to the (+12) terminal of the battery, through the three upper cells, to the (−) grounded terminal of the battery (G2), to the (−) ground of the grounded brush of the generator (G3).

This would be termed **a series and multiple connection.** There are two sets of three cells of batteries connected in series; then the two sets are connected **in multiple** with the generator. This is the principle used on the 1917 "Maxwell 25," where a 6-volt generator and a 12-volt starting motor were used (see Index for Maxwell diagram).

The starting motor circuit is shown below (Fig. 17A). We shall assume that the switch lever has been thrown to the left, thus connecting 10 and 11, and 12 and 13; 6 and 14 have been cut out, opening the generator circuit.

The starting-motor circuit is then from (+12) of the battery, to (12) on the switch, to (13) on the switch, to battery terminal (−13), through the three lower cells to (+10), to (10) on the switch, to (11), to the (+) brush of the starting motor, through the starting motor field and armature, to the (−) grounded brush of the starting motor (G3), to the (−) grounded terminal of the battery (G2), through the three upper cells, to (+12), where we originally started.

This would be termed **a straight series connection.** The six cells of the battery are connected in series with the starting motor.

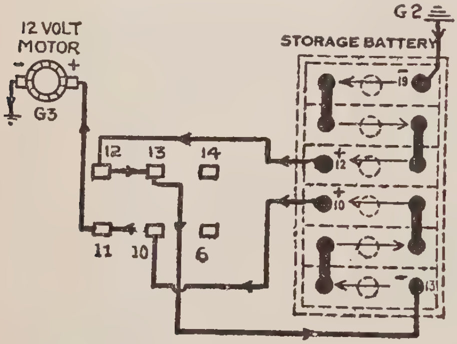

Fig. 17A. This illustration presents the same 12-volt battery as shown in Fig. 17. It is now being used on **discharge** to operate a 12-volt motor. Note how the battery connections are changed at the switch, in order to place the six cells in series, thus obtaining 12 volts from the battery.

Fig. 18. A 6-cell (12-volt) battery with cells connected in series. In this case we should have a voltage of 12 volts at the battery terminals.

If each cell had a capacity of 80 ampere-hours with this straight series connection, we should obtain only an **80-ampere-hour capacity** from the six cells at **12 volts.**

Watts = volts × amperes; 12 volts × 80 amperes = 960 watts. Therefore the **watt capacity** is 960.

Fig. 18A. A 6-cell battery with two sets of three cells connected **in series,** which would be 6 volts for each set. The two sets are then connected to the line **in multiple.** At the (+) and (−) terminals of the wires, we should have 6 volts, or the voltage of three cells in series. If the cells are of 80 ampere-hour capacity, we should have an **80-ampere-hour** capacity for each set of three cells in series, or a **160-ampere-hour capacity** for the two sets connected in **multiple** at 6 volts.

The watt capacity would be the same as in Fig. 18; for example, 6 volts × 160 amperes = 960 watts. Therefore the total output or capacity, as shown in Figs. 18 and 18A, is the same, the only difference being the rate of output.

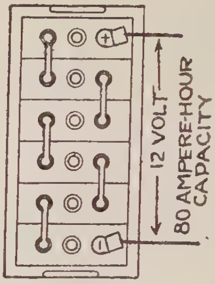

Fig. 18

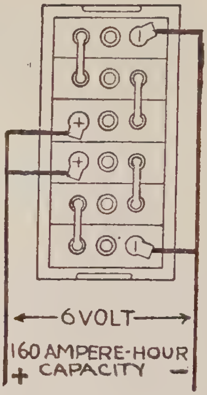

Fig. 18A

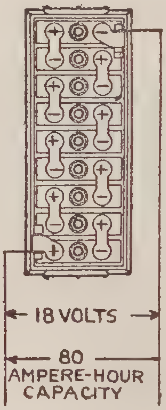

Fig. 18B

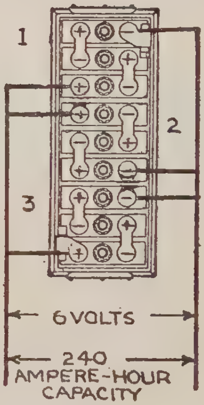

Fig. 18C

Fig. 18B. A 9-cell (18-volt) battery with cells connected in series. The terminal voltage is 18 volts. **The ampere-hour capacity is 80 ampere hours,** assuming that each cell is an 80 ampere-hour capacity battery.

Watt capacity would be 18 volts × 80 amperes = 1,440 watts.

Fig. 18C. A 9-cell (18-volt) battery with three sets of three cells connected **in series,** which would be 6 volts for each set. The three sets are then connected to the line **in multiple.** At the terminals, or wires, we should have 6 volts, or the voltage of three cells in series.

If cells are of 80 ampere-hour capacity, we should have an **80 ampere hour capacity** for each set of three cells in series, or **240 ampere-hour capacity** for the three sets connected in **multiple,** at 6 volts.

The watt capacity would be the same as in Fig. 18B. For example, 6 volts × 240 amperes = 1,440 watts.

The capacity of the battery, as will be observed in the examples given, is greater when the cells are connected in **multiple** than when connected in **straight series. The voltage, however,** is less; thus the watt capacity is equalized.

PARTS OF A MODERN STARTING, LIGHTING, AND IGNITION BATTERY (THE EXIDE USED AS AN EXAMPLE)

The external parts of the Exide type "3-XC-13," manufactured by the Electric Storage Battery Co., Philadelphia, Pa., are shown in the illustration (Figs. 20 and 21). By referring to page 523, we find that 3-XC-13 means 3 cells using plates, separators, jars, covers, etc., of the XC type; the 13 signifies that there are 13 plates in each cell. If there are 13 plates in each cell, then there would be 7 negative plates and 6 positive plates, as there are always more negative than positive plates.

The internal parts consist of, first, a wooden case for holding the cells. The cells are then placed in the wooden case, made of hard wood, thoroughly coated with an acid-proof paint. The jars in which the plates are placed are made of hard rubber. There are three jars or cells in this case; thus it is a 6-volt battery.

Note in Fig. 21, that a section is cut away to show the parts of the cell in the jar at the end of the case.

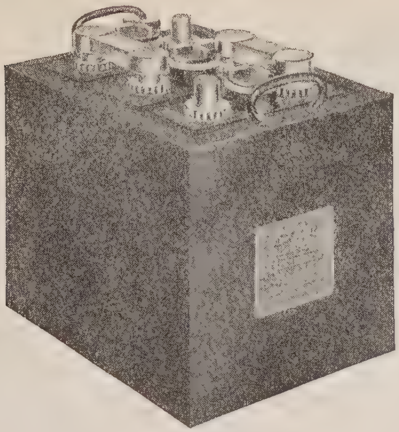

Fig. 20. Starting and lighting battery. Note the heavy connections. (Exide type 3-XC-13.)

Observe, first, that there is a negative plate, then a separator, then a positive plate, and so on, until there are 13 plates per cell (Fig. 21).

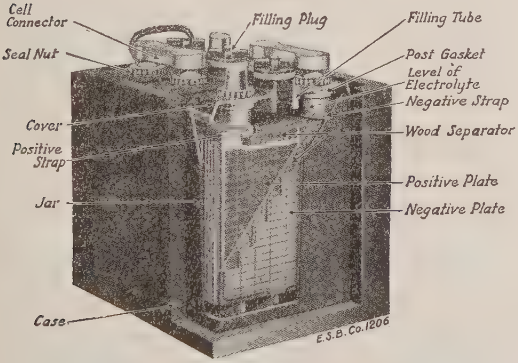

Fig. 21. The Exide type "3-XC-13," 3-cell battery; shown in section.

Jar:[1] The cell container is a rubber jar of special composition which will withstand the vibration of the car and any ordinary handling without breakage. The plates rest on stiff ribs or bridges in the bottom of the jar (Fig. 27), allowing space for the gradual accumulation of "sediment."

The plates are different in color, the positive (lead oxide) being a deep chocolate color, and the negative a gray (pure lead).

The plates are pasted and formed in groups. A positive and a negative plate of the Exide make are shown in Figs. 22 and 23.

Group: A set of plates burned to a strap is known as a "group," either positive or negative.

Fig. 24 shows a negative group of seven negative plates.

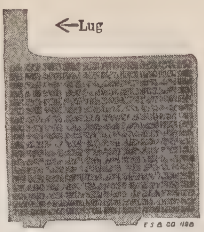

Fig. 22

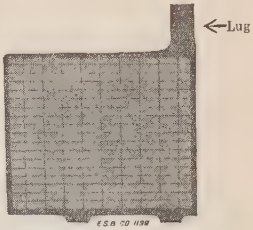

Fig. 23

Fig. 22. "Positive" plate, brown or dark.
Fig. 23. "Negative" plate, gray or light color.

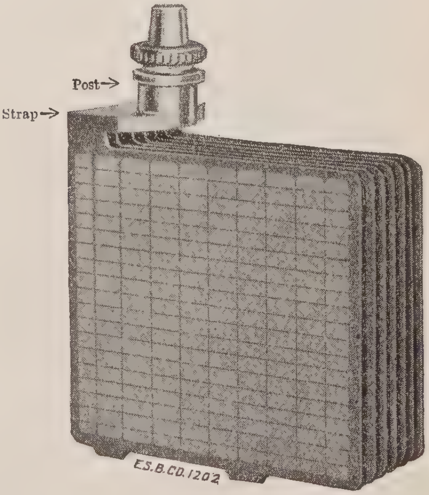

Fig. 24. A group consisting of seven negative plates and post and strap burned to lugs of plates.

A positive group would be arranged in the same manner, except that there would be one less plate of the positive group, or six plates.

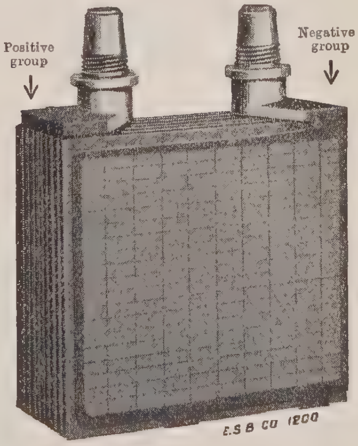

Fig. 25. Two groups, or the negative and positive plates, are called "elements." The two groups are interleaved, that is, the positive group of 6 plates is placed between the negative group of 7 plates, with wood separators between them. Thus two of the negative plates are always on the outside.

Element: A positive and a negative group together with the separators constitute an "element," as explained above.

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[1] The Exide battery is now using a composition case called Gummite, which is a very hard and durable substance in which some of the batteries are being assembled. This case takes the place of the rubber jars formerly used with each cell and of the wood case. The case is made with three compartments so that the plate elements are put right in these compartments and then sealed with the regular cover.

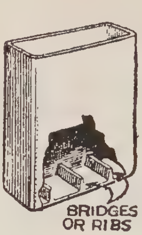

Fig. 26. Separators, which are placed between the plates.

Fig. 27. Jar with side open to show ribs at the bottom on which the element rests.

Separators: When the positive and negative groups are assembled together, the adjoining plates are insulated, or kept out of contact with each other, by means of wood separators, ribbed side against the positive plate. The separators (Fig. 26) are made of wood particularly adapted for the purpose and given a special treatment to remove harmful substances (explained farther on).

Lugs: Both the positive and negative plates are provided with an extension or "lug" at the top of each plate (see Fig. 23). The positive lugs come at one side of the jar and all the negative lugs at the other, thus enabling each set to be burned together with a connecting "strap," giving one positive and one negative pole. The burning is done by a hydrogen flame, or an electric arc, which melts or fuses the metal of both lugs and strap into an integral union.

Straps: The straps (Fig. 24) are made of a hard lead alloy and are burned to the lugs on the plates. The straps are provided with "posts" to which the cell connections are made.

Connectors are then placed so as to join the posts of one (−) group to the post on a (+) group in the next cell. See Fig. 21, "cell connector," showing how the connectors are placed. The connectors are burned to the posts. Sometimes they are not burned well, and a loose connection which causes heating and resistance is the result.

Electrolyte: The fluid, known as "electrolyte," is dilute sulphuric acid. The element (explained above, see Fig. 25) is placed in the jar with the electrolyte. This is also termed the "battery solution" (explained farther on).

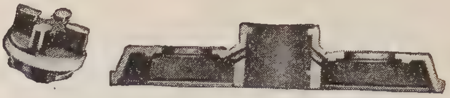

Fig. 28. Exide filling plug and sectional view of cover with plug removed.

Illustration (Fig. 28) shows the *filling plug*, together with a section of the cover with the plug out. The *filling tube* is the opening in the cover through which water may be added to replace evaporation, and through which hydrometer readings may be taken. The plug is so arranged as to catch electrolyte spray and return it to the cell, thereby keeping the top of the battery dry. It should always be kept tightly in place, except when adding water or testing.

When the complete element is placed in the jar and the electrolyte is in the jar, before the connectors are burned or welded in place, the cover and vent tube are placed over the top of the jar and sealed. The connectors are then burned to the posts.

Cover: The jar cover and method of sealing and venting is very important. The cover on the "Exide" battery (Fig. 28) is flanged in such a way as to give a more perfect seal to the jar than the old flat type of cover, and each cell is a separate sealed unit.

Vent or filler plugs are made of hard rubber, and screw into an opening in the cover. They are necessary in order that the gases generated in the battery when charging or discharging may escape, but the acid cannot splash out. They are also removed for the purpose of refilling, or putting water into the jar.

The small vent-hole should be kept open, as it is very necessary that the gases escape.

By looking down into the filler tube when adding water, it can be seen when the electrolyte is at the bottom of the tube, which is the correct level.

There are a number of different methods used for refilling and for ventilation. The purpose is the same in all, however.

Terminals: The **positive** terminal is marked (+), and can always be determined by the **dark** color. The **negative** terminal is a **light-gray** color, and is marked thus (−).

For directions for **testing a wire lead** from a generator or battery for its polarity, if not marked, see Index under "Polarity, how to find."

THE DRY STORAGE BATTERY

The difference between the **"wet storage battery"** and the **"dry storage battery"** lies chiefly in the method of preparing the acid.

The **"wet storage battery"** uses **liquid electrolyte,** and it is the sulphuric acid in this electrolyte which conducts the current, or, in other words, the sulphuric acid in the solution between the plates allows the current to flow through it. For a certain amperage discharge a certain amount of sulphuric acid must be used. The less acid, the greater the resistance.

When a battery is charged, the acid is mostly in the solution. When a battery is discharging, the acid is **diffused** or circulated through the separators into the plates, and the plates gradually absorb the acid from the solution. The **capacity** of a battery therefore depends upon the diffusion or circulation of the acid.

If a battery is discharging at a slow rate, the **diffusion** action is slow; if discharging at a high rate, as, for example, when used for operating a starting motor, the discharge is heavy and the **diffusion** action must be very rapid (see page 529 for meaning of diffusion).

When a charged battery is put on discharge, the diffusion action is more rapid because there is very little sulphate to clog the pores of the active material. As the discharge progresses, sulphate begins to form on the active material on the plates and fills up the pores, and diffusion is slower. Badly sulphated plates or clogged separators will cause slow diffusion.

Where batteries are used for stationary work and discharge rates are moderate, as with farm lighting batteries, etc., the diffusion action is slower, and it is thus possible to use larger cells and a greater quantity of solution with a lower acid gravity, which is easier on the plates and separators.

With a battery for automobile use, for lighting and starting work, the battery must be very compact, and only a limited space is provided for the solution. Thus a higher acid gravity must be used in order to obtain rapid diffusion, because at a half-discharged point, most of the acid would be in the plates and not in the solution.

The **"dry storage battery"** does not use liquid electrolyte. Usually, sulphuric acid is mixed with some kind of silicate base which, after being poured into the cells, turns to a **jelly substance,** and the principle or action is then similar to the use of liquid electrolyte.

This type of battery is not a new idea, and it would appear to be a very satisfactory battery for low-rate discharge. For a high rate of discharge, however, as with a starting motor, the question arises as to whether or not the **diffusion** action would be rapid enough.

It is claimed by some of the dry-storage battery manufacturers that this type of battery is an advantage, in that no separators are used, and that there being no liquid, it will not freeze, etc

As we are unable to obtain sufficient information from manufacturers of this type of battery, it is not our intention to condemn it, but inasmuch as the majority of automobiles are using the "wet storage battery," it is with this type that we shall deal in our instructions.

INSTRUCTION No. 47

THE STORAGE BATTERY; INTERNAL CONSTRUCTION; PRINCIPLE OF ACTION: Electrolyte; Hydrometer Tests

GLOSSARY TO THE STORAGE BATTERY INSTRUCTION[1]

This glossary is provided for reference, in case the reader is not familiar with words or terms used.

Acid: As used in this book, this word refers to sulphuric acid (H_2SO_4), the active component of the electrolyte.

Active material: The active portion of the battery plates: peroxide of lead on the positives, and spongy metallic lead on the negatives.

Alternating current: Electric current which does not flow in one direction only (like direct current), but rapidly reverses its direction or "alternates" in polarity, so that it will not charge a battery.

Ampere: The unit of measurement of the rate of flow of electric current.

Ampere hour: The unit of measurement of the quantity of electric current. Thus, 2 amperes flowing for ½ hour, equals 1 ampere-hour.

Arc burning: Making a joint by means of electric current which melts together the metal of the parts to be joined.

Battery: Any number of complete cells assembled in one case.

Battery terminals: Devices attached to the positive post of one end-cell and the negative of the other, by means of which the battery is connected to the car circuit.

Buckling: Warping or bending of the battery plates.

Burning strip: A convenient form of lead in strips, for filling up the joint in making burned connections.

Case: The containing box, which holds the battery cells.

Cell: The battery unit, consisting of an element complete with electrolyte in its jar, with cover.

Cell connector: The metal link which connects the positive post of one cell to the negative post of the adjoining cell.

Charge: Passing direct current through a battery, in the direction opposite to that of discharge, in order to put back the energy used on discharge.

Charging methods: "Series" method and "Constant Potential" method—see page 579.

Charge rate: The proper rate of current to use in charging a battery from an outside source. It is expressed in amperes and varies for different sized cells.

Corrosion: The attack of metal parts by acid from the electrolyte; it is the result of lack of cleanliness.

Cover: The rubber cover which closes each individual cell; it is flanged for the sealing compound, to insure an effective seal.

Diffusion: The act of spreading or circulating in every direction. The action of the acid mixing with the water that is left in the pores of the plates and at the surface of the plates from discharge, is explained as follows: When the battery is **being discharged,** the acid in the pores of the plates and right at the surface of the plates breaks up into water and sulphates, the sulphate going into the plates as lead sulphate. This leaves water in the pores of the plates and at the surface of the plates. In order for the storage-battery action to continue, fresh acid must be obtained from the reserve outside of the plate or in the cell, and this is accomplished by this outside acid **diffusing** or mixing with this water and forming acid again in the pores of the plates and at the surface of the plates.

Dry-storage battery: A type of battery using a paste or jelly substance instead of liquid electrolyte. See page 528. The "wet" battery is in general use, and is the type dealt with in these instructions.

Discharge: The flow of electric current from a battery through a circuit. The opposite of "charge."

Electrolyte: The fluid in a battery cell, consisting of specially pure sulphuric acid, diluted with pure water.

Element: One positive group, and one negative group, with separators, assembled together.

Filling plug: The plug which fits in and closes the orifice of the filling tube, in the cell cover.

Flooding: Overflowing through the filling tube. With the "Exide" automatic filling tube, this can usually occur only when a battery is charged, with the filling plug out.

Freshening charge: A charge given to a battery which has been standing idle, to insure that it is in a fully charged condition.

Gassing: The bubbling of the electrolyte caused by the rising of gas set free toward the end of charge.

Generator system: An equipment, including a generator, for automatically recharging the battery; in contradistinction to a straight storage system where the battery has to be removed to be recharged.

Gravity: A contraction of the term "specific gravity," which means the density, compared to water as a standard. See "Specific gravity" below.

Grid: The metal framework of a plate, supporting the active material, and provided with a lug for conducting the current and for attachment to the strap.

Group: A set of plates, either positive or negative, joined to a strap. Groups do not include separators.

Hold-down clips: Brackets, for the attachment of bolts, for holding the battery securely in position on the car.

Hydrogen flame: A very hot and clean flame of hydrogen gas and compressed air, used for making burned connections.

Hydrogen generator: An apparatus for generating hydrogen gas for lead burning.

Hydrometer: An instrument for finding the specific gravity of the electrolyte.

Hydrometer syringe: A glass barrel enclosing a hydrometer and provided with a rubber bulb for drawing up electrolyte.

Jar: The hard-rubber container, holding the element and electrolyte.

Lead burning: Making a joint, by melting together the metal of the parts to be joined.

Lug: The extension from the top frame of each plate connecting the plate to the strap.

Maximum gravity: The highest specific gravity which the electrolyte will reach by continued charging; indicating that no acid remains in the plates.

Oil of vitriol: Commercial name for concentrated sulphuric acid (1.835 specific gravity). This is never used in a battery and would quickly ruin it.

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[1] From **Exide Manual** except sections in smaller type. See page 556 for "Storage Battery Troubles" and page 454 for "Digest of Troubles."

Plates: Metallic grids, supporting active material. They are alternately positive (brown) and negative (gray).

Polarity: Electrical condition. The positive terminal of a cell or battery, or the positive wire of a circuit, is said to have positive polarity; the negative, negative polarity.

Post: The portion of the strap extending through the cell cover, by means of which connection is made to the adjoining cell, or to the car circuit.

Rectifier: Apparatus for converting alternating current into direct current.

Resistance: Material (usually lamps or wire) of low conductivity, inserted in a circuit to retard the flow of current. By varying the resistance, the amount of current can be regulated.

Rubber sheets: Thin, perforated hard-rubber sheets, used in combination with the wood separators in some types of batteries. They are placed between the grooved side of the wood separators and the positive plate.

Sealing compound: The acid-proof compound, used to seal the cover to the jar.

Sealing nut: The notched round nut which screws on the post and clamps the cell cover.

Sediment: Active material which gradually falls from the plates, and accumulates in the space below the plates, provided for that purpose.

Separators: Sheets of grooved wood, specially treated, inserted between the positive and negative plates to keep them out of contact.

Short circuit: A metallic connection between the positive and negative plates within a cell. The plates may be in actual contact or material may lodge and bridge across. If the separators are in good condition, a short circuit is unlikely to occur.

Spacers: Wood strips, used in some types to separate the cells in the case, and divided to provide a space for the tie bolts.

Specific gravity: The density of the electrolyte compared to water as a standard; often abbreviated as "gravity" or "sp. gr." or "S. G."

Starvation: The result of giving insufficient charge, in relation to the amount of discharge, resulting in poor service and injury to the battery.

Strap: The leaden casting to which the plates of a group are joined.

Sulphated: The condition of plates having an abnormal amount of lead sulphate, caused by "starvation," or by allowing the battery to remain discharged.

Tie bolts: Bolts which, in some types, extend through the battery case between the cells, and clamp the jars in position.

Top nut: The hexagon nut which, in batteries with bolted connections, screws on the post, and holds the connectors and sealing nut in place.

ELECTROLYTE

Electrolyte (also termed battery solution) **is put into the jar in which the plates are submerged.** It consists of chemically pure sulphuric acid having a specific gravity of 1.835 (H_2SO_4),[1] diluted with water (H_2O), the proportion being about 1 part of sulphuric acid to 2½ parts of water, by volume, this proportion of water and acid being such that the density of the solution will have a specific gravity of about 1.300 at 70° F. See table, Fig. 5, page 535.

Concentrated sulphuric acid (full strength) is a heavy, oily liquid having a strength or specific gravity of about 1.835. If put into a battery, it would quickly ruin it, and must, therefore, first be diluted with **pure water** to the proper strength for the particular type of battery cells to which it is to be added.

Chemically pure electrolyte: Both the water and the sulphuric acid used in making electrolyte should be **chemically pure** to a certain standard. This is the same standard of purity as is usually sold in drug stores as "CP" (chemically pure), or by the chemical manufacturers, as "battery acid."

In this connection, the expression "chemically pure" acid is often confused with acid of "full strength." Acid may be of full strength (approximately 1.835 sp. gr.) and at the same time not chemically pure.

If this chemically pure acid of full strength be mixed with chemically pure water the mixture would still be chemically pure, but not of full strength. On the other hand, if a small quantity of some impurity be introduced into chemically pure acid, it would not materially reduce the strength, but would make it impure.

The usual method of determining the strength or density of electrolyte is by taking its specific gravity. The method is possible on account of the fact that sulphuric acid is heavier than water. Therefore the greater the proportion of acid contained in the electrolyte, the heavier the solution, or the higher its specific gravity. The mixing of electrolyte is explained on page 534.

Specific Gravity

By specific gravity is meant the relative weight of any substance compared with water as a basis. Pure water, therefore, is considered to have a specific gravity of 1, usually written 1.000, and spoken of as "ten hundred." One pound of water is approximately one pint. An equal volume of concentrated sulphuric acid (oil of vitriol) weighs 1.835 pounds. It therefore has a specific gravity of 1.835, and is spoken of as "eighteen thirty-five." Acid of course is much heavier and denser than water.

If water is mixed with the sulphuric acid, it will reduce its specific gravity from 1.835. The more water that is added, the nearer its specific gravity will come to that of water (1.000). Thus when a hydrometer reading is taken, and shows the specific gravity to be 1.100, it will be seen that it is almost water.

Why Four Figures Are Used in Reading Specific Gravity

As stated, **water is taken as a standard unit, or as 1,** or if divided into one thousand parts, it would then be expressed decimally as 1.000 (1,000/1,000), and if mixed with acid to a certain proportion, say 1.400, it would mean 1,400/1,000, or 1.4 ($1\frac{4}{10}$).

If **acid,** which is heavier than water, is mixed with it, it **will increase the weight or gravity** of the solution or mixture.

If a sufficient amount of acid is used to make a 1.400 specific-gravity solution, it simply means that instead of the volume weighing 1 lb., which it would do if pure water, it will weigh $1\frac{4}{10}$ lbs., which, reduced to a decimal fraction, would be 1.4.

A solution often tests in fractions, which necessitates carrying out the decimals to a greater length, in order accurately to express the gravity of the solution, as, for instance, 1.275. Therefore quite often, in fact more often than not, four figures are necessary with most of the readings. Thus instead of expressing a reading as 1.4, the two extra ciphers are added so as to make any gravity be expressed uniformly in thousandths, instead of in tenths.

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[1] See page 536 for meaning of H_2SO_4, etc.

Farther on, explanations will be given, showing that **when a battery is fully charged, the specific gravity is 1.275 to 1.300.** This is as strong a mixture as dare be used in a battery. When the battery is fully charged, the acid and water are combined in the solution. But when the battery is being **discharged, the acid goes into the plates;** when it is fully discharged, there is very little acid left in the solution. If its specific gravity were tested under these conditions, it would be found that it is almost water, and (when the battery is fully discharged) would have a specific gravity of about **1.120 or 1.150.** This explains the fact that the solution in a battery freezes when the battery is discharged.

A STORAGE-BATTERY HYDROMETER

A hydrometer is used to test the specific gravity of the electrolyte when it is being mixed, and also for testing the specific gravity of the solution in a cell to see if it is charged or discharged.

If a battery is fully charged, the specific gravity will be between 1.275 and 1.300.

If fully discharged, the specific gravity will be between 1.150 and 1.120. See table in Fig. 1.

Note. Where a battery is used for starting motors, 1.275 to 1.300 sp. gr. at 70° F. is the "full charge," or top mark for battery specific gravity. A battery with gravity below 1.225 can hardly inject the requisite energy into the starter to spin the engine, so that 1.225 is practically the low mark. Then 1.280 minus 1.225 = .055, termed "55 points," covers the range between full charge and complete discharge.

Of course, a battery with gravity below 1.225 can operate the lights at a lower gravity. Suppose you try a hydrometer diagnosis and find the reading to be 1.255. Then 1.280 minus 1.255 = 22½ out of the 55 points of full range, from which you know that your battery is half-charged or half-discharged. 1.260 indicates three-quarters charged or one-quarter discharged.

A battery's capacity is considerably less during zero weather than in summer heat. Hence the importance of seeing that it is kept fully charged.

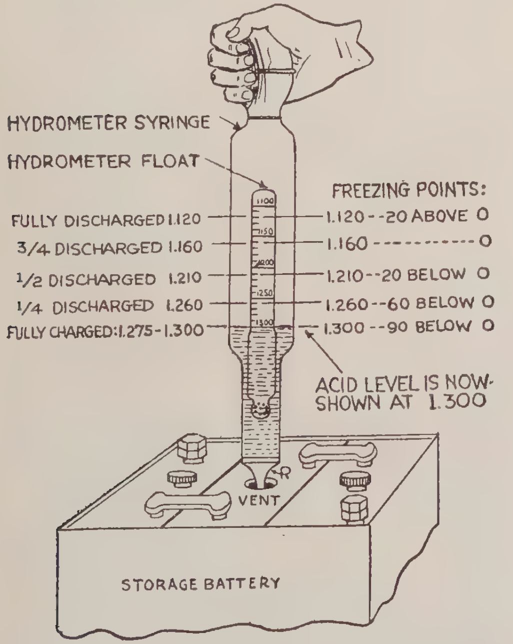

Fig. 1. A **hydrometer syringe** for testing the specific gravity of electrolyte or battery solution. Note the table showing **"charged"** and **"discharged"** readings and **"freezing points"** of electrolyte.

Construction of a hydrometer syringe: This device consists of a closed glass tube with a rubber bulb at one end and a rubber or glass tube (R) at the lower end, termed the nozzle. Inside of the glass tube a hydrometer is provided, with a graduated scale. A reading of this scale shows the specific gravity of the electrolyte.

Method of use: To test the specific gravity of the electrolyte in a cell, the vent plug is removed and nozzle (**R**) is inserted. The rubber bulb is depressed, which draws the electrolyte into the glass tube when released. Thus if a sufficient quantity is drawn into the tube, the hydrometer will float in the electrolyte. A small quantity of small shot is placed in the bottom of the hydrometer in order that it may sink to a certain depth, and to cause it to stand upright.

It will be observed that the highest specific gravity readings of the scale are at the lower part of the hydrometer, whereas the lowest readings are toward the top of the hydrometer.

The denser the electrolyte, the less will the hydrometer sink into it; therefore the specific gravity reading will be **higher.**

The less dense the electrolyte, or the nearer it approaches the density of water, the deeper the hydrometer will sink into the electrolyte; therefore the specific gravity reading will be **lower.**

To prevent the hydrometer from sticking to the side of the barrel, it is necessary that the syringe be held in a vertical position. The reading is taken at the surface of the electrolyte and when there is no compression on the bulb.

When the specific-gravity readings of electrolyte are taken, the temperature of the latter is supposed to be at 70° F. If the electrolyte is warmer or colder than this, it will affect the reading, as will be explained farther on under "Temperature corrections of hydrometer readings."

Pointers on the Use of the Hydrometer

When to take a hydrometer reading: Take a reading of each cell with the hydrometer syringe at least once a week, and just before adding water.

Electrolyte should be kept above the level of the plates. If not above, add pure water.

If hydrometer readings are taken after adding water, they are of no value, as only water or very weak electrolyte will be drawn into the syringe. This is due to the water being lighter than the electrolyte, and therefore remaining on the surface.

If the electrolyte is below the top of the plates, or so low that enough cannot be drawn into the barrel to allow of a proper reading of the hydrometer, fill the cell to the proper level by adding pure water; then do not take a proper reading until the water has been thoroughly mixed with the electrolyte by the gassing at the end of a recharge.

Take hydrometer readings at any time that any part of the electric system does not work properly, as they may indicate the trouble in the battery.

In using the hydrometer, certain points should be kept in mind: In the first place, the liquid taken up by the hydrometer from one cell should never be put into another cell, as this will be likely to cause some trouble, because of "high acid" in one cell, or weakened electrolyte in another.

Also care should be taken, when using the hydrometer, not to have any air bubbles form in the cell, as it is very difficult to get these out, and, as a result, the extra electrolyte is spilled. When heated up, the bubbles disappear and the level of the electrolyte sometimes falls below the tops of the plates.

When all cells are in good order, the specific gravity will test about the same (within 25 points) in each cell. (Note: gravity readings are sometimes expressed in "points"; thus the difference between 1.275 and 1.300 is 25 points.)

Some of the Troubles of a Battery as Indicated by a Hydrometer Reading

The storage battery is heir to many troubles, to so many, in fact, that a "Digest of Storage Battery Troubles" is provided on page 556. A few of the most common tests of a battery with a hydrometer are given below.

When the gravity will not rise above 1.225 or 1.250 from the generator charge on the car, this may be due to excessive use of lights, together with slow running of the car, which cuts down the charging current from the generator; or it may be due to trouble in the system. See "Digest of Storage Battery Troubles."

The remedy for the first-mentioned case is to use the lights sparingly, until the gravity rises above 1.250. If the gravity will not rise above 1.250 within a reasonable time, look for trouble in the system. See also page 478, under "Examine battery."

If, after the battery has been fully charged, the gravity again falls to 1.250 or less, it indicates that there is trouble somewhere in the system which must be located and corrected, and the battery should be charged from an outside source.

A cadmium test or high-ampere discharge test should then be made to find out if the trouble is within the battery and which one of the cells is causing the trouble. This subject is treated farther on.

The specific gravity readings of all cells of a battery should normally rise and fall together, as all cells of a battery, as used with most systems, are connected in series so that the charging and discharging current passes through all alike.

If the hydrometer reading of one cell should be considerably lower than the readings of the other cells in the battery, and if this difference should increase from week to week, it is an indication of trouble in that cell.

The trouble may be due to an internal short circuit in one of the cells, causing the cell to discharge itself, or it may be due to a leaking jar, as a slight leak will allow electrolyte to escape, and if the leak is not noticed, the addition of water to replace its loss will lower the gravity.

A discharged battery should be recharged immediately, for if it is left discharged, the plates will become sulphated (explained farther on).

How the Temperature Affects the Hydrometer Readings

Electrolyte, like most substances, expands when heated. Its specific gravity is affected, therefore, by a change in temperature, and the hydrometer readings will be affected accordingly.

Standard Temperature

The temperature adopted as the standard for a basis of comparison of specific gravities of electrolyte is 70° F. Thus, when we say that a specific-gravity reading of 1.280, taken by a hydrometer, indicates full charge, and that 1.225 or 1.220 indicates practical discharge for starter purposes, or that 1.150 indicates a total discharge, we mean that these are the specific gravities when the electrolyte has a temperature of 70° F.

Suppose a hydrometer reading is taken when the temperature of the electrolyte is much warmer, say 100 degrees Fahrenheit (expressed as 100° F.), above zero, instead of 70° F. What is the result? As previously stated, the electrolyte expands as it gets warmer. Thus it becomes lighter and less dense, and therefore the hydrometer will sink deeper into the solution, thus causing a **lower specific gravity reading.**

For example: See Fig. 1. Note that the lower readings are toward the top of the hydrometer, and that the higher readings are toward the bottom of the hydrometer.

Assume that a test is made at a temperature of 100° F. above zero, and the electrolyte level was even with the figure 1.270, on the hydrometer. This would indicate that the specific gravity of the electrolyte was 1.270. As a matter of fact, it would be 1.280, arrived at by what is termed "temperature correction."

Temperature Corrections

It has been found that if 70° F. is taken as a standard temperature for making hydrometer specific-gravity readings, then **for every 3 degrees rise in temperature above 70° F. it will be necessary to add 1 point on the hydrometer reading,** because the hydrometer sinks 1 point deeper into the solution with every 3 degrees of rise in temperature above 70° F.

Therefore with a temperature of 100° F. above zero, there would be a difference of 30 degrees (100—70=30), and if 1 point must be added for every 3 degrees of rise in temperature above 70° F., we should have to add (30÷3=10) 10 points; thus the **corrected reading** would be 1.270+10=1.280.

When colder than 70° F., the electrolyte becomes thicker, or more dense. In this case, the hydrometer will **rise,** thus giving a greater specific gravity reading. Hence, we should **deduct,** instead of adding, points.

For example: Refer again to Fig. 1. Note that the higher readings are toward the bottom of the hydrometer.

Assume that a hydrometer test is being made at 40 degrees Fahrenheit (40° F.) above zero, and that the electrolyte level is even with the figures 1.290. In this case the actual reading would be 1.280, arrived at by the "temperature correction" rule.

For every three degrees of temperature below 70° F., 1 point is deducted, because the hydrometer rises 1 point higher in the electrolyte with every three degrees of drop in temperature below 70° F.

Therefore with a temperature of 40° F. above zero, there would be a difference of 30 degrees (70—40=30), and if 1 point must be deducted for every three degrees of drop in temperature below 70° F., we should have to deduct (30÷3=10) 10 points; thus the **corrected reading** would be 1.290—10=1.280.

Although the two actual readings (1.270 and 1.290) differ by 20 points, the difference is all due to temperature. If the temperatures were the same, the readings would be the same. Thus, when the temperature is much above or below the normal (70° F.), the hydrometer readings should be "corrected for temperature."

Since the change of temperature does not alter the actual amount of acid in the electrolyte, but changes its specific gravity only, the readings taken with a hydrometer should be corrected, as stated above, by adding or deducting, as the case may be, one point for each three degrees of change in temperature above or below 70° F.

Temperature corrections are unnecessary when you compare the gravities of the different cells of a battery at any one time, since all have about the same temperature when in health, and affected alike.

Temperature corrections are also unnecessary, when you use the hydrometer, for testing, say, the middle cell, which we will call the "pilot cell," to secure an approximate index of the battery's condition. That is, corrections are in general unnecessary, except when there is reason for a really critical study of the battery's condition, as when you suspect things are not going well with the battery.

Note too that the actual proportion of water in the electrolyte slightly affects the gravity independently of the state of charge. That is, the more water there is, the lower the gravity. Therefore to derive the greatest benefit from the hydrometer readings, try to keep the electrolyte surface between a point ¼″ above the plates and the electrolyte level designated for the battery, either on the name plate or in the instruction pamphlet that you receive with the battery. Use the glass tube level-tester (page 562) consistently in conjunction with the hydrometer, and add water promptly when it is needed.

Battery Thermometer

For convenience, a thermometer (Fig. 2) has been designed with a special red ink scale opposite the temperature scale, and a glance at it tells how many **points to add or subtract from the hydrometer reading** when making tests of the electrolyte at different temperatures, in order to correct for temperature.

For example, an electrolyte temperature of 94° above zero means: **add** 8 points to the actual hydrometer reading.

An electrolyte temperature of 46° above zero means: **deduct** 8 points from the actual hydrometer readings.

An electrolyte temperature of 70° above zero indicates that no correction is to be made, as this is the normal temperature.

Electrolyte in Tropical Climates

Electrolyte is weaker in batteries used in tropical climates, and is purposely made so, because batteries operated in tropical climates give better results if the solution is weaker than that used in batteries for cooler climates.

Places where freezing of water never occurs are regarded as tropical climates.

Specific Gravity and Temperature Table

A table showing the variation of the specific gravity with temperature is given above. Note that instead of using 70° F. as a standard temperature, 60° F. is used in this table. Some manufacturers use 60° F. and others 70° F.

The specific gravity of the acid in a fully charged battery should not exceed 1.300 at 60° F. If hydrometer readings are taken at other acid temperatures than 60° F. allowance must be made for the temperature of the acid.

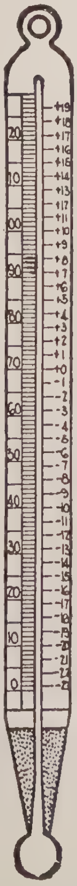

Fig. 2

The figures in black are acid gravities at 60° F. The others represent readings of these same gravities at the different temperatures shown at the top of each column, i.e., 1.300 at 60° becomes 1280 when the electrolyte temperature is raised to 110°, etc.

Read the temperature—read the hydrometer—then follow down that temperature column below which is nearest the observed acid temp., find the figures nearest the observed specific gravity reading, and trace horizontally across to the black column—these black figures are the true acid gravity and should form the basis for any acid adjustment.

0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	110°	120°
1170	1166	1163	1160	1157	1153	**1150**	1147	1143	1140	1137	1134	1130
1180	1177	1173	1170	1167	1163	**1160**	1157	1153	1150	1146	1143	1140
1190	1187	1184	1180	1177	1173	**1170**	1167	1163	1160	1156	1153	1149
1201	1198	1194	1190	1187	1183	**1180**	1176	1173	1169	1166	1162	1159
1211	1208	1204	1201	1197	1194	**1190**	1186	1183	1179	1176	1172	1168
1222	1218	1214	1211	1207	1204	**1200**	1196	1193	1189	1185	1182	1178
1232	1228	1225	1221	1217	1214	**1210**	1206	1203	1199	1195	1192	1188
1242	1239	1235	1231	1227	1224	**1220**	1216	1213	1209	1205	1201	1198
1253	1249	1245	1241	1238	1234	**1230**	1226	1222	1219	1215	1211	1207
1263	1259	1255	1251	1248	1244	**1240**	1236	1232	1229	1225	1221	1217
1273	1269	1265	1261	1258	1254	**1250**	1246	1242	1238	1235	1231	1227
1283	1279	1275	1271	1268	1264	**1260**	1256	1252	1248	1245	1241	1237
1293	1289	1286	1282	1278	1274	**1270**	1266	1262	1258	1254	1250	1247
1303	1300	1296	1292	1288	1284	**1280**	1276	1272	1268	1264	1260	1257
1314	1310	1306	1302	1298	1294	**1290**	1286	1282	1278	1274	1270	1267
1324	1320	1316	1312	1308	1304	**1300**	1296	1292	1288	1284	1280	1276
1334	1330	1326	1322	1318	1314	**1310**	1306	1302	1298	1294	1290	1286
1344	1340	1336	1332	1328	1324	**1320**	1316	1312	1308	1304	1300	1296
1355	1351	1347	1343	1338	1334	**1330**	1326	1321	1317	1313	1309	1304

Average cell voltage at 80° usually falls between 2.5 and 2.7
" " " " 100° " " " 2.4 " 2.6
" " " " 120° " " " 2.35 " 2.55

Baume Scale

On some hydrometers **another scale is sometimes used, called a Baume scale.** It also is sometimes used for ascertaining the specific gravity of electrolyte. The hydrometer scale as shown in **Fig. 1** is in general use.

Fig. 4.

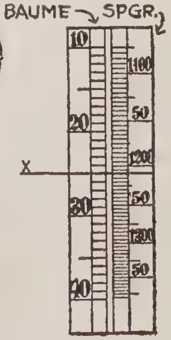

Fig. 3.

A comparison of the Baume scale and specific-gravity scale is given in the accompanying table, and also in the scale of the hydrometer in Fig. 3. Note the scale at (X). If the hydrometer is level in the electrolyte at this point, the Baume reading would be 25, or the equivalent of a 1.208 specific-gravity reading.

COMPARISON OF THE BAUMÉ AND SPECIFIC GRAVITY SCALES AT 60° FAHRENHEIT.

Degrees Baume	Specific Gravity	Degrees Baume	Specific Gravity	Degrees Baume	Specific Gravity	Degrees Baume	Specific Gravity
0	1.000	17	1.133	34	1.306	51	1.542
1	1.007	18	1.142	35	1.318	52	1.559
2	1.014	19	1.151	36	1.330	53	1.576
3	1.021	20	1.160	37	1.342	54	1.593
4	1.028	21	1.169	38	1.355	55	1.611
5	1.036	22	1.179	39	1.368	56	1.629
6	1.043	23	1.188	40	1.381	57	1.648
7	1.051	24	1.198	41	1.394	58	1.666
8	1.058	25	1.208	42	1.408	59	1.686
9	1.066	26	1.218	43	1.421	60	1.707
10	1.074	27	1.229	44	1.436	61	1.726
11	1.082	28	1.239	45	1.450	62	1.747
12	1.090	29	1.250	46	1.465	63	1.768
13	1.098	30	1.261	47	1.479	64	1.790
14	1.107	31	1.272	48	1.495	65	1.812
15	1.115	32	1.283	49	1.510	66	1.836
16	1.124	33	1.295	50	1.526		

Ball Electrolyte Tester

An electrolyte tester (seldom used) is shown in Fig. 4.

If the acid is at its proper strength (30° to 32° Baume, or 1.260 to 1.280 specific gravity), both balls will remain in the center of the tube when the battery is fully charged.

If both balls float, the acid is too strong and it should be reduced by adding water.

If both balls sink when the battery is discharged, the battery should be fully charged, and then if the white ball does not float, stronger acid should be added.

Voltmeter, Cadmium, and High-Rate Discharge Tester

A voltmeter is also used for testing the voltage of batteries on charge or discharge, as is also a "cadmium test meter," and a "high-rate discharge" test. These tests are generally used by repairmen, and will be explained under the discussion devoted to the repair of storage batteries.

Freezing of Electrolyte

The freezing point of electrolyte depends upon its specific gravity. There is little danger of freezing except with a discharged battery.

Water will freeze at 32° F. Hence, if the battery were to be discharged by some means to the point of where the electrolyte is near the gravity of water, the electrolyte would of course freeze near this point.

In order to avoid freezing of the electrolyte, the battery should always be kept in a fully charged condition. A table is given in Fig. 1 which shows the freezing points of electrolyte.

When a battery is stored away for a period of time, care should, therefore, be taken that the battery is kept in a fully charged condition.

If the electrolyte becomes frozen, the expansion will sometimes break the jar. If it does not, simply place it in a warm place and it will come back to its normal charge. It is best, however, to recharge it first, and then pour out the old electrolyte and put in new electrolyte of a specific gravity of 1.300.

MIXING ELECTROLYTE

On page 530 we discussed the meaning of electrolyte and what it is composed of. We shall now deal with the mixing of electrolyte.

When mixing electrolyte, the following precautions should be observed:

1. A glazed stone vessel or a lead-lined tank should be used. Never use tin or any metal other than lead. Glass, porcelain, stone, rubber, or glazed earthenware can be used.
2. Put the water in the vessel first.
3. Fill the hydrometer syringe with chemically pure sulphuric acid and add it to the water by holding the nozzle under the surface. Stir the solution with a glass rod or clean piece of wood.
4. Rinse the syringe and test the strength of the solution. If it shows only about 1.160 sp.gr., allow it to cool, when it will be stronger.
5. If not strong enough, add more acid.
6. If too strong, add water.
7. The pure acid should not be allowed to remain in the syringe.

Specific Gravity of Electrolyte to Be Mixed

If the specific gravity of full-strength sulphuric acid were tested with a hydrometer it would show approximately 1.835, which of course is too strong to put into a battery cell. Therefore its density and strength must be reduced by diluting it with pure water.

The density or specific gravity of electrolyte[1] that should be put into a cell should never exceed 1.400 sp. gr. In fact, this might be termed the standard density or specific gravity of electrolyte sold by supply houses, and which should be kept on hand by battery service stations. In other words, the usual practice is to mix the acid and water in such proportions that the density of the solution will have a specific gravity of 1.400.

The 1.400 sp.gr. electrolyte can then be reduced to 1.300, 1.280, 1.275, 1.260, or to any density or specific gravity desired.

When to Use Electrolyte

When at the desired density, **it is used to adjust the specific gravity of the solution in a battery which is on charge,** providing the specific gravity fails to rise to its proper value.

It is also used to refill batteries after repairing, and also to restore any lost through slopping and leakage.

The loss of solution from evaporation, occasioned during charging and discharging, consists ordinarily entirely of water, and pure distilled water is used to replace it.

Loss due to slopping or leakage is a loss of solution, and must be replaced with solution.

Too much acid strength will reduce the life of the battery.

Proportions of Water and Acid to Mix

For the proper proportions in which to mix full-strength concentrated acid and pure distilled water, in order to make a mixture of 1.400 specific gravity (or any other gravity) electrolyte, reference should be made to the chart (Fig. 5). It will be noted that the curve shows the proportion by weight and also by volume.[1]

Meaning of "By Volume" and "By Weight"

The term **"by volume,"** as used in the curve (Fig. 5), refers to the use of measurements, such as pints, quarts, etc. If 1½ parts of water is the "volume" called for in the curve at the left, then use, say, 1½ pints of water and 1 pint of acid. See explanation under Fig. 5.

The term **"by weight,"** used in the curve, refers to the use of weight measurements, as on a scale. An example of mixing 1.400 sp. gr. electrolyte by weight would be, to follow the vertical line from 1.400 (Fig. 5) to the curve marked "Parts by Weight"; then follow the horizontal line to the left, which will

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[1] The Gaselli Chemical Co., Cleveland, Ohio, with branches in all large cities, carries electrolyte ready prepared in densities of 1.100, 1.300, 1.400, and 1.800.

1.400 is the best proportion to purchase. The electrolyte is usually shipped in carboys, weighing about 150 lbs.

The General Storage Battery Co., St. Louis, Mo., also supplies electrolyte in small or large quantities, as well as separators, plates, and other battery supplies.

[1] This chart, or curve, is taken by permission from the Exide (copyrighted) instruction book.

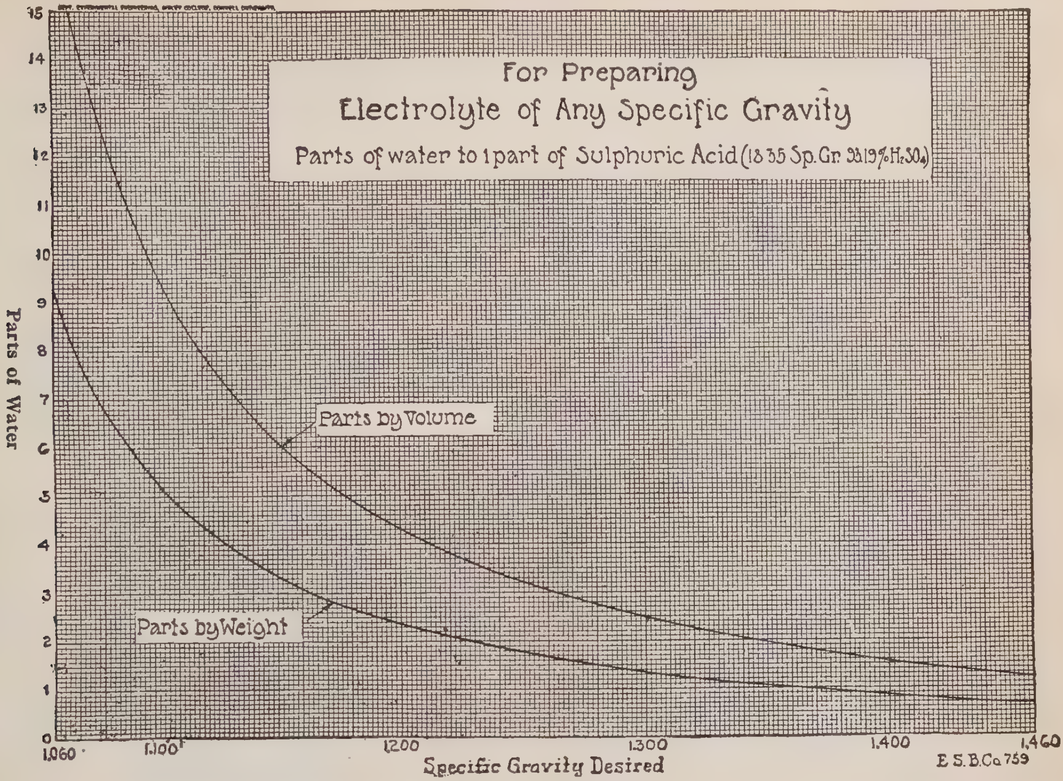

Fig 5. Curves showing the proper proportions of distilled water that should be used with one part of sulphuric acid; the parts are given by volume and also by weight.

How to read: If, for example, a solution of 1.400 sp. gr. electrolyte is desired, first find the 1.400 on the bottom line of the chart; then follow the vertical line until the curved line (parts by volume) is reached. Follow the horizontal line to the extreme left of the scale, and it will be found to indicate 1.5. This shows us that, for electrolyte solution of 1.400 sp. gr., 1½ parts of pure water is the quantity to be used with 1 part sulphuric acid, and a test with the hydrometer should show a reading of 1.400, if the temperature of the solution is 70° F.

If the temperature is more or less, then corrections in the hydrometer reading should be made in accordance with directions given under "temperature corrections" (page 532). The horizontal lines in the chart are divided into tenths.

show that 9/10 is the amount of water by weight to use with 1 part by weight of acid. Therefore, take 1 lb. of acid, and then 9/10 lb. of water, which, by volume, would be 1½ times 1 part of acid.

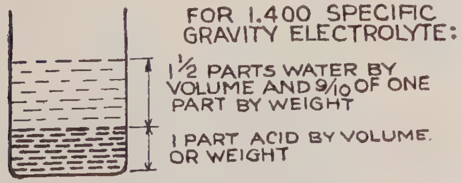
FOR 1.400 SPECIFIC GRAVITY ELECTROLYTE:
1½ PARTS WATER BY VOLUME AND 9/10 OF ONE PART BY WEIGHT
1 PART ACID BY VOLUME OR WEIGHT

Fig. 6.

A careful reference to the illustration (Fig. 6) will probably assist in making the meaning clear.

Why Electrolyte of 1.275 to 1.300 Sp. Gr. Is Used

The reason why 1.275 to 1.300 specific gravity acid is used in a charged battery may briefly be stated as follows:

The resistance of the electrolyte to the passage of current internally in the cell is greater when the electrolyte is weak. The resistance is less when the **electrolyte is stronger, or more dense (up to a certain point).**

Since density, or a higher specific gravity, is a better conductor than a lesser density, or lower specific gravity, the voltage increases with the increase of conductivity (i.e., the strengthening of the electrolyte). Therefore the internal resistance of a cell is less when the gravity is higher.

With too high a gravity (too much acid), the lead part of the plates will be **attacked,** and the active material on the plates would be changed to lead sulphate when idle.

Thus it will be clear that the proper proportion of acid to use is a highly important detail.

"Adjusting" the Specific Gravity of the Electrolyte or Solution in a Battery—also Termed "Balancing" Electrolyte

Many batteries have been ruined by having the electrolyte too strong, or by adding acid at the wrong time to bring up the gravity—termed **"doping"** the battery. Sulphuric acid does not evaporate; the water evaporates. Therefore when the electrolyte falls below the level of the plates, pure water only should be added. And, as previously stated, when water is being added, the battery should have a **charging current** run through it to mix the water with the electrolyte before taking a hydrometer reading. The reason for this will now be explained.

When through a hydrometer reading, the specific gravity is shown to be 1.150, the battery is discharged, meaning that the acid is **in the plates,** and the solution consists mostly of water. If acid should be added under these conditions, the solution would show a higher specific gravity reading, yet the battery would be discharged. Then when the battery was charged, the acid in the plates would mix with the acid that was added, and thus a very high specific gravity reading would result. The excess acid would attack the plates and cause sulphation.

The addition of a stronger acid solution, or electrolyte, should be made only under certain conditions.

When and How to Adjust the Gravity of the Solution

When a battery is fully charged, the specific gravity reading should be 1.275 to 1.300—usually about 1.280.

When the battery is charged, the acid is **out of the plates** into the solution; this is the proper time to adjust or balance the electrolyte, and not when the acid is **in** the plates, at which time the battery is discharged. It is customary to adjust the electrolyte in a battery two or three times a year.

Therefore an adjustment of the specific gravity of the solution in a battery should be made only when the battery is fully charged.

When the specific gravity of the electrolyte is tested with the object of balancing or adjusting the electrolyte, the battery should be charged under its normal rate (usually specified on the plate on the battery). Then test the electrolyte with the hydrometer, from time to time as the charging progresses, until after four or five hours no further increase of the specific gravity is noticed. When the charge is complete, as indicated by the gravity remaining constant for five hours, the gravity in all the cells should be between 1.275 or 1.280 to 1.300. If the gravity in one or more cells does not come between these limits, it should be adjusted or balanced.

If the gravity reads over 1.300, withdraw some of the electrolyte and replace with distilled water, using a syringe for the purpose. The amount of water to be added depends upon how much the gravity exceeds 1.300; ability to judge comes with experience.

If the gravity reads less than 1.275, some of the electrolyte should be withdrawn and replaced with diluted acid of 1.400 sp. gr., until the solution in all cells tests 1.280. The battery is then placed on charge at the finish rate, until the gravity remains constant.

If at the end of the charge the gravity of the electrolyte is above or below the limit, acid or water should be added as required, and the battery should be put on charge again.

If the adjustment necessary is considerable, or if the solution is suspected of having been "doped," it will be found more convenient to empty out the solution and refill with electrolyte of specific gravity estimated to bring it right, allowing for the effect of the old solution held in the cells. Experience will enable the operator to gauge this quite accurately.

When emptying a battery of its solution, it is best to draw the solution out instead of turning it upside down to pour it out, because the sediment in the bottom of the jar will work its way between the plates.

After any adjustment, charge for some minutes to allow the gassing to mix the solution thoroughly before taking hydrometer readings.

If the temperature is far from normal, correct the hydrometer readings by adding one point (.001 sp. gr.) for each 3 degrees above, and subtracting one point for each 3 degrees below 70° F. (See page 532).

Always wipe off the top and sides of the battery with weak ammonia after adjusting electrolyte.

If the electrolyte of one cell tests lower than the others, it indicates that this cell is not in good order. It may have an internal short circuit, or a leaky jar, or perhaps new separators are required. See "Digest of Storage-Battery Troubles."

The activity of the electrolyte increases as its temperature increases. Thus in warm or tropical climates it is advisable to use electrolyte of lower gravity than that specified for temperate zones.

The subject of **using a battery solution over again** after installing new plates, as well as **the proper strength of acid to use after overhauling a battery,** is discussed farther on.

Exide Instructions for Adjusting Electrolyte

It will be unnecessary to adjust the strength of the solution except in the cases called for, otherwise harm may result.

To adjust the strength to between 1.270 and 1.300 (1.200[1] and 1.230),[1] the simplest procedure is as follows:

1. Be sure the battery is completely charged.
2. Have ready some electrolyte with a strength of 1.285 (1.215).[1] This may be prepared as outlined on page 534.
3. Dump the solution out of the cells, and at once fill the cells with the prepared electrolyte. Do not allow the battery to remain empty.
4. Charge for an hour at the charging rate given in the table on page 577 ("Initial Charge and Repair Charge").
5. If the hydrometer reading is still below 1.270 (1.200),[1] or above 1.300 (1.230),[1] adjust again until it is between these limits.

STORAGE BATTERY: CHEMICAL TERMS

H_2O: **Water,** a liquid which is made up of hydrogen two parts (H_2), and oxygen one part (O).

H_2SO_4: **Sulphuric acid,** a liquid chemical compound of hydrogen (a gas) 2 parts (H_2); sulphur (a solid) 1 part (S); and oxygen (a gas) 4 parts (O_4).

Pb: **Lead,** which is a solid.

PbO: **Litharge,** consisting of lead 1 part, and oxygen 1 part.

PbO_2: **Lead peroxide** (a solid), made up of lead 1 part (Pb), and oxygen 2 parts (O_2).

$PbSO_4$: **Lead sulphate** (a solid), made up of lead 1 part (Pb); sulphur 1 part (S), and oxygen four parts (O_4).

Litharge: Oxide of lead.

Oxide: A compound of oxygen and a base.

Peroxide: The oxide of a base which contains the largest portion of oxygen.

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[1] These alternative figures apply to tropical climates.

Sulphate: When speaking of storage batteries, it is lead sulphate that is meant, the substance into which the active material of both positive and negative plates is charged or discharged.

There are four elementary substances as follows:

H: **Hydrogen,** a gas.

O: **Oxygen,** a gas.

S: **Sulphur,** a solid.

Pb: **Lead,** a solid.

Two of these are gases and two solids. The sulphur which is used to form the compounds mentioned above as H_2SO_4, and $PbSO_4$ does not entirely separate itself from them, but remains with O_4. The compounds, however, split up into H_2 and SO_4. Pb, and SO_4.

INTERNAL CONSTRUCTION OF A STORAGE BATTERY

The pasted plate: A grid for the Faure type of plate is shown in Fig. 7. It is the plate now used for automobile storage-battery work.

The Plante type of plate (Fig. 8) is not used very much for automobile starting and lighting purposes, as the Faure plate is much lighter and delivers a much greater capacity per pound of weight, and is also easier to manufacture.

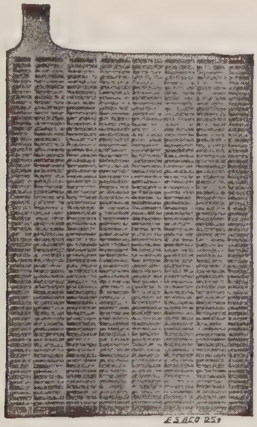

Fig. 7. A lead grid for a pasted type of plate ready for the paste.

Each cell is composed of a certain number of negative plates and a certain number of positive plates. There is always one more negative plate to a cell than there are positive plates.

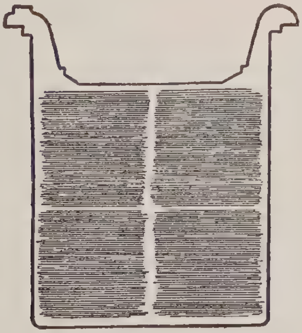

Fig. 8. Plante type of plate.

The reason there is an odd number of plates in a cell is that there is one more negative plate than positive. A negative plate is placed at each end, so that there will be action on both sides of all positive plates. The positive plates are thicker and have more active material. The positive plates also have a tendency to recede from the negative, and if a positive plate were placed at either end, it would buckle and bend away from the negative plate.

The positive plate and the negative plate are each made of lead (Pb), and are cast in the form of grids (Fig. 7) so that paste can be inserted into the grids.

The paste which is set into the lead grids goes through a forming process of charging and discharging, and is hardened and is converted into what is termed **active material.**

There are many different formulas for making this paste which are trade secrets of different manufacturers. The base, however, for forming the active material for the plates is an oxide of lead, usually red lead (Pb_3O_4) (lead 3 parts, oxygen 4 parts) for the positive plate, and litharge (PbO) (lead 1 part, oxygen 1 part) for the negative plate.

The litharge for the negative plate is formed into a paste by combining it with diluted sulphuric acid (H_2SO_4), and then working it up to a desired putty-like consistency for applying to the grid.

Owing to the tendency of litharge on the negative plate to contract, when subjected to the electrochemical action which takes place in the cell, it is necessary to use what is termed an **"expander."** Barium sulphate ($BaSo_4$) or magnesium sulphate, lamp black, or graphite are also used by some battery manufacturers.

The red lead is likewise made into a paste for the positive plate, by mixing with diluted sulphuric acid (H_2SO_4). It is necessary to use a "binder" with this paste in order to prevent shedding. Ammonium sulphate $[(NH_4)_2SO_4]$ is largely used for this purpose.

After the paste is applied to the grids of the plates, the plates are dried. The paste will then harden and turns to lead sulphate ($PbSO_4$) on both the negative and positive plates.

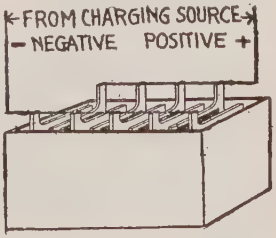

Fig. 9. Forming the plates.

Forming: The plates are then placed in the charging tank (Fig. 9) with the negative and positive plates alternating, and with plenty of space between them. All the positive plates are connected with the positive terminal of a direct-current charging source, and the negative plates are connected with the negative terminal of the charging source. There is, of course, electrolyte in the tank, of about 1.100 or 1.200 specific gravity, when used for forming. The passing of the charging current through the plates forms peroxide of lead (PbO_2) on the positive plate which turns to a dark-brown color, and to gray, spongy, porous, soft lead (Pb) on the negative plate.

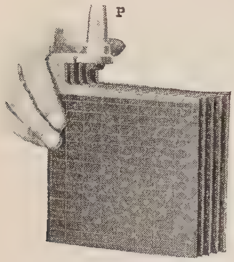

Fig. 10

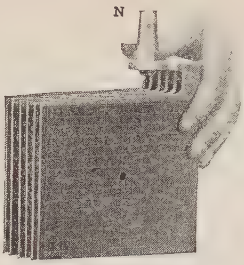

Fig. 11

Fig. 10. A positive group of 5 plates.

Fig. 11. A negative group of 6 plates.

The illustrations are taken from the catalogue of the General Storage Battery Co., St. Louis, Mo., and are the plates of type 116, 11-plate starting and lighting battery.

The average starting and lighting batteries use either 11 or 13 plates, of about 80 to 100 ampere-hour capacity.

In a 13-plate battery, there would be 7 negative (gray) plates and 6 positive (dark-brown) plates. In an 11-plate battery, there would be 6 negative plates (Fig. 11) and 5 positive plates (Fig. 10). The negative plates are always on the outside, as shown in Fig. 13.

The positive plate lugs are burned to a positive strap and post (**P**) (Fig. 10), and the negative plate lugs are burned to a negative strap and post (**N**) (Fig. 11), forming two groups of plates.

Fig. 12. Separators are placed between the positive and negative plates. The illustration represents a set of California redwood separators used in the General storage battery.

Separators (Fig. 12) are placed between the negative and positive plates, which are then interleaved as in Fig. 13, and this forms an **element** ready to be placed in the jar which contains the electrolyte.

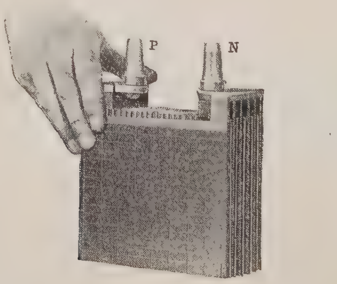

Fig. 13. An element, consisting of the positive and negative plates (Figs. 10, 11) interleaved with separators (Fig. 12) between the positive and negative plates.

The electrolyte for a new battery, where plates have been formed, is of about 1.300 specific gravity. In some cases it is stronger and in others weaker, depending on the condition of the separators. If new, they will soak the acid up; hence the reason for using an electrolyte of higher specific gravity (explained farther on).

The element (Fig. 13) is then placed in the hard rubber jar (Fig. 14) in which the electrolyte was placed first. The **cell cover** and **vent tube** (Fig. 15) are then placed over the top of the plates.

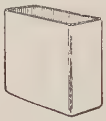

Fig. 15

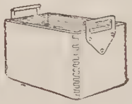

Fig. 14 Fig. 17 Fig. 16

The cells are then placed in the **battery box** (Fig. 16) and are then connected together with **connectors** (Fig. 17), which are burned on to the posts. Sometimes this joint between connector and post is not welded perfectly and the loose connection offers resistance and reduces the voltage and causes heating.

Each cell, when charged, gives approximately 2 volts, therefore 3 cells connected in series would give 6 volts; thus it would be termed a "6-volt battery." If there are 6 cells connected in series, then the terminal voltage would be 12 volts; if 8 cells in series, 16 volts; if 12 cells in series, 24 volts.

The battery is then charged by being connected in series with a source of "direct" current. The electric current flows from the positive (+) brush of the generator to the (+) terminal of the battery, to the positive plates, to the negative (—) plates (internally), out through the (—) plates, back to the (—) brush of the generator, through the armature, to the (+) brush again.

When the battery discharges, the current flows from the battery positive (+) plates, to the (+) terminal, through the circuit, to the negative (—) terminal and plates, to the positive plate (internally).

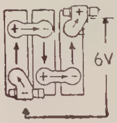

Fig. 18

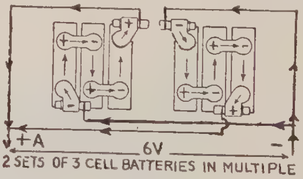

Fig. 19

Series connections of one cell with another, as shown in Fig. 18, form the usual method of connecting batteries. In this example, there are 3 cells connected in series; therefore it is a 6-volt battery. Note that the arrow points show the direction of current flow when the battery is discharging. If it were being charged, the current flow would be in the opposite direction. The **ampere-hour capacity** would be that of one cell.

Two 6-volt (or any other voltage) batteries could be connected in multiple, on the principle shown in Fig. 19. In this instance, there are two 3-cell batteries of 6 volts, as in Fig. 18. Each set is connected in "series," and the two sets are connected in "multiple." Therefore we have a terminal voltage at (+**A**) and (—**B**) of 6 volts, or the voltage of 3 cells.

The ampere-hour capacity would be twice that of the battery (Fig. 18).

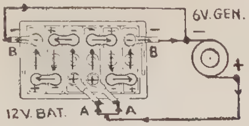

Fig. 20.

A 12-volt battery could be charged, by a 6-volt generator, if "multiple" connections were made as in Fig. 20, by connecting the two halves in multiple, as shown. The dynamo (generator) voltage, of course, must always be slightly higher than the battery voltage, otherwise the generator would have a tendency to operate as a motor.

Note that the generator current starts at the (+) brush, thence to (+) terminals (**A**) of battery, through each set of 3 cells, out through (−) battery terminals (**B**), to (−) brush of generator.

A 6-volt lighting circuit or ignition circuit could be operated from this circuit, by connecting with the circuit at (**A**) and (**B**). See also page 525, showing how a 12-volt starting motor operates from a 12-volt battery, and how a 6-volt generator charges the battery.

PRINCIPLE OF THE ACTION OF A STORAGE BATTERY WHEN DISCHARGING AND CHARGING[1]

Under the subject of "Electromagnetic Induction" (page 183) the fact is brought out that **when a conductor or closed loop of wire is passed through a magnetic field at right angles to the field,** an electromotive force (e.m.f.) will be set up at the terminals of the wire, which will cause electricity to flow in the wire if the circuit is completed. This action is called generating electricity "magnetically," or by "induction."

In a storage battery, the electricity is not stored, but, through a "chemical action," electromotive force (electric pressure) is created between the plates, causing electricity to flow. In other words, the storage battery **converts chemical energy into electrical energy when discharging,** and **electrical energy into chemical energy when charging.** For instance, if two different metals are placed in a liquid which will produce a chemical action more on one than on the other, an electromotive force (electrical pressure) will be produced which will cause electric current to flow.

This flow of current will continue until the metals or substances are entirely changed. If these chemical changes which split up the gases and solids form gases, the gases escape and are lost, whereas if they form solids by combining with the metal, they are not lost. When a battery is charged at too high a rate, or is overcharged, or when it is fully charged, it will be noticed that there will be an excessive passage of the gases.

Primary cells (Fig. 21), such, for example, as the gravity cell[2] used for telegraph work, consisting of a negative zinc plate and a positive copper plate, produce, just as soon as they are immersed in a solution of blue stone and water, an electrical pressure between the plates when the circuit is closed. Thus chemical energy is converted into electrical energy. It cannot, however, convert electrical energy into chemical energy.

The chemical action of the electrolyte on the zinc sets free gas bubbles which are charged with electricity and which deposit themselves on the copper plate. The copper plate serves merely to collect the bubbles, and is thus termed a positive (+) plate. The zinc, which is acted upon by the solution, is termed the negative (−) plate.

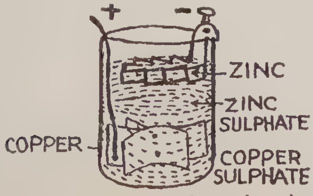

Fig. 21. A gravity cell: one form of a primary cell.

The internal circuit is from zinc plate (−), to copper plate (+); **the external circuit** is from copper plate (+), through circuit, to zinc plate (−).

Almost any salt or acid will act as an electrolyte if it will combine chemically with one of the elements, and if it does not offer too much resistance in doing so.

The current strength will vary according to the kind of plates or elements used, and will be greater when the chemical action is greater between the negative plate and the solution, or electrolyte.

Either alkali or an acid solution can be used for electrolyte in different kinds of batteries.

A secondary, or storage-battery cell: By the primary cell described above we converted chemical energy into electrical energy. With a storage battery a direct current of electricity is passed through the cells, which produces a chemical change which will put the plates and electrolyte into such a chemical condition, that an electromotive force (electrical pressure) will be produced when this change is completed. This action is termed "charging," and is the process of converting electrical energy into chemical energy.

The cells can then be connected to an external circuit, such as lamps, etc., and an electric current will flow through the circuit. This is termed "discharging," and is the process of converting chemical energy into electrical energy.

In other words, **after "discharging," the storage-battery cell can be "recharged,"** whereas, with a primary cell, fresh solution or new elements must be provided in order to obtain electric current again, after it has discharged.

On "discharge," electric current from a storage cell always flows externally, from the positive (+) terminal, through the circuit to the negative (−) terminal, and **internally** from the negative (−) plate to the positive (+) plate.

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[1] Those who desire to go deeper into this subject should see the advertisement in the back of this book describing a good book on the Storage Battery.

[2] Called "gravity cell" because the two fluids separate from each other by gravity.

[1] A book dealing exclusively with the Storage Battery can be secured of A. L. Dyke, Granite Bldg., St. Louis, Mo. Price $5.

The object of this explanation is to point out how the acid passes to the plates when discharging, forming **lead sulphate** ($PbSO_4$), which covers the plates, and to show how, if **left** in this condition, the lead sulphate which is in fine crystalline form, would, in time, act on the plates to such a depth that it would recrystallize into larger and harder crystals which are difficult and sometimes impossible to change back again to lead peroxide and lead sulphate. This is one of the most dangerous of storage battery diseases. It results not only from the battery being left for a long period fully discharged, but also from other causes, as explained under "Sulphation of Plates."

It is quite in order, however, during the discharge process, for the lead sulphate to form on the plates, but the plates should not be **left** in this condition, which can be avoided by immediately recharging. If the discharging continues after the voltage of a cell drops below 1.8, an excessive formation of sulphate will result.

Even though a battery is charged and not used, it should be charged at a low rate occasionally, as a charged battery will, in time, become discharged; and when discharged, the action is to form lead sulphate over the active material. The result will be that this sulphate will finally have the same action as stated above, on a discharged cell.

The active material is what was formed on the plates when under the process of "pasting" and "forming," which is lead (Pb) on the negative plate, and lead peroxide (PbO_2) on the positive plate.

Action of a Charged Cell

A fully charged cell on open circuit is shown in Fig. 22. For the purposes of illustration, only two plates are used, a positive (+), and a negative (−).

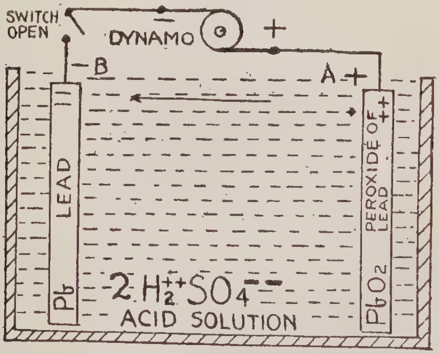

Fig. 22. **A charged cell on open circuit.** Note that the acid is in the solution and not in the plates. The active material on the negative plate is Pb, and on the positive PbO_2. The active material is not now covered with lead sulphate, as the SO_4 is in the solution.

When a cell is in a charged condition, the plates are not covered with lead sulphate ($PbSO_4$), as the SO_4 is then in the solution, which forms the electrolyte, which in turn consists of chemically pure sulphuric acid (H_2SO_4) diluted with pure distilled water, thus giving $H_2SO_4+H_2O=2H_2+SO_4$.

This acid was driven out of the plates when charged, and if a hydrometer is placed in the solution, it will be found that the solution is dense or thick and that the hydrometer will not sink as deep into the solution. The specific gravity would therefore be higher, and the specific-gravity reading will be between 1.280 and 1.300 when the solution is fully charged.

Another point, while on the subject of solution: Inasmuch as chemical changes take place, it is clear that if water is used which has metal in it, for instance, water taken from a metal roof, or if the water is not distilled, this would cause a different chemical action, injurious to the plates.

The positive plate (Fig. 22), which is supposed to be in a fully charged condition, is in the original condition as when formed, and has an active material of lead peroxide (PbO_2) in its grid. It is of a **dark-brown color.** Thus it is in a charged and healthy condition.

It is in a **diseased** condition when it fails to throw off all of the lead sulphate ($PbSO_4$) when being charged (the lead sulphate having been diffused over the active material when it was discharged).

The negative plate has thrown off the lead sulphate with which it was covered when discharged, during the process of charging, and is now a finely divided, spongy, **gray-colored,** soft lead plate (Pb).

Action of Cell When Discharging

Note that when the cell is discharging (Fig. 23), the current flows out of the (+) plate, through the motor, lamps, or other apparatus, into the (−) plate, through the electrolyte to the (+) plate.

Let us assume that the plates were in a fully charged condition, as in Fig. 22, when the circuit was closed, that is, the negative Pb, the positive PbO_2, and the solution H_2SO_4.

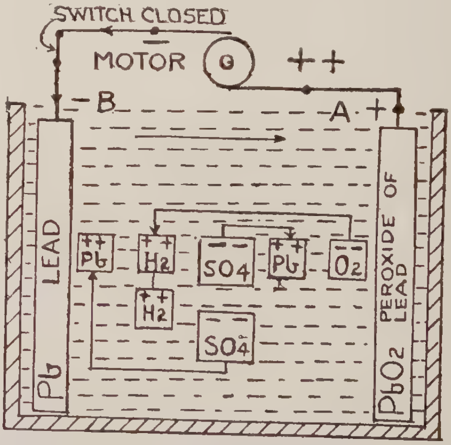

Fig. 23. **Discharging.** Note that the acid is going into the plates and will form lead sulphate ($PbSO_4$) and cover over the active material (Pb and PbO_2) on the plates. The solution will finally lose its acid and become water.

Refer now to Fig. 23. The active material (Pb) of the **negative plate** is combining with the acid (SO_4) of the electrolyte, and is converting the active material on the negative plate into lead sulphate ($PbSO_4$).

The **positive plate** active material (PbO_2) is combining as shown: the Pb with SO_4, and the O_2 with $2H_2$, and is thus being converted into lead sulphate ($PbSO_4$). See footnote below relative to the "ionic principle."[1]

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[1] **The ionic principle** recognizes the law that every substance as well as liquids is made up of positive (+) and negative (−) electricity, and that if separated by chemical action, the positive will attract the negative. Note that when water is divided into its two parts, as hydrogen (H_2) and oxygen (O), the hydrogen particles are (+) and the oxygen particles are (−).

Action of a Fully Discharged Cell

A fully discharged cell is shown in Fig. 24. The active material on the negative lead plate (Pb) is now covered over entirely with lead sulphate ($PbSO_4$).

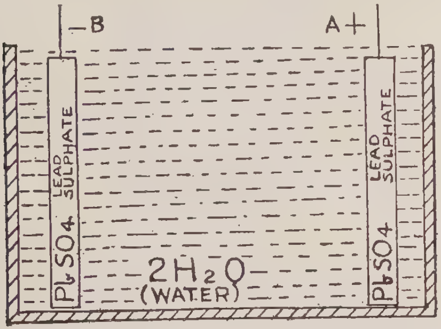


Fig. 24. **Fully discharged.** Note that the acid (SO_4) is out of the solution and into the plates, thus having combined with the lead of the plates (Pb) and having formed lead sulphate ($PbSO_4$) over the active material on both plates. The solution is now water, and is not dense.

As the acid has gone into the plates, this now leaves water around the plates, as solution. This accounts for the fact that a storage battery will **freeze quickly** when in a discharged condition.

If a hydrometer is now placed in the solution it will sink deep, as the water, without acid, is not as dense as with acid. The nearer a cell approaches a discharged condition from a charged condition, the less will the density become, until it approximates the density of water. When fully discharged the specific gravity will be about 1.150. The starting and lighting battery should be recharged before it is discharged this low.

Action When Charging a Fully Discharged Cell

A fully discharged cell just starting to be charged is shown in Fig. 25. The active material (Pb) on the negative plate is covered with lead sulphate ($PbSO_4$). The active material (PbO_2) on the positive plate is also covered with lead sulphate.

The passing of "direct current" through the cell, from the (+) terminal of the dynamo to the (+) positive plate, through the cell, to the (−) negative plate, to the (−) terminal of the dynamo (generator) causes the lead sulphate to be carried from the plates to the solution.

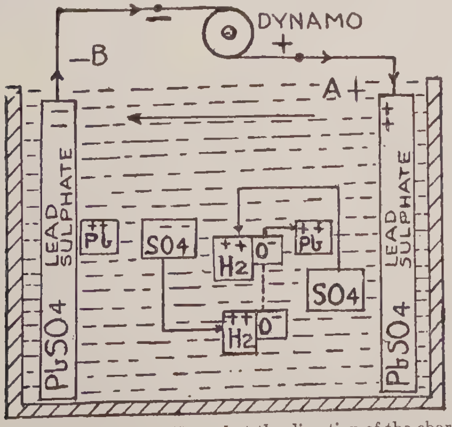


Fig. 25. **Charging.** Note that the direction of the charging current is as indicated by the arrow, or the reverse of that when discharging, as in Fig. 23. The lead sulphate ($PbSO_4$) which formed over the active material in the lead plates when discharging is now being driven off by the charging current, and the SO_4 is combining with the water. Thus the solution is gradually increasing in density or specific gravity. When fully charged the plates and solution will be as shown in Fig. 22.

Inasmuch as **the lead sulphate** ($PbSO_4$) merely covering the plates is quite accessible, it **is driven off with slight difficulty,** and the voltage rise in the cell during this period is very slight.

Note that the acid (SO_4) is passing from the plates on each side, and is combining with the H_2O (water).

As the charging continues, the lead sulphate which is buried deeper into the plates is more difficult to drive out with the charging current. The cell voltage is gradually rising.

After all lead sulphate has been removed from the plates, continued charging decomposes the water into hydrogen and oxygen which passes off in the form of gases. The voltage of the cell is then approximately 2.5 volts.

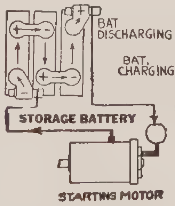
As the charging continues, the lead sulphate in the interior of the plates is more difficult to reach by the charging current, and the voltage of the cell rises as high as 2.65 to 2.70 volts.

If the charging is continued further, the temperature of the cell will rise and hydrogen and oxygen gases will pass off freely and thus the charging current is wasted and **the cell is heated.**

When the cell is fully charged, the conditions will be as shown in Fig. 22. The acid will be in the solution as $2H_2SO_4$, and the active material Pb, on the negative plate, and PbO_2 on the positive plate, will be exposed to the action of electrolyte.

Paths of Current Outside and Inside Storage Battery Cells

The external circuit of a battery discharging is as shown in Fig. 26: from the (+) terminal of the battery to the starting switch, to the starting motor, to the (−) terminal of the battery.



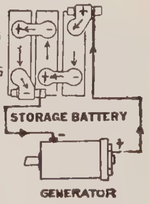


Fig. 26. Battery **discharging; external circuit.**

Fig. 27. Battery **charging; external circuit.**

The external circuit of a battery being charged is as shown in Fig. 27: from the (+) terminal of the generator, to the (+) terminal of the battery, through the battery, to the (−) battery terminal, to the (−) terminal of the generator.

Internal Circuit of a Cell Being Charged

The internal circuit of a battery cell being charged is shown in Fig. 28. We will assume the cell is an

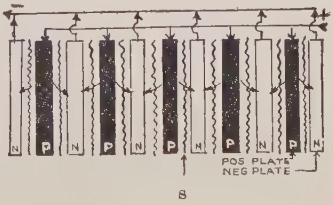


Fig. 28. **Charging the cells; internal circuit.**

11-plate cell, with 5 positive (+) plates (**P**), and 6 negative (−) plates (**N**). Note the separators (**S**) between the negative and positive plates, and note also that the negative plates are on the outside.

Each of the negative (−) plates are connected together, and each of the positive (+) plates are connected together; thus we have a positive (+) terminal and a negative (−) terminal to each cell.

The separators are placed between the negative and positive plates to insulate them from one another. The separators are porous and thus do not prevent the electrolyte or electric charges from acting on the plates, but merely serve to keep the plates from touching. In time, the separators rot, break, or become clogged, and permit the plates to touch. This causes an internal short circuit, which produces heat, and heat causes the plates to expand and to press against or through the separators more firmly.

Note in Fig. 28 that when the cell is being charged, the positive (+) current from the (+) side of the charging circuit flows into the positive (+) plates of the cells, to the negative (−) plates, and out to the (−) side of the charging circuit.

Internal Circuit of a Cell Being Discharged

The internal circuit of a battery cell being discharged is shown in Fig. 29. Note that the current path is in the opposite direction to that shown in Fig. 28, when the cell is being charged.

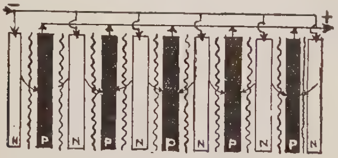


Fig. 29. **Discharging** the cells; **internal** circuit.

As the cell discharges, the active material on the plates is changed. The spongy lead (Pb) in the negative plate, and the lead peroxide (PbO_2) on the positive plate, are gradually changed to lead sulphate ($PbSO_4$). The acid in the electrolyte also passes to the plates as the discharge progresses. As the pores of the plates thus become filled with the sulphate, the **free circulation of acid into the plates is retarded;** and since the acid cannot then get into the plates fast enough to maintain the normal action, the battery becomes less active, as is indicated by the **drop in voltage,** or a discharged condition.

Voltage Drop of a Cell

Drop in voltage: Each of these actions tends to produce internal resistance, until finally a point is reached where the plates are fully coated, or changed to lead sulphate ($PbSO_4$), and where the acid is almost entirely out of the electrolyte.

The internal resistance is then so great, that the voltage is affected until it has dropped to about 1.6 if fully discharged. A cell, however, should not be discharged below 1.8 volts, and should be recharged immediately, otherwise it will be difficult for the charging action to throw off the lead sulphate from the plates, which was formed on them during the discharge action.

Electrolyte test: As the acid is withdrawn from the electrolyte during the discharge action, and replaced in the electrolyte during the charging action, it is clear that the most reliable test for determining the charged or discharged condition of a cell is to take a hydrometer reading of the cell, as explained on page 531.

Voltage of a Charged and Discharged Cell

When the battery is fully charged and before the charging circuit is opened, the voltage of each cell will be about 2.5 to 2.7.

When opening the charging circuit, the voltage of a cell drops to approximately 2.1 volts.

If the battery is then discharged at a continuous normal rate, it will gradually drop to 2 volts, which voltage will be maintained until it is about one-half discharged. From this point on, it will drop more rapidly to about 1.6 volts. The voltage of the cells, however, should not be permitted to drop lower than 1.8 volts per cell.

If the discharge rate is heavy, the voltage will drop much more rapidly. The reason for the drop in the voltage is explained on pages 522, 542.

If a high discharge rate is given, as when using the starting motor, the heavy discharge is only momentary. The result will be that the voltage will drop, probably to 1.8 to 1.6, at, say, a 200-ampere discharge, but will regain its normal voltage quickly when the circuit is opened—that is, if the battery is not already more than half discharged when the high rate of discharge is applied. See also pages 542, 545.

INTERNAL TROUBLES OF STORAGE BATTERIES

Some of the common troubles that a storage battery is heir to, are:

1. Sulphation of plates.
2. Buckling of plates.
3. Sediment.
4. Overheating.
5. Separators.
6. Short circuit of plates.

There are, of course, many other troubles, as enumerated in the "Digest of Storage-Battery Troubles," but those mentioned above are the most common, and usually account for the necessity of repairing a battery. The meaning as well as the causes are given below, and also in the "Digest of Storage-Battery Troubles." Tests are given elsewhere. See Index.

Sulphation of Plates

When cell plates are sulphated, it means that both plates are covered with lead sulphate ($PbSO_4$), the condition in which they are when discharged. This sulphation can act on the plates to such a depth that ordinary charging will not cause it to separate from the plate. In such a case, the battery will not hold a charge or give very much of a charge for any length of time, depending on the depth to which the plate is sulphated.

A sulphated plate has the appearance shown in Fig. 30. A white chalky substance forms on the negative plate which is a non-conductor and insoluble. This is usually caused by leaving a battery in a discharged condition for a long period of time and without water over the plates.

The remedy is to charge and discharge several **times at a low rate.** Owing to the sulphate on the

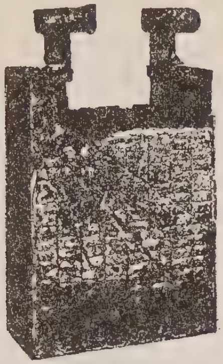


Fig. 30. A sulphated plate.

plates, the chemical action which takes place is very slow. The sulphate covers the active material, and thus only a small current can be absorbed by the active material; and **if charged at a high rate,** the water will be decomposed and form gas and give the impression that the battery is fully charged. (The active material referred to is Pb on the negative plate and PbO_2 on the positive plate, which is covered over with sulphate.)

It is more difficult to restore the negative plate than the positive plate. Only long-continued slow charging will tell. See Index under "Sulphated plates, how to restore." If this does not remedy the trouble, the plates should be examined; most likely new plates are necessary.

Sediments

Any impurities that the water contains are left behind in the cells by the evaporation of the water, and thus they settle to the bottom of the cell jar.

Mud and sediment will accumulate in the bottom of the battery and will eventually accumulate to such a height as to cause an internal short circuit of the plates, if any other than distilled water is used. The paste, or active material, falling off the plates will also result in the collection of sediment.

When cleaning the sediment from a jar, it is generally wise to replace the separators at the same time. The need for cleaning is usually indicated by lack of capacity, excessive evaporation of the electrolyte, and excessive heating when charging.

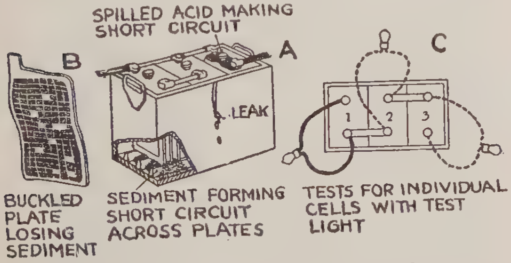

SPILLED ACID MAKING SHORT CIRCUIT
A
B
C
LEAK
1
2
3
BUCKLED PLATE LOSING SEDIMENT
SEDIMENT FORMING SHORT CIRCUIT ACROSS PLATES
TESTS FOR INDIVIDUAL CELLS WITH TEST LIGHT

Fig. 31. Common battery troubles and a simple test.

Buckling or Warping of Plates

There is a tendency for the plates to shed the paste after it hardens on the grid, called "buckling" of the plates, meaning to distort, or get crooked, from sudden high discharges. Other causes will often result in the active material (paste) loosening and falling out of the grids to the bottom of the jar, and causing a "short circuit" from one plate to another.

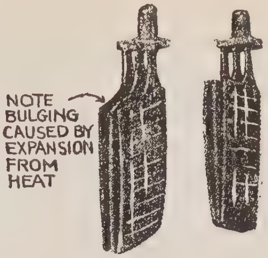

NOTE BULGING CAUSED BY EXPANSION FROM HEAT

Fig. 32. Buckled plates.

Some of the causes are: Dead short circuit, as between starting motor and battery, thus causing overheating; overcharging, and at an extremely high rate, thus overheating; violent discharging and short circuits inside of the battery, which also produces excessive heat.

When the battery does not hold its charge, it is usually due to one or more defects internal of the battery, as just described, and each cell should be tested.

It will thus be observed that heating is the principal cause of buckling of the plates. Heat causes the plates to expand, and if heat is excessive and continued for a long enough period, the plates will assume a shape as shown in Fig. 32, which will cause the plates to cut through the separators.

As a plate discharges, lead sulphate is formed on it, and thus occupies more space than the active material on it. If it expands equally, it will do no harm, but if the battery is over-discharged or charged at a very high rate, the active material will expand and heat, because the portion of the plate on which there is least sulphate will carry most of the current and thus overload this section of the plate. The result is excessive heat which results in expansion and "buckling."

Plates which are not buckled too badly can be straightened by putting them in a press.

Overheating

Overheating caused by overcharging may occur if the regulation system goes wrong and permits the generator to deliver excessive current.

It is well to feel the battery occasionally, particularly the lead links and cover, after a long, hard drive. Should you suspect overheating, remove the vents from the cells and insert a thermometer, of the type made for insertion into liquids, into the electrolyte of each cell.

The battery temperature should never be allowed to exceed 110° F. Garage men who make a practice of charging batteries in their plant should enforce this rule rigidly.

Overheating should be avoided, because it expedites evaporation of water from the electrolyte, causes deterioration of plates and separators, and tends to buckle the plates. Overheating of one-half the battery should be guarded against.

Sometimes heat will be produced at the connectors, where they are welded to the posts of the plates, owing to improper welding. This, of course, would then necessitate re-welding, and would be external of the cell.

Separators

The purpose of separators is explained on page 542. Where a high rate of discharge is required from a battery, as with a starting motor, a freer and more rapid circulation of the electrolyte with the active material on the plates is necessary.

If a battery is used solely for low rates of discharge, as for ignition, then thick plates and **perforated hard-rubber separators** are generally used, which give a very long life to the battery.

Where a very high discharge is required at times, which in many instances may be over 200 amperes, then, as stated above, the rapid circulation of the electrolyte can better be accomplished through the **pores of certain woods.** The thin plates are used and many of them, in order to give sufficient plate area, and thus the action of the electrolyte on the plates is more rapid.

Various kinds of wood, and various methods of treating wood separators are employed by different manufacturers of storage batteries for starting, lighting, and ignition purposes combined. Those woods which are porous and will withstand the chemical acid are such woods as cypress, white cedar, California redwood, Douglas fir, poplar, basswood, cherry, etc.

The Exide battery uses a grooved specially treated cypress wood separator of a very porous nature. The Eveready battery uses cherry wood. The General storage battery uses California redwood. The Willard battery uses separators made of rubber fabric pierced by hundreds of cotton threads. The electrolyte is carried through the thread from one side to the other by capillary action.

When wood is used for separators, it is specially treated after sawing and grooving. The separators are placed in a warm alkaline solution of about 3 per cent caustic potash. This neutralizes the acetic acid which wood contains (and which if permitted to go into the cell would tend to dissolve the lead and cause it to crumble), and also removes resin from the pores. The pores must be fully open in order that the acid can act through them.

The alkali is removed by soaking for about two to three days, and then washing in running water. The separators can then be used. If separators are not used after treating, then place them in a weak acid solution of about 1.025 or 1.050 sp. gr. The separators have a tendency to expand in the solution, and therefore, if they are not kept wet, they will shrink.

When new separators are received, they should be soaked for about five days in a solution of electrolyte of about 1.250 sp. gr., so that they will expand to the proper proportions outside of the cell instead of allowing them to expand in the cell. Separators are the weakest part of the battery.

If the pores of wood separators clog from dirt, impurities in the water, or lead sulphate, this will prevent the electrolyte from circulating and the separators should be replaced with new ones.

Battery Internal Short Circuits

Battery short circuits may be external or internal.

External battery short circuits may be due to acid on the top of the battery forming an electrolyte between terminals as at (A) (Fig. 31); to battery terminals being sulphated, or in contact with the top of the metal battery box, or to the battery wire connections being acid-soaked.

Internal battery short circuits may be due to the internal condition of the battery, such as plates warped or buckled, or a collection of sediment at the bottom of cells due to disintegrating plates, although the latter is rare because of the height of the plates above the bottom of the jar (see **A**, Fig. 31). The usual cause is broken or rotted separators, which permit the plates to touch.

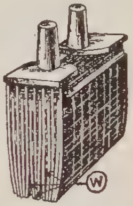


Fig. 33. The arrow points (W) show how broken down wood separators allow a plate to bend and to touch, causing a **short circuit of the plates.** Buckled plates usually cause this trouble, and too much acid rots the separators.

When one plate touches another inside of a cell, as at (W) (Fig. 32), it causes an internal short circuit. Owing to the fact that the cells are connected in series, the other cells will then send a current through the shorted plates in a reversed or discharged direction, and the negative plate (Pb) will have a coating of the active material (PbO_2) of the positive plate formed over it, and the positive plate will become a negative plate, through the reversal.

This action also occurs when the terminals of a battery are reversed with the charging current. Most of the generators, however, on automobiles of the present-day type of construction will reverse their polarity to that of the battery.

Internal short circuits, if of long standing, will necessitate new plates and separators. If the short circuit is not serious, the plates can be cleaned and new separators can be put in.

If a battery is charged in the wrong direction for a period of time with the terminals reversed, or long enough to change the positive plates to negative and negative to positive, new plates and separators will usually be required. Sometimes batteries can be reversed by long-continued charging in the right direction. In fact, batteries have been used with plates reversed, while others in the same condition would fail to hold a charge at all.

In time, even if batteries are kept in good condition, age will tell on them, and the positive plates will begin to crumble. The active material on the negative plates will lose its porous, spongy lead formation and become hard (porosity is very important in battery plates so that acid can circulate through the plates as well as through the separators).

From 15 to 24 months is the average life of a battery used for continuous daily starting purposes and general use (150 to 250 amperes discharge), as starting work is very hard on any battery.

INSTRUCTION No. 48

TESTING STORAGE BATTERIES: Voltmeter Tests; Cadmium Tests; High-Amperage Discharge Tests

TESTING A STORAGE BATTERY WITH A VOLTMETER

A battery should never be discharged completely. As we have already stated, when testing with a hydrometer 1.150 is the limit for batteries used for ignition and lights, and 1.225 for starting motors.

A voltmeter can also be used to test the battery, but bear in mind that the test is not practical unless it is made **when the battery is discharging or charging.**

No cell should ever show less than 1.8 volts per cell, or 5.4 volts for a 6-volt battery (readings taken when battery is discharging or charging). The normal voltage of the battery is 2.2 volts per cell when doing no work, which, if the electrolyte be 1.250 sp. gr., is usually lowered to about 2.1 volts, because of internal resistance.

The storage battery, unless worked below 1.8 volts, **has a recuperative power** of rising from 1.8 volts to the normal 2.1 or 2.2 volts within a few minutes after the discharge current has been discontinued. This act has often led many users astray as to their opinion of the condition of their cells.

For instance, suppose one to be out with his car, and the spark is not sufficiently strong to give satisfactory ignition of the gases; he stops to locate the defect. Usually the first thought is: Are the batteries right? The voltmeter is taken and put to the cells, and because they show a reading of 2.0 to 2.1, they are deemed all good.

As a matter of fact, if the reading had been taken while the battery was discharging, the voltmeter would probably have read 1.8 volts or perhaps less per cell. In this way it often occurs that much time is lost in going over the car looking for the defect, while all the time it has been the batteries which have innocently showed 2.0 volts, because they were standing idle.

The voltmeter can also be used to determine the positive and negative poles of the battery. Touch the voltmeter terminals instantaneously across the circuit. If the needle runs upward in the normal direction on the scale, the voltmeter is properly connected and the wire which touches the positive meter terminal is thus identified as positive. If the connections were reversed, the needle would kick off the scale, indicating that the positive terminal of the voltmeter should be connected to the other wire.

Note: Never connect an ammeter to the terminals of a battery, unless a shunt is used.

The specific gravity test with a hydrometer is the method generally used to determine whether a storage battery is charged or discharged. Provide yourself with a hydrometer to enable you to test the gravity of your electrolyte periodically, and you will avoid a great deal of trouble.

It may be said that the condition of the specific gravity is the pulse of the cell, and certainly it is the one means of ascertaining the exact condition of health of the cell or battery.

The voltmeter is generally used by battery repairmen, and is very necessary under certain conditions, if properly used, for testing for a defective battery, or for grounds and short circuits, etc.

The voltmeter can also be used to test a battery for its charged or discharged condition. When a charged battery is discharging it will give, say, about 2 volts per cell until 50 per cent of its capacity is used, and then gradually drop to 1.8 volts per cell. Therefore a meter reading in one-tenth part of a volt will give an accurate test if the battery is on discharge, telling the condition between the 2-volt drop and 1.8-volt drop in fractions of a volt.

The voltmeter, however, is more often used to test the condition of the individual cells.

When to Test

A voltmeter is used to test a battery when it is being charged, in combination with a hydrometer test (see pages 547, 531).

A voltmeter is also used to test for defective cells, as explained below.

As previously stated, a battery is usually tested with a hydrometer in order to show if it is charged or discharged, but sometimes, the hydrometer reading will show 1.275 or 1.300, which, supposedly, represents a charged condition. Yet the battery fails to hold its charge. In this instance, it is necessary to use a voltmeter to determine the cause which is usually found to be internal of the cell.

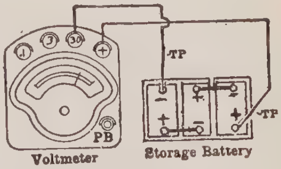


Fig. 1. Testing a 3-cell, 6-volt battery with a voltmeter.

The first step is to test the entire lot of cells, after determining that the battery has been charged and that the electrolyte reads from 1.275 to 1.300. Use the 30-volt range (model 280 Weston instrument as an example), and make connections as shown in Fig. 1. The test should be made with the battery discharging at a normal rate, say with the lights on.

A 3-cell, 6-volt battery (as in Fig. 1) should test 2 volts per cell, or approximately 6 volts for the three cells.

If the test shows the proper voltage and the specific gravity is 1.275 to 1.300, then the fact that the battery does not hold its charge is due to outside causes, such as loose connections, grounds, etc.

If the test shows a decided drop in voltage and yet the battery is known to have been charged, then the trouble is internal of the battery, probably in one or more cells.

If all cells do not come up to test, then test each cell of the battery separately, in order to find, on normal discharge, which cell is defective.

There are three methods used for testing battery cells:

1. With a low-reading voltmeter.
2. With a cadmium voltmeter.
3. With a high-amperage discharge test.

Example of Testing Individual Cells of a Storage Battery with a Low-Reading Voltmeter

The Weston model 45 voltmeter, designed especially for battery testing, will be used as an example.

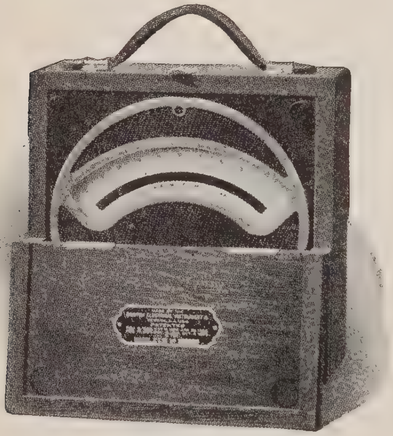


Fig. 2. Weston model 45. Low-reading battery-testing voltmeter.

This instrument is a direct-current permanent-magnet moving-coil voltmeter, having a range of 0.2–0–3.0 volts, intended for testing individual cells. It will test for low readings and also make the cadmium test.

The scale (Fig. 3) has 160 divisions, each division having a value of 0.02 volt. When reading this instrument, look directly down upon the scale, so that the image of the pointer in the mirror exactly coincides with the tip of the pointer itself. Slight deviations in the zero position of the pointer are corrected by means of the zero adjuster screw.

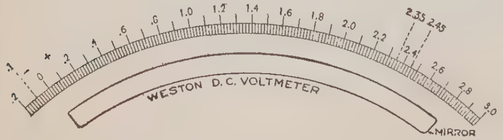


Fig. 3. Scale as used on the Weston model 45 battery-testing voltmeter. Approximately half actual size.

Note. The 2.35 and 2.45, as also (–) and (+) and .1, are not actually shown on the scale. These figures have been added here in order to show the points generally used for cadmium tests, as explained farther on.

Open-Circuit Cell-Voltage Test

This test consists of measuring the voltage of each cell of the battery **without any current** being passed into or taken from the battery.

The purpose of this test is to find out if the cells are in a **charged** or **discharged** condition.

Procedure: Connect the cable (Fig. 4) having the plain spike terminal (T) to the binding post of the voltmeter marked (+).

Connect the cable having the combination spike (T1) and cadmium (C) to the (–) binding post.

Press the plain spike terminal (T) into the (+) terminal of a cell and the combination terminal (T1) into the (–) terminal of the same cell. Be careful to penetrate into the metal of the cell terminals. Test all cells in the same manner.

Note. This test is for the open-circuit voltage of the cell. Although the cadmium stick (C) is attached to the spike (T1), it is not in use.

The voltage indicated should be 2 volts or a little higher. If it is 1.8 or lower, the cell should be tested under load, as explained under the following heading.

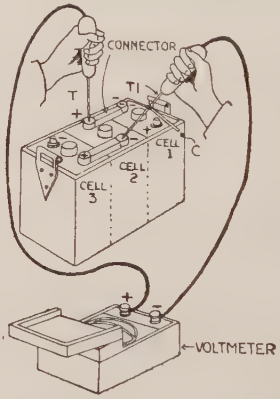


Fig. 4. Open-circuit voltage test of cells.

Testing the Voltage of Cells with Current Flowing

Purpose of the test: In the paragraph preceding, the statement was made that if 1.8 volts, or lower, was indicated the cell should be tested under load. The object of this would be to find out if the fact that the cell tested only 1.8 was due to a **discharged** condition or to a defect internal of the battery cell.

Procedure: When this test is to be made on a battery of the automotive type, connect a "resistor" across the terminals of the battery, as shown in the illustration (Fig. 5).

This **resistor**[1] can be readily made by winding about 9 feet of No. 16 soft-iron wire in the form of a helix with the convolutions separated so as to prevent touching, and is for the purpose of having the battery on **discharge** during the test.

With the resistor in place, as in Fig. 5, the current is flowing through it, and the battery is discharging. Press the spike (T) into the (+) terminal of the cell under test, and the spike (T1) into the (–) terminal of that cell. Make this test on all cells.

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[1] See page 554, explaining how to make a "heavy discharge tester" which can be used in place of this resistor.

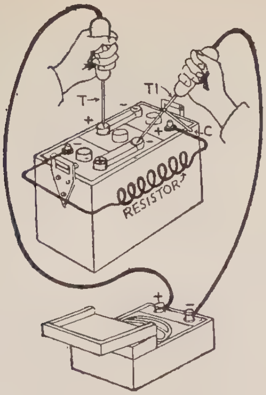

Fig. 5. Voltage test of cell with battery discharging.

If the tests on all cells of the battery show approximately the same voltage, the battery is in a **discharged** condition.

If any cell has a voltage which is lower than that of the others by a relatively large amount, it is quite possible that **the plates of that cell are defective** and should be carefully examined. This is usually done by opening the cell.

By making a cadmium test, the condition of the plates can be ascertained without opening the cell, and furthermore, the cadmium test will indicate if it is the positive or negative group of plates which are defective, as will be explained farther on.

Specific Gravity Test of Electrolyte

The test just described was to ascertain if the cells were defective or discharged. It was pointed out, that if one cell shows a voltage relatively lower than the others, it was probably defective internally, and the proper test then to make would be the cadmium test. If, however, the tests show approximately the same voltage (1.8) or less, then all cells are probably discharged. The test to make in such a case is the specific-gravity test.

After determining the cell voltage with current flowing (as in Fig. 5), and ascertaining that the battery is in a **discharged** condition, the electrolyte should then be tested with a hydrometer, as described on page 531. When using the hydrometer caution should be exercised to draw only enough solution into the tube to float the hydrometer freely, and never to put electrolyte taken from one cell into another cell. Care must also be taken not to cause air bubbles in the cell, as these are very difficult to remove and will often result in loss of electrolyte.

A fully charged battery will have an electrolyte gravity of from 1.275 to 1.300.

A discharged battery will test only 1.150 to 1.175.

If the gravity test is low, charge the battery until the hydrometer does not show any further increase in the gravity. Then repeat the test with current flowing.

If there are no defects in the cells, the voltage with current flowing will approach a value of 2 volts per cell.

If, however, the voltage drops considerably, the plates are likely to be defective.

CADMIUM TEST OF A STORAGE BATTERY CELL

Let us assume that when the test was made, as in Fig. 5, the voltage of one cell was lower than that of the others by a relatively large amount. Let us assume also that after making the specific-gravity test with the hydrometer after the battery was put on charge, the voltage dropped considerably. The indications then point to its being a defective cell internally.

The cadmium test should then be made in order to find out which group of plates are defective: whether **it is the negative or positive plates of the cell.**

The cadmium test is never made with a battery on open circuit. It is always made when the battery is **on charge or discharge.** An explanation of the principle of the cadmium test is given farther on.

Cadmium Test with Battery on Charge

Procedure in the cadmium test: Charge the battery until its voltage and specific gravity attain constant values, and, while on the finishing rate of the charge, make the test.

Connect the plain spike (T) cable to the (+) binding post of the voltmeter (Fig. 6), and the one with the cadmium stick to the other binding post.

Testing the positive group of plates of a cell: Insert the cadmium stick into the vent hole of the cell to be tested, taking care that it does not touch the plates. Press the plain spike terminal into the (+) terminal of the cell under test, and, with the "finishing rate" of charging current passing into the cell, observe the reading of the voltmeter.

Before taking the reading, the cadmium stick should be kept in the electrolyte until the voltage reading has become constant.

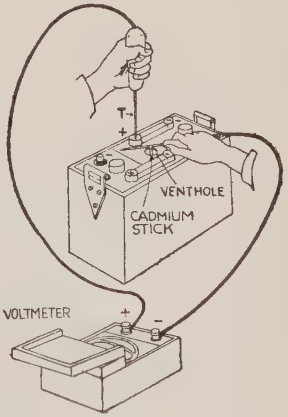

Fig. 6. Cadmium test of a cell.

If the positive plates are in good condition, the reading will be between 2.35 and 2.45 volts.

If the reading is less than 2.35, it is probable that the positive plates are defective.

Testing the negative group of plates of a cell: Transfer the plain spike terminal to the (—) terminal of the cell. The reading this time will be to the left of the zero on the scale of the instrument.

A fully charged negative group in good condition should be between 0.1 and 0.2 volt, to the left of zero (0).

If the reading approaches zero, or if it is **to the right of zero,** the **negative plates** are probably **defective,** or are in a sulphated condition requiring an extended period of charging to put them back in a healthy condition.

If the test on both the positive and negative plates gives readings which approach zero, the battery is short-circuited.

In general, it is understood in the case of a battery **on charge,** that if the cadmium test to the **negative plates** does not give a **minus** reading, the battery is not up to capacity, but a minus reading is not necessarily proof that the battery is up to full capacity. This can be determined by making **a discharge test.**

Cadmium Test with Battery on Discharge

Procedure: The battery should be discharged at its normal discharge rate until the voltage per cell is 1.8 volts with current flowing. Keep a record of the time in hours required to do this. Then with a discharge current of 5 amperes flowing, the cadmium test should be repeated.

The reading to the **positive plates** should be about 2.05 volts, and to the **negative plates** about +0.25 volt, or to the right of zero (0).

If the reading to the positive plates is much below 2 volts, it is probable that the positive group is defective.

If the reading to the negative group is greater than +0.25 volt, it is probable that the negative group is defective.

When the readings indicate defective plates, it is advisable to make a thorough inspection of the plates.

Upon reaching the voltage of 1.8 volts per cell, the battery should have given its rated ampere-hour capacity. This is determined by multiplying the ampere discharge rate by the time in hours. If the full ampere-hour capacity has not been given, the battery is lacking in capacity, and it is probable that one or both groups of plates may be defective.

When the cadmium readings show the plates to be in a fully charged condition, the density of the electrolyte should be determined. This should be between 1.275 and 1.300. If it is not, the electrolyte should be made to have the correct density.

If the density indicates a fully charged cell but the cadmium test does not show fully charged plates, the charge should be continued to see if the cadmium readings will become what they ought to be. If not, the plates are probably defective.

Remarks on Cadmium Tests

The cadmium test is usually made when a battery is tested with a hydrometer and the tests show that the battery is fully charged, but when a battery is put into service the voltage drops rapidly and the battery fails to deliver its capacity. If the battery voltage failed merely because the battery was discharged after delivering its normal capacity, then there is no need of making a cadmium test. The battery in this instance needs recharging, simply.

If, however, as mentioned above, the hydrometer tests show the battery to be charged, but that when put into service it fails to maintain its charge for its rated capacity, and the voltage drops rapidly on normal discharge, this condition is probably due to defective plates. The cadmium test will determine which set of plates are defective, or which set fails to hold its charge.

The cadmium test is also made when a battery on charge does not attain its proper voltage (2.6) per cell, and its specific gravity will not rise to a normal reading of 1.280 to 1.300 sp. gr.

The cadmium test is usually made when the battery is still on the charging line. The charging rate should be that recommended by the manufacturer, which is the "finishing rate." The battery should be charged until the voltage and specific gravity attain a constant value, and will rise no higher.

Voltmeter Used with a Cadmium Test

Parts of the cadmium outfit are more fully explained on page 550.

The voltmeter used for making cadmium tests should be a low-reading voltmeter with an additional reading to the scale on the **left of zero.**

Cadmium reading scale of voltmeters: On some cadmium-test voltmeters the scale is marked especially for cadmium readings, as discussed on page 550.

The scale used on the Weston model 45 (Fig. 2) voltmeter, is shown on page 546.

The scale used on the Weston model 280 combination volt-ammeter (Fig. 15, page 468) does not show the cadmium reading which has been added to the scale.

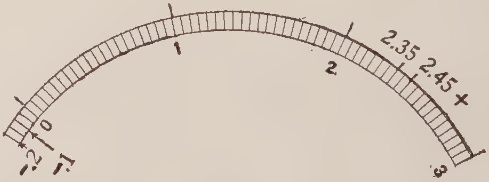

Fig. 7. The scale which is now used on the Weston model 280 volt-ammeter.

The illustration (Fig. 7) shows the scale now being fitted to this instrument, by which it is possible to make cadmium readings. The scale has 60 divisions from 0 to 3, each division being .05 of a volt. Four divisions to the left of "0" have been added for the cadmium negative readings, which are .05 of a volt each, or .1 volt for two divisions.

Cadmium Test-Points and Test-Cables

The cadmium test-points and test-cables for use with the Weston models 45 and 280 are shown in Fig. 8.

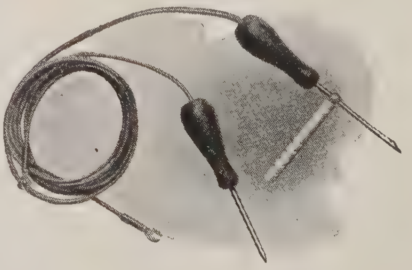

Fig. 8. Cadmium test-points and cables.

They consist of two flexible rubber-covered cables **6 feet long,** having fork terminals on one end. One of the cables is provided with a plain spike terminal, and the other cable with a combination spike and cadmium stick terminal. The cadmium stick is provided with a perforated insulating covering to keep the stick from coming in contact with the plates of the cell. Price per pair, including the cadmium stick, as shown in Fig. 10, $5; cadmium cable, stick and point, $2.75; plain spike and cable $2.25. (These can be secured of A. L. Dyke, Electrical Department, St. Louis, Mo.)

Principle of the Cadmium Test

When making a cadmium test, the cadmium stick is placed into the electrolyte vent hole of a cell, as shown in Fig. 6, page 547. The test-point is then placed on the terminal of the (+) positive plate group, to test the positive plates (Fig. 6), and on the terminal of the negative (−) plate group, to test the negative plates. Either of these tests really makes **two distinct cells** out of the one cell.

For example, let us take two plates of a cell, as shown in the simplified illustration (Fig. 9). The test is made of the positive plate **when the battery is on charge,** and of the negative plate (Fig. 10) when the battery is on charge, that is, when the battery has about reached its charged condition and is still on the line, being charged at the finishing rate.

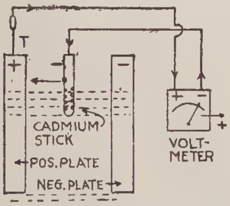

Fig. 9

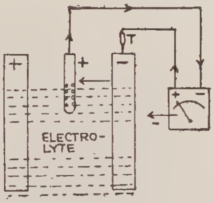

Fig. 10

Fig. 9. Positive plate test when on charge.
Fig. 10. Negative plate test when on charge.

Testing the positive plates of a cell on charge: With the prod (T) on the positive plate (Fig. 9), which is connected to the (+) terminal of the voltmeter, and the cadmium stick in the electrolyte, which is connected with the (−) terminal of the voltmeter, the cadmium acts as a negative (−) plate. Thus **the voltage would be taken of the positive (+) plate,** and the voltmeter needle will read in its normal, or right-hand direction, because the current is flowing through it from the (+) plate, to (+) of the meter, from (−) of the meter, to (−) of the cadmium.

Testing the negative plates of a cell on charge: If we now place the prod (T) on the negative (−) plate (Fig. 10), then the cadmium acts as a (+) plate. Thus **the voltage would be taken off the negative plate,** but the meter needle would read in a reverse, or left-hand direction (if charged), because the cadmium stick, which is now acting as a (+) plate and from which the current first flows to the meter, being connected with the (−) terminal of the meter, will cause the voltmeter to read in the reverse direction, not only on this voltmeter but on any other. Hence the addition to left of (0) on scale of a voltmeter (Fig. 3, page 546, and Fig. 7).

When the positive and negative plate tests are made, as described in the foregoing explanation (Figs. 9 and 10), the test is being made when the cell **is on charge.** Therefore, when a cell is being tested while on charge, and is charged or almost charged, the negative plate readings should be on the **left** or (−) side of (0) on the scale of the meter.

By adding the readings of the positive plate and of the negative plate, when a cell is being tested on charge as described above, the sum should be the voltage of the cell, because, when tests were made, as in Figs. 9 and 10, the cell was divided into two parts.

The object of making the test is to determine whether the positive plates test up to the standard as they should, when the cell is supposed to be charged, and whether the negative plates are up to standard voltage. If either of them fail to come up to this standard, then they are probably defective, if the electrolyte tests as it should.

The standard voltage of the positive plates (when charged) should read approximately from 2.35 to 2.45 volts, and that of the **negative plates** should read from .1 to .2 of a volt (to the left, or (−) of the scale), if in good condition.

Thus, if the two voltage readings are added together (2.45+.2=2.65), we have 2.65 volts as the total voltage of the cell, or a fully charged cell.

Suppose, however, that a cadmium test was made after the battery was put on the charging line, yet the cells are not charged, being nearer a discharged condition than a charged condition. In this instance, the negative plate reading would probably be on the right, or (+) side of (0) of the scale; and therefore the negative plate readings when on the (+) side of (0) are **subtracted or deducted** from the positive plate readings, which should give the total voltage of the cell. See an example of a test of this kind in the table, on page 551.

As another example, let us use two plates of a cell, as shown in the simplified illustrations (Figs. 11 and 12). The tests are being made when the battery cells are **discharged** to 1.8 volts and while the battery is being discharged at 5 amperes.

When making this test, the battery is first discharged at its normal rate, until the voltage drops to 1.8 volts. During the discharge, the battery is closely observed to see if it gives its rated capacity during the time it is discharging.

A cadmium test of a discharged battery is usually made if a battery fails to give its rated ampere-hour capacity, for if it is in good condition, it should do so.

The ampere-hour capacity or discharge rate of a battery is usually stamped on the nameplate of the battery. For example, if a battery had an "ampere-hour capacity" of 80 ampere-hours, and the "discharge rate" was 10 amperes, it would discharge at 10 amperes for 8 hours, gradually dropping to 1.8 volts, at which time it is discharged, and, if in good order, has delivered its full capacity.

If the battery is known to be fully charged and the electrolyte tested to 1.275 to 1.300, yet in an appreciable difference in time it drops to 1.8 volts before it has delivered its rated capacity, this may possibly be due to the condition of one of the group of plates, positive or negative, or of one or more cells, which discharged first. The purpose of the test **on discharge** is to determine if it is the negative group or the positive group which are defective, or which failed first. If one or the other fails to come up to the **standard voltage** under certain conditions, as outlined above, then the group (positive or negative) which differs greatly from the standard is the one at fault.

The cadmium test is then taken, after the cell is discharged to 1.8 volts and with the battery discharging at 5 amperes, in the following manner:

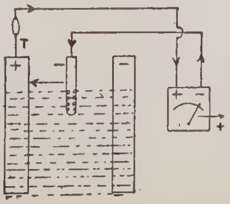

Fig. 11

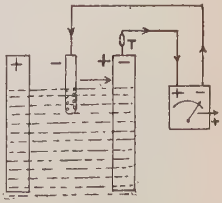

Fig. 12

Fig. 11. Positive plate test when on discharge.
Fig. 12. Negative plate test when on discharge.

Testing the positive plates of a discharged cell: With the prod (T) on the positive (+) (Fig. 11) the cadmium now acts as a (−) plate. Therefore the test is of the positive plate. When the battery is discharged and is discharging at 5 amperes, the reading of cadmium to positive (+) plate should show about 2.05 volts, if the plates are in good condition.

Testing the negative plates of a discharged cell: With the prod (T) on the negative plate (Fig. 12), the cadmium acts as a (−) plate and the negative plate acts as a (+) plate (when discharged). Therefore the test is of the negative plate, and the reading should show about +0.25, or to the right of (0) on the scale (Fig. 3, page 546). When a discharged cell is tested while on discharge, the negative plate readings will be on the right, or the (+) side of (0). Therefore the negative plate reading is deducted from the positive plate reading, which should give the voltage of the cell being tested.

For example, suppose the reading of the cadmium to the positive (+) plate (Fig. 11) is +2.05 volts, and the cadmium reading for the negative plate (Fig. 12) is +0.25 volts. The difference would be: 2.05−0.25=1.80 volts, or 1.8 volts, which is the voltage of a discharged cell in good condition and the voltage the cell should test if the voltmeter is placed on the cell terminals.

THE AMBU CADMIUM-TEST VOLTMETER

This instrument has a **specially designed scale** which is easy to read. Explanations are given below.

Readings on the Scale of the Voltmeter

This special voltmeter (Fig. 13) has the (0) line near the left end of the scale. The scale is marked especially for cadmium tests.

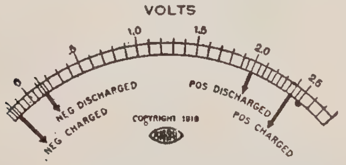

Fig. 13. Ambu special cadmium scale.

To the left of the (0) line is a red line marked "NEG. CHARGED." This line indicates the reading of −0.175, which should be obtained when testing **new negative plates which are fully charged,** that is, when making a cadmium test on the negatives, the pointer should move to this red line. If the pointer does not move as far as the red line, the negatives are not fully charged.

Similarly, there is a red line at +0.175, marked "NEG. DISCHARGED"; at +2.00 marked "POS. DISCHARGED"; and at +2.42 marked "POS. CHARGED."

Old cells will give readings which are not quite as high as those indicated by the red lines.

Any accurate voltmeter, which gives readings up to 2.5 volts in divisions of .05 volt, can be used, but the advantage of this instrument is in the scale prepared especially for cadmium-test readings.

Cadmium Stick and Test-Points

Cadmium is a metal. It looks like zinc, but is pure, because there is no other substance mixed with it.

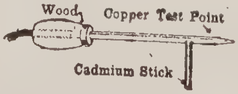

Fig. 14. The test-point, with the cadmium stick riveted to it. The cadmium is the part which is inserted in the electrolyte. It is always connected with the (−) side of the voltmeter.

A cadmium testing outfit[1] consists of two copper test-points, one of which has a stick of cadmium, about 3½" long and ¼" in diameter riveted to it, as in Fig. 14, and a special-reading voltmeter.

Why a Cadmium Test Is Necessary

The condition of a storage battery is usually ascertained by taking a specific -gravity reading of the electrolyte, with a hydrometer, a reading of 1.275 to 1.300 being usually considered as indicating a fully charged cell. While specific-gravity readings with a hydrometer should always be made, yet they should not be relied upon entirely.

For instance, a battery which gave entirely satisfactory hydrometer tests may show a rapid drop in voltage when in use, yet this condition could not be foretold by hydrometer readings alone, because the hydrometer readings would not tell us the condition of either the positive or negative plates, and it is their condition which determines the amount of energy in any battery.

Voltmeter Tests of Cells

We may also take a voltage reading of all cells of the battery, as in Fig. 15, while the current is being drawn from the battery which gave satisfactory hydrometer readings. This would tell us if the plates were not in good condition, but it would not tell us which set of plates was at fault, because the voltage reading includes all positive and negative plates, as in Fig. 15.

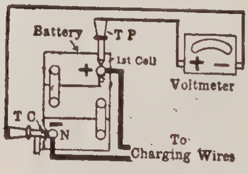

Fig. 15

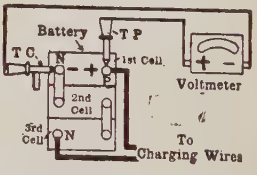

Fig. 16

Fig. 15. Testing the voltage of all cells of a battery, when the battery is on charge, and preliminary to taking a cadmium test.

Fig. 16. Testing one cell of a battery when on charge, and preliminary to a cadmium test.

If we took a voltage reading of one cell of the battery, as in Fig. 16, while the battery is on charge, it will be readily seen that the test includes both positive and negative plates. Suppose the battery will not take a full charge, which set of plates is defective: the positive or the negative?

Therefore, to determine the condition of the positive and negative plates separately, we must make a test between each set of plates and some neutral substance. Theoretically, a number of substances could be used for the neutral substance, but for practical reasons cadmium is used.

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[1] Can be secured of A. L. Dyke, Electrical Department, Granite Building, St. Louis, Mo. See advertisement at the back of this book.

The cadmium test can be made while a battery is on charge or when it is being discharged. As a rule, the test is made only near, or at the end of a charge, in order to determine if both positive and negative groups are taking the charge properly.

How to Test a Battery on Charge

The charging current must be passing through the battery at a normal rate when the test is made, and the needle of the voltmeter should be exactly on zero—this can be set with the zero adjustment. The best time to test is at the finishing of the charge. Then proceed as follows:

First measure the voltage of one cell, by holding one of the test-points on the positive (+), and the other on the negative (−) terminal of the cell, as in Fig. 16.

If the cell is fully charged, the reading of the voltmeter will be from 2.5 to 2.6 volts, depending on the age of the battery; a new battery giving a higher reading than an old one.

Cadmium Test of Positive Plates When on Charge

Test the positive plates of one cell, by inserting the cadmium rod on test-point (TC) in the electrolyte at vent (V) of the cell, as shown in Fig. 17, being sure that the cadmium does not touch the top of the plates (a rubber tip at the end of the cadmium stick is provided on the Ambu set, to avoid any probability of touching it).

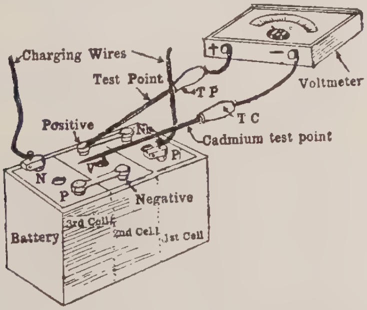

Fig. 17. Making cadmium test of the positive plates of one cell of the battery. Each cell is tested in the same manner.

Allow the cadmium to remain in the electrolyte for several minutes, until the electrolyte has no further effect on the cadmium. Then hold the pointed end of the other test-point (TP) on the **positive cell terminal.**

If the positive plates are fully charged, the voltmeter reading will be, to the right of line (0) (Fig. 13), at least 2.35 and possibly 2.42 or even 2.50, if the battery is new. Should the reading be less than 2.35, then **the positive plates are not fully charged.**

Continue the charge, and if the positive plates will not then give a reading of at least 2.35, the **positive plates are defective.**

Cadmium Test of Negative Plates When on Charge

Test the negative plates by placing the test-point (TP) on the negative terminal of the cell, as shown in Fig. 18.

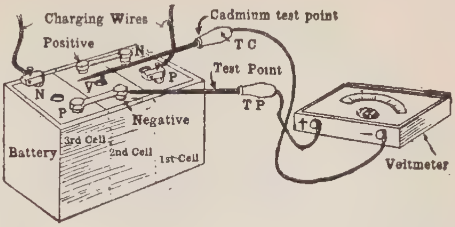

Fig. 18. Making cadmium test of the negative plates of one cell of a battery. Each cell is tested in the same manner.

If the negative plates are fully charged, the voltmeter reading will be from −0.175 to −0.2, that is, the needle will move to the left (or [−] side) of (0) on the scale (Fig. 13).

Should the reading be very nearly zero, or if the needle swings to the right (or [+] side) of the (0) (Fig. 13), **the negative plates are not fully charged.**

Continue the charge, and if the negative plates will not give a reading of from 0.175 to 0.2 volts to the left of the (0) line on the scale, then **the negative plates are defective.**

Test the positive and negative plates of the other cells of the battery in the same manner.

If the positive and negative readings, taken when charging a battery at finishing rates, or when a test is made of a battery almost charged, are added together, the sum should be the voltage of the cell, that is, when the negative readings are on the left, or (−) side of (0) on the voltmeter.

Example of Cadmium Test-Readings of a Battery

The following table furnished by the Ambu Co., gives the voltmeter and cadmium readings taken at hourly intervals on a battery during the time when it was being charged at a normal rate. A healthy battery should not depart widely from these readings.

Hours on charge	Reading across cell-volts	Reading positive pole to cadmium-volts	Reading, negative pole to cadmium-volts
0	2.10	2.25	+ .15
1	2.17	2.27	+ .10
2	2.19	2.28	+ .09
3	2.21	2.29	+ .08
4	2.23	2.31	+ .08
5	2.24	2.32	+ .08
6	2.25	2.33	+ .08
7	2.30	2.35	+ .05
8	2.48	2.43	− .05
9	2.60	2.50	− .10

(+) in front of the figures means that the reading is on the right or (+) side of "0" of voltmeter.

(−) in front of figures mean the reading is on the left or (−) side of "0" of voltmeter.

Explanation of Readings Given in the Table

Whether the cadmium readings should be added to or subtracted from each other depends entirely on the question whether the negatives give a positive (+) or negative (−) reading.

If they give a positive (+) reading, the cell voltage is the difference between the readings, while if a negative (−) reading is obtained, the cell voltage is the sum of the readings.

With a battery on charge, the negatives will give a negative (−) reading as they approach a state of charge. While the cell is still in a discharged condition, the negatives will give a positive (+) reading, even though the cell is being charged.

If a charged battery is put on discharge, the negatives will give a negative (−) cadmium reading until the cell approaches a discharged condition, and will then give a positive (+) reading.

Note that we have previously stated that when a cell was fully charged the voltage of cell should be 2.5 to 2.6, measured while the cell is on charge.

In the table above, the battery was put on the charging circuit when the voltage of the cell was 2.10 (or 2.1) volts as shown, which practically represents a fully discharged condition, as the voltage was measured while the cell was on charge. If the cell voltage were measured on discharge, it would be about 1.8 volts. Therefore, when the positive plate reading was made, it showed 2.25 volts, and thus positive plates are practically in a discharged condition. The negative plate readings showed + .15, meaning that the needle moved to the right or to the (+) side of zero, which it should do if the negative plate is discharged.

Whenever the needle of the voltmeter moves to the right, or the (+) side of (0), when making a negative plate test, then the plate is not charged; and by subtracting the negative readings from the positive readings, the difference will be that of the cell voltage.

For instance, note the first line of the table: The positive plates read +2.25 volts and the negative +.15 volts. The difference between +2.25 and +.15 =2.10, which is the cell voltage.

Whenever the needle of the voltmeter moves to the left, or (−) side of (0), in making a negative plate test, then we know the negative plate is either near charge, or charged, and by **adding** the negative readings to the positive readings, the sum should be that of the cell voltage.

For instance, refer once again to the table, and note the line where the battery has been on charge for 8 hours. The positive plates read 2.43 and the negative −.05, meaning that the needle of the meter is now reading on the left of (0). Therefore by adding 2.43 and .05=2.48, we have the actual voltage of the cell.

After 9 hours, the positive plates read 2.50 and the negative plates −.10. Therefore, by adding 2.50 and .10=2.60 (or 2.6), we get the true voltage of the cell. The plates and cell are fully charged.

How to Test a Battery on Discharge

The battery should be discharging for this purpose, and to this end it may be connected to a number of lamps which will draw about 5 amperes from it. The test should be made after the battery has been discharged to 1.8 per cell. Then make the cadmium test.

Test the positive plates on discharge in the same manner as before mentioned when testing a battery on charge.

If the positive plates are discharged, they will give a reading of 2.00 to 2.05 volts.

If the hydrometer test shows that the battery is discharged, and the positive plates give a reading greater than 2.05, they are not discharging properly, or else there is an incorrect amount of acid in the electrolyte.

Test the negative plates on discharge in the same manner as before mentioned when testing a battery on charge.

If the negative plates are discharged, they will give a reading of about 0.175 to the plus side, or **right** of the (0) line on the scale.

If the negative gives a reading between (0) and 0.175, but less than 0.175, they are not discharging properly.

The difference between the positive and negative readings gives the total voltage of a cell, when tested on discharge, or when the reading of negative plates is on the **right,** or (+) side of (0) of the voltmeter.

What to Do if Cadmium Tests Show Defective Plates

Usually, when the cadmium tests show that either positive or negative plates are not taking a charge satisfactorily, it is only necessary to continue the charge until the proper readings are obtained.

If the specific gravity of the cell is not from 1.275 to 1.300 when the cadmium tests show that both positives and negatives are fully charged, some of the electrolyte should be removed and replaced by pure distilled water, or by 1.400 specific gravity electrolyte, as the case may require.

If the specific gravity reading is too high, add the distilled water.

If the specific gravity reading is too low, the 1.400 specific gravity electrolyte should be added until the gravity is from 1.275 to 1.300.

Should the specific gravity reading indicate that a cell is fully charged, that is, if the hydrometer tests give readings from 1.275 to 1.300, but the cadmium tests indicate that both sets of plates are not fully charged, continue the charge to see if the proper cadmium readings can be obtained.

If it is impossible to obtain the proper cadmium readings on one or both sets of plates, these plates are defective.

If the operation of the battery on discharge is satisfactory, the only effect of the defective plates will be to cause the battery to lose its charge more quickly than normal, and thus require frequent charging.

If the operation of the battery on discharge is not satisfactory, however, the battery should be opened, and the defective plates repaired, or new plates put in.

Pointers to Remember When Making Cadmium Tests

1. **Remember that current must be passing through the battery** when you make the cadmium tests.
2. **The temperature of the electrolyte** should be about 70° F. when cadmium tests are made, if accurate results are desired.
3. **Do not send out a new battery** unless the hydrometer readings are from 1.275 to 1.300, until the positive-to-cadmium tests give at least 2.40 volts, and the negative-to-cadmium tests give about 0.175 volts.
4. **Do not scrape off the coating of sulphate** which forms on the cadmium.
5. **Do not allow the cadmium to become dry** after you have made tests with it. Keep the cadmium immersed in a glass of pure distilled water, or dilute the electrolyte.
6. **Be sure to get good contact** when you hold the sticker on the battery terminal. Bear down on the handle so that the point of the sticker digs down into the terminal.
7. **If both positive-to-cadmium and negative-to-cadmium readings are very nearly zero,** the cell is short-circuited and must be inspected for excessive sediment, or defective separators.
8. **The end of the cadmium rod must not be allowed to touch the tops of either set of plates,** as this would give worthless readings.

THE HIGH-AMPERAGE DISCHARGE TEST

The high-amperage discharge test is a valuable aid in determining whether batteries or individual cells require repairs or not, particularly in cases where the hydrometer readings give false indications, as for instance, if acid has been added instead of water. The high-amperage discharge test **must be used in conjunction with hydrometer readings.**

When making a high-amperage test, the actual voltage of the cells is not so important as how they **compare** with each other. It may be used to test both **incoming and outgoing batteries,** and the method of using it depends upon whether the battery is coming in or going out. This test also indicates how **battery performs** when the starter is in use.

Advantages of Testing a Battery at a High-Amperage Discharge

This test is useful for determining the following:

1. The condition of the connections: if loose or poorly burned.
2. The condition of the separators.
3. The condition of the positive and negative plates.
4. Prevents charging a defective battery which will not hold its charge.
5. Whether or not there are internal short circuits.

There are various methods employed for making a high-amperage test, some of which are shown on pages 552–554.

In either case, **the test consists of** discharging the battery at a fairly high amperage and taking the voltage reading of each cell while discharging.

A suitable current rate for this test is approximately 28 amperes for the number of positive plates in each cell for the usual types of automobile starting and lighting batteries. For example, take an Exide 3-XC-13 battery, which has 13 plates per cell (7 negative and 6 positive plates). The required amperage discharge would be 6×28=168 amperes, which would be the approximate discharge rate of entire battery.

Hold the current for about 10 or 12 seconds, and then take the individual cell voltage readings.

Test for Battery Coming in for Charging or Repairs

First take a hydrometer reading of each cell.

If the readings are within 25 points of each other, and all are below 1.200 (1.130),[1] most likely all the battery needs is a bench charge (see page 573), with a possible adjustment of the strength of the solution.

If the readings are above 1.200 (1.130)[1], or one cell differs from the others by 25 points or more, make the discharge test, and if the voltage readings are within 0.10 (.1) volt of each other, the battery needs a bench charge with an adjustment of the strength of the solution, or else replacement of a leaky jar.

If the voltage readings differ by 0.10 volt and the battery is pretty well charged, there is something internally wrong with the cell having the low reading, provided it has not been short-circuited in service. It should be opened and examined.

With a discharged battery, the difference in voltage will be greater, depending on the extent of discharge, and only experience can guide the battery man in drawing correct conclusions.

Test for a Battery after Charging and when Ready for Service

Just before putting the battery into service, make the test as a check on the internal condition, particularly if the battery has been repaired or has stood for some time since being charged. (It is assumed that the battery has the strength of solution properly adjusted.) **The battery should not show more than 0.10 volt difference between any two cells,** and no cell should read less than 1.7 volts at a discharge of from 150 to 225 amperes.

If every cell reads below 1.7, it is probable that the battery is not completely charged.

If one cell is more than 0.10 volt lower than the rest, that cell still needs attention.

Trouble Causes as Determined by a High-Amperage Discharge Test

1. **When each cell shows 1.7 volts or more, and the hydrometer test shows 1.200 or more** (at 60° or 70° temperature) then the cell is in proper condition.
2. **When any cell shows less than 1.7 and the hydrometer test is below 1.200,** the cell is either discharged or defective. Charge the battery carefully and test again. If the voltage still drops on any cell and the gravity of that cell came up on charge to 1.275 or 1.300, either the trouble is due to separators whose pores are clogged up, or which have never been properly treated to make them porous, or it is due to the plates themselves being too hard.

When the plates are too hard, they may be softened by charging and discharging the cell five or six times. If this does not improve the capacity so that the cell stands up under test, the cell should be opened and the separators changed.

If, however, the gravity of the cell did not come up on charge to 1.275 or 1.300, and the cell does not stand up to 1.7 volts on testing after charging, the cell should be opened at once, as it is defective internally.

3. **When one or more cells show a voltage of less than 1.7 volts and the hydrometer shows a gravity reading of more than 1.200,** it is due to troubles in the battery or the specific gravity of the electrolyte is too high (too much acid). Recharge the battery and test again, and lower the electrolyte density by using a separate jar for it, if necessary.
4. **When the voltage varies more than a fraction of a volt in each cell,** during a test of a fully charged battery, then the trouble is probably in the interior of the battery. Be sure that all connections are burned well, as the trouble may be in the connector instead of in the battery.
5. **When testing a fully charged battery at this high discharge** for about 10 or 12 seconds, if any of the cell connections heat, it indicates poorly burned connectors.
6. **When testing with a voltmeter,** a battery which is supposed to be fully charged, **if any cell should cause the voltmeter to read in the reverse direction,** it may be due to a fully discharged cell or to internal trouble, such as separators or sediment. Recharge and test again.
7. **When a cell bubbles too freely and froths when being discharged,** it is due to internal troubles. Recharge and test again. If it still froths, open the cell and look for defective plates, or for a short circuit internally, or for badly sulphated plates.

A low-amperage discharge test means that the capacity of the battery is tested at a low rate of discharge, usually 8 or 10 amperes, until discharged from a fully charged condition. The purpose is to determine the capacity of a battery at low rates, as, for instance, for lighting service.

The high-amperage discharge test is usually sufficient and can be given for as long a period as 15 minutes. If a battery is up to capacity at this 15-minute rate, it will practically be sure to give its capacity at a lower rate of discharge.

However, the high-amperage discharge test of a battery does not always mean testing for capacity. It may mean simply finding out how the voltage of the battery stands up at a high-amperage discharge, and this discharge is not carried on until the battery is fully discharged. A battery might have hard plates and give a fairly satisfactory high-discharge test for a minute or two and then fall down, whereas, if it were up to capacity, it would hold this discharge for 5, 10, 15, or 20 minutes according to what the discharge rate was.

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[1] The reading in parentheses applies to batteries used in tropical climates.

The voltage at which a battery is considered discharged during a discharge test is higher for the low-amperage discharge test than for the high-amperage discharge test, being 1.7 for the low-amperage discharge, and as low as 1 volt on a heavy high-amperage discharge test.

How to Make a High-Amperage Discharge Tester[1]

A very convenient outfit for making high-amperage discharge battery tests on the individual cells without using the resistor referred to in Fig. 5, page 547, is illustrated in Fig. 19. Two spikes are arranged in a handle so that the distance between them will be the distance between the positive and negative terminals of a cell.

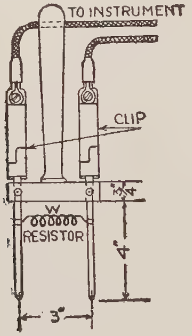

Fig. 19. Construction of a heavy-discharge tester.

Cables are attached to the spikes which are connected to the binding posts of the voltmeter. Between the spikes is connected about 1 foot of ⅛" nichrome wire (W) (Fig. 19) to form the load resistor.

When the spikes are firmly pressed into the cell terminals, the voltmeter will indicate the cell voltage under current flow.

For the convenience of those who desire to purchase such an outfit, instead of making it, A. L. Dyke, Electrical Department, St. Louis, Mo., can supply the Weston model 453 Heavy Discharge Battery Tester, either with or without a voltmeter, mounted on the prod.

Instructions for Using the Weston Model 453 High-Amperage-Discharge Battery Tester

To ascertain the actual condition of a storage battery of the automotive type it is desirable to test the voltage of each cell of the battery while a relatively heavy discharge current is flowing. A comparison is then made of one cell with another.

To use the tester, press the points of the prod into the cell terminals with sufficient force so that the reading of the voltmeter does not increase if further pressure is applied. Test each cell, one at a time, and note the reading obtained on each one. For a battery which is not defective, the readings should be very nearly the same on all of the cells.

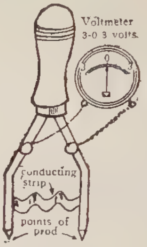

Fig. 20

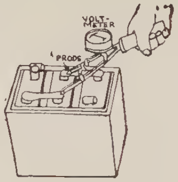

Fig. 21

Fig. 20. Weston heavy-discharge battery tester with voltmeter separate.

Fig. 21. Weston heavy-discharge battery tester with model 301 voltmeter.

When the reading on a cell differs by 0.1 volt or more from the reading on another cell of the battery, the one giving the lower reading should be carefully examined for defects.

If no reading is indicated, then that cell is in bad condition.

If readings are alike at first, and then drop appreciably, the indication is that the cell is short-circuited. If the tests on standard size automotive battery such as is used on starting, lighting and ignition systems show **cell voltages of less than about 1.4 volts,** the battery requires charging.

The resistance of the conducting strip between the legs of the prod is very closely equal to 0.01 ohm. It is designed to carry 200 amperes at a potential of 2 volts. The actual current taken from the cells when making these tests will vary with the capacity and condition of the battery. Its approximate value can be obtained by multiplying the voltmeter reading by 100. For example, if the voltmeter reading is 1.8 the approximate current passing through the conducting strip will be 180 amperes.

The passing of current through the conducting strip will cause the strip to heat, but this in no way affects the operation or reliability of the outfit. It is well, however, to keep the tester across the cell only long enough to procure the desired reading, as prolonged discharging of the battery at the high rate of current flow may harm an otherwise good battery.[1]

The F. B. Battery Tester[2]

The instructions with this tester read as follows: **Press the two tester-points firmly on the two terminals of one cell,** as shown in the illustration, being sure to make a good contact. Test each cell separately in this manner. (See Fig. 22.)

The tester will light either red or green. If red, it indicates that the condition of the battery is too low to operate properly in service, and it must be taken out and filled with distilled water and charged. If the light shows **green,** it indicates that the battery is in a **well-charged condition** and needs no further attention other than probably to be well filled with distilled water.

When the tester-points are touched to the battery terminals, the battery discharges at a 500-ampere rate through the heavy resistance of the tester, and the voltage across the points falls to a certain value, depending upon the condition of the battery.

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[1] From instructions furnished with the Weston model 45 battery testing voltmeter described on page 546.

[1] Price without meter, $8.50; price with voltmeter, $18.00. Can be obtained of A. L. Dyke, Electrical Department, Granite Building, St. Louis, Mo.

[2] Manufactured by F. B. Electric & Mfg. Co., Detroit, Mich. Can also be secured of A. L. Dyke, Electrical Department, Granite Building, St. Louis, Mo., price $15.00.

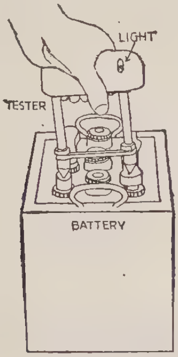

Fig. 22. F. B. Battery tester.

If the battery is in good condition, the voltage will be maintained at a point high enough to force sufficient current through the electromagnetic mechanism of the tester to cause it to operate and light the green lamp.

If the battery is in poor condition, the voltage falls to such a point that it will fail to operate the indicating mechanism, in which case the red lamp will light.

Home-Made Carbon High-Amperage-Discharge Tester

A home-made discharge tester is shown in the illustration (Fig. 23), consisting of an asbestos-lined box 4″ wide by 6″ long. It is sufficiently deep to take a lot of old electric light carbons to a depth of about 12″.

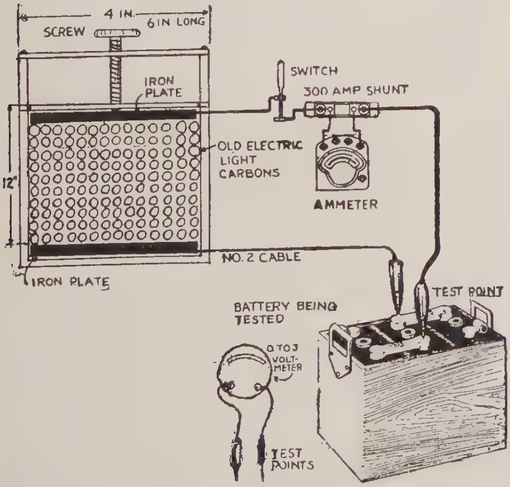

Fig. 23. A home-made carbon heavy-discharge tester.

An iron plate with one connection is placed at the bottom for the carbons to rest on. Another iron plate is placed above, with a screw arrangement for tightening or loosening the pressure of the top iron plate on the carbons.

Note. The resistance can be increased by placing brass plates about ½″ thick between the iron plates and the carbon sticks.

The exact number of carbons to use can be determined by experiment.

When connection is first made, start with no pressure, then gradually increase until the desired amperage discharge is obtained.

With a light pressure, the resistance is greater, hence a lesser discharge.

As the pressure is increased, the resistance is less, because better contact is made; therefore, the discharge rate will be greater.

This outfit will give from 5 to 500 amperes. It is not advisable to pass more than 300 amperes, at the most, through it, as it will get very hot.

Ammeter: A suitable shunt (of not less than 300 amperes) should be used with the ammeter (model 280 Weston shown).

Voltmeter: Can be a separate meter, as the model 301, or the voltmeter connection on the model 280 can be used. The voltmeter is placed **across** the circuit, and the ammeter with shunt in **series** with the circuit.

Test-points can be made as explained on page 464.

Heavy cable, about No. 2, should be used.

Home-Made Resistance High-Amperage Discharge Tester

A method of using iron wire resistance instead of carbons is shown in Fig. 24. The size of the iron wire and the length of the coils are given in the illustration, as: 4 coils of 33 ft., No. 16 iron wire; 3 coils, 71½ ft., No. 8; 6 coils, 57½ ft. No. 8.

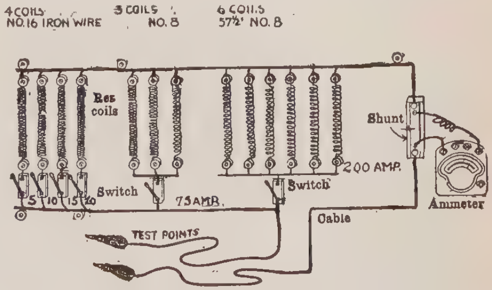

Fig. 24

The model 280 Weston combination volt-ammeter is shown connected in the circuit with a 300-ampere shunt.

The test-points are connected with the battery in a manner similar to that by which the test-points of the carbon principle are connected.

The rate of discharge can be made 5 amperes by closing the first switch to the left; the next switch will add 5 amperes more, making 10 amperes, and so on, until all switches are closed, at which time a 200-ampere discharge will be given.

The coils will get very hot, and should be protected with asbestos.

INSTRUCTION No. 49

A DIGEST OF STORAGE-BATTERY TROUBLES; EXTERNAL AND INTERNAL: Pointers; Care of a Storage Battery

A DIGEST OF BATTERY TROUBLES (EXTERNAL)

Battery troubles can be classified under three headings:

1. Failure of generator to charge battery.
2. Battery will not hold charge.
3. Battery voltage drops immediately after charging.

1. Indications of a generator not charging the battery can be observed on the ammeter, as explained on page 471.

The cause may be attributed to generator troubles, to defective cut-out (points not closing), to open circuits in the line, or to ground or terminal connections of the battery. Often poor connections at battery terminals and grounded wire will result in dim lights and weak current supply. Always clean battery terminals with a file when connecting the battery. Sulphated or **corroded battery terminals** are also a common cause of a battery not getting a full charge.

For **tests**, see pages 482–489.

2. Indications of the battery not holding its charge are: slow cranking of starting motor; dim lights when the battery supplies current; missing of ignition.

Cause (a): The car is not run enough in the daytime without lights, or at high enough speed for the generator to charge the battery and replace the current that is taken from it when the lamps are burning with the engine idle or running at very low speed. Or the car may be run mostly at low speeds.

There is more trouble from discharged batteries in winter than in summer, owing to the fact that engines are usually more difficult to start and the battery is used more. Consequently the generator does not have an opportunity to put back the current taken out—especially if the car is run more at night with the lights on.

The engine crank is more difficult to turn over on cold days after standing a long while, since the oil is heavy and congealed, and unvaporized gasoline is present.

Keeping battery charged: Keep the engine tuned up so that it starts on the second or third turn. This minimizes the amount of current used in starting, and, remember, this is very large. **Be economical with lights.** Use headlights only when absolutely necessary. **Determine the car speed at which the cut-out relay makes connection with the battery,** and operate the car as much as possible above this speed.

If you drive much in a congested city district and stop your engine many times, you will find that your battery can be kept more nearly charged by changing gears in traffic whenever necessary, instead of trying to do it all on high gear. The reason for this is that by changing gears you boost your engine speed so that the battery is charged, while if you try to pull slowly on high you get down to a speed at which charging stops, because of the opening of the cut-out.

Remedy: Have battery recharged from an outside source. Use the starting crank as often as possible. Use the starting motor as little as possible. Use dimmer lights instead of headlights, thus saving on the current consumption. Provide a good "choker" or primer, which will start the engine quickly.

Cause (b): The output of the generator may not be properly adjusted, as for instance, the third brush. Or the third brush, or the main brushes may not be seated properly.

Cause (c): A ground in the car wiring: With the engine idle and all switches "off," disconnect the battery wire and touch it lightly on the battery terminal a few times, as shown in Fig. 5, page 453. If there is a spark produced there is a ground in the wiring between the battery, the cut-out, and the generator.

Remedy: See Index under "Testing for grounds." This may be done as follows: At night, or in a dark garage, turn on all the lamp switches, but remove the bulbs from the sockets and disconnect the battery ground wire at the ground plate. Then strike the bare end or terminal of the ground wire against the ground plate; if sparks are noticed, there is a ground in the wiring, which should be looked for and removed.

Cause (d): Cut-out is not operating properly. Examine the cut-out and see that it is properly connecting and disconnecting the generator circuit (see page 351). The cut-out switch should be in the open position when the engine is not running, or should stay in the closed position when the engine is running above "cut-in speed." If the switch does not close, the windings may be defective, or there may be oil on the brushes or the commutator of the generator, or one of the brushes may be worn too short, or may not be seating properly.

Cause (e): A constantly discharged battery can also be caused by an overload on the starting or lighting system.

Quite often extra large lamps, or additional electrical devices, or a short circuit in the electric horn, will cause undue waste of current. Replace by lamps with a lower candle power and use the least number possible. Spotlights are handy, but consume current. Use the headlights.

Cause (f): A constantly discharged battery, if not caused by lack of sufficient charging current, or open or grounded circuits, is then to be attributed to internal troubles of the battery, such as weak electrolyte, water below the level of the plates, internal short circuits, defective separators, buckled plates, or connectors not properly welded to the battery plate posts. The battery jar may also be leaking.

3. Indications of the battery voltage dropping immediately after charging are generally noticed by the starting motor turning over very slowly and the lights becoming unusually dim. The voltage, even with a good battery, will drop probably to 1.8

volts when about 200 amperes are drawn from it for the starting motor, but if it drops to much less than this, when it is known to have just been fully charged, then the car trouble is probably internal.

Causes: Internal short circuit of one or more cells; grounded starting switch; poor or loose connections at the battery terminals, ground connection or connectors; electrolyte below the level of the plates.

Tests: The battery should be given a "high-rate discharge test."

If trouble should develop, as shown by the engine not cranking properly, lights burning dimly, or "missing" of the engine when the battery is used for ignition, look for the cause as indicated below.

1. Make sure that **all connections are tight** and that all contacts are clean.
2. **Take a hydrometer reading** of each cell. If the battery is found to be exhausted (gravity 1.150 or thereabouts), give a special charge from an outside source. See that the electrolyte is above the level of the plates.
3. **If, after having been fully charged, the battery is soon exhausted again,** there is trouble somewhere else in the system, or the battery is defective internally. In this case a "high-rate discharge test" and a "cadmium test" should be made.
4. **The wiring may have become grounded** to the frame of the car, and cause a leakage of current which in time may completely discharge the battery.
5. **If a broken jar or short-circuited cell** is indicated (gravity considerably lower than in other cells), have the battery repaired.

When lamps burn dimly, turn on all the lamps and read the voltage with a low-reading portable voltmeter of each cell or of the battery (see pages 545, 546, 483, 470).

If the voltage per cell is 2 volts or thereabout, the trouble is in the connections.

If cell voltage is low (1.8 volts or lower), the trouble is in the battery.

When the lamps burn brightly, but the engine will not crank, notice when attempting to start the engine whether the lamps become very dim or go out; if they do, the trouble is in the battery.

If they continue to burn brightly, the trouble is in the motor or motor circuit.

Causes of a Battery Becoming Discharged through Lack of Care and Attention

1. **Frequent starts** with but short runs.
2. **Insufficient input** to the battery on account of short runs at low speed.
3. **Use of headlights** while standing at the curb.
4. **Ignition switch left on** the battery overnight.
5. **Unnecessarily high candle-power lamps,** including spotlight.
6. **Lamps left burning** overnight.
7. **Moving car in garage or elsewhere on the power** from the battery.
8. **Prolonged attempt to start** in cold weather without priming and without warm water in the radiator.
9. **Prolonged attempt to start without investigating engine troubles,** such as:
    - Poorly adjusted carburetor.
    - Dirty or cracked spark plugs.
    - Gummed and sticky valves.
    - Carbon.
10. **Starting and lighting system:**
    - Worn generator brushes.
    - Sticking of points in automatic cut-out.
    - Loose belt (leather).
    - Loose connections.
11. **Loose connections,** generator, motor or battery terminals, fuse box, ground wire, switch or spark plugs.
12. **Grounds,** due to loss of wire insulation through chafing.
13. **Corroded battery terminals.**
14. **Infrequent testing** and water filling of battery.

Battery Box Acid-Soaked

Grounds quite frequently result from old battery boxes which have become thoroughly soaked with acid, as a result of the covers not being sealed properly, split covers, overfilling with water, or boiling when being charged at too high a rate. This acid forms an electrical path between the terminals of the battery, through the damp box to the metal frame on which it rests.

A test can be made by disconnecting the terminals of the battery and connecting a voltmeter between one terminal and the metal frame. If there is any indication at all, examine the battery box and see if it is damp or soaked.

See also, page 484 for testing with a 110-volt test-light.

The remedy would be to place dry wood between the box and metal frame; clean the battery thoroughly and paint it with acid-proof paint.

DIGEST OF STORAGE-BATTERY TROUBLES (INTERNAL)

Sulphation

Indication: Gravity cannot be brought up by charging.

Causes: Overdischarge; standing in discharged condition; raw acid added to replace evaporation; electrolyte level low; short circuits and grounds; local action.

Remedy: Give a long 24-hour charge at a low rate. If this fails, replace the elements; balance the electrolyte in each cell, and charge for a long period.

Local Action

Indication: Gravity will drop rapidly after a charge, owing to internal causes.

Causes: Impurities in electrolyte; active material loose in grids.

Remedy: Disassemble and wash the plates, and put in new separators and electrolyte. Put in new plates if the active material is loose.

Lack of Capacity

Indication: Battery will not hold charge.

Causes: Excessive use of lights or starter; external short circuit; local action; internal short circuit; cracked jar; sulphation; clogged separators; rotted separators; sediment.

Remedy: Use lights and starter less. Dismantle, and clean out the sediment, and put in new plates and separators if necessary, and if the battery does not come up and hold the charge on as long, charge at a slow rate.

Internal Short Circuit

Indication: The gravity of an internally short-circuited cell will always be low, as it is discharged internally, owing to internal causes.

Causes: Rotted separators; sediment; buckled plates.

Remedy: Disassemble and clean; replace the separators and plates if necessary. Plates may be pressed back when buckled, in some cases.

Constant Low Gravity

Indication: When gravity is 1.210, the battery is about half discharged.

Causes: Using starter too much; sulphation; short circuits and grounds; stopped electrolyte—replace with water; cracked jar.

Remedy: If below 1.200, remove and charge from outside source. See "Sulphation"; see "Internal short circuit"; see "External short circuit."

High Gravity

Causes: Evaporation replaced with electrolyte or acid; wrong gravity of electrolyte used.

Remedy: Balance the electrolyte in each cell.

Low-Voltage Reading When on Discharge

Causes: Battery discharged. Do not permit the voltage to fall below 1.8 on discharge; internal resistance high; low-gravity electrolyte; dead cell.

Remedy: Recharge. See "Sulphation"; see "Low gravity."

Buckling of Plates

Causes: Sulphation; overheating.

Remedy: See "Sulphation."

Terminals Corroded

Cause: Slopping.

Remedy: Use ammonia wash, or soda.

Separators in Wrong

Cause: Flat side of separators in contact with positive plate or inserted with grooves horizontal.

Remedy: Insert properly. If the plates are damaged, replace them.

Separators Rotted

Causes: Overheating: gravity too high; buckling.

Remedy: See "Overheating"; see "High gravity"; see "Buckling."

Separators Clogged

Cause: Impurities in pores of separators.

Remedy: New separators. Wash battery out.

External Short Circuits

Causes: Circuit grounded or shorted; battery terminals shorted; battery box acid-soaked.

Remedy: Trace circuit.

Lights Dim, Weak Starter

Causes: Discharged battery; loose connections; dead cell or cells.

Remedy: Test and charge battery. Tighten connections after cleaning. Test with hydrometer and cadmium voltmeter.

Electrolyte Level Low

Causes: Evaporation; slopping; broken jar.

Remedy: Replace evaporation with distilled water. See that the battery is properly sealed. Replace the jar.

Negative Plates Harden

Never allow negative plates to dry unless all acid has first been removed.

Cause: Plates exposed to air.

Remedy: New plates required if repeated charge or discharge fails.

Active Material on Plates Soft

Cause: Overcharge.

Remedy: Press back, but better put in new plates.

Battery Frozen

Causes: Battery discharged; water added without charging.

Remedy: New plates.

Broken Jar

Causes: Vibration; battery dropped or set down hard.

Remedy: New jar.

Active Material Shedding

Causes: Overdischarge; overcharge; buckling; short circuits and grounds; overheating.

Remedy: See these headings.

Overdischarge

Indications: Gravity less than 1.150 and voltage less than 1.8 on discharge.

Causes: Faults in electric system; improper operation of system.

Remedy: Use caution in using starter, lights, etc. See if the generator is properly charging the battery.

Overcharge

Indications: Buckled plates; shedding of active material; overheating. Gravity will be about 1.275.

Causes: Car used mostly during the day and on long runs; generator regulator out of adjustment or third brush adjusted for too high a charge.

Remedy: Burn lights part of the time. Test output.

Internal Resistance High

This will result in overheating and loss of capacity.

Causes: Sulphation; clogged or reversed separators; low gravity.

Remedy: See these headings.

Overheating

Causes: Charging rate too high; discharge rate too high; high internal resistance; short circuits and grounds; dead cell; excessive temperature of atmosphere, and high charging rate.

Remedy: See "Sulphation"; "Separators"; see other headings in this Digest. Use the battery sparingly on warm days and also on extremely cold days.

LOCATING BATTERY TROUBLES WITH A HYDROMETER

Low gravity in all cells: If the starter occasionally fails to spin the engine, and if the battery lacks energy, it may be that on testing with a hydrometer and finding the "gravity" low, say below 1.225, all that the battery requires is an extra charge. The battery may have been previously discharged to so low a state that the normal generator output has not been sufficient to restore it.

If failure, due to low gravity, recurs after this extra charge, then the generator is failing to put enough current into the battery. Or it may be that a short circuit in the wiring is causing the battery energy to be wasted. It may be that the battery box is acid-soaked.

Low gravity in one cell: If it is found that the gravity is low in any cell, say 50 points lower than in the others, then make hydrometer tests of the cells oftener to determine whether the difference in gravities of the cells is increasing.

If the trouble increases, the cause undoubtedly is that a short circuit is just beginning. Some one of the following conditions may be the cause: separators wearing through, or sediment accumulating in the bottom of the jar until it touches the plates, or a piece of metal has fallen into the cell and has bridged across the plates. Water containing certain minerals may have been put into the cell, preventing the cell from holding its charge.

The remedy is to remove the element and remedy the cause. New separators should in almost every instance be installed in all cells.

It is advisable to make a "high-rate discharg test" or a "cadmium test" before disassembling a battery.

A broken jar is sometimes the cause of constant low "gravity" in a cell. A broken jar can be detected from the fact that you will have to add water more frequently to its cell than to the others, to keep the plates covered. The leak may be between the jar walls and the sealing compound. The addition of water to replace the electrolyte lost from such a cell will naturally reduce that cell's "gravity."

Sulphation and low gravity: Suppose the gravity of a cell is persistently low and water is added often. As a result, the tops of that cell's plates may have been left exposed to the air for a period of time, and so the plate tops may have become sulphated, and the disease has proceeded downward so as to affect the plates throughout. If this evil had progressed far enough, the cell would not respond to charging, and the "gravity" would not rise. The cell would become unduly hot during charge, and would hasten the evaporation of water.

1.150 or lower: With "gravity" as low as this, the battery cannot be depended upon, even to operate the lights.

Gravity too low to read: Hydrometer readings usually run as low as 1.150. Batteries may be found with gravities too low to be measured with the ordinary hydrometer, so that you cannot fully diagnose the battery with this instrument alone. These are extreme cases, however. Possibly all they require is a thorough charge, but the special conditions of the necessary charge must be observed. Should there be sulphation—and there is likely to be if the battery has stood long in a state of low "gravity"—the rate of charge secured in the automobile would undoubtedly overheat and buckle the plates, and so injure both plates and separators.

Constantly high "gravity": While 1.285 is usually indicated as the proper top mark for full charge, a reading of 1.300 of itself need cause no alarm.

However, if a few hydrometer tests show that the battery is being charged regularly, but that for considerable periods after charging the "gravity" reaches 1.285, it is then necessary to reduce the charging rate, for the battery is getting more than enough, and this is daily shortening its normal life.

Excessive gravity: Gravity above 1.300 is certainly abnormal and indicates that the battery has been **"doped"** by the addition of excessive acid. Prompt reduction of the acid proportion is needed to save the battery's life.

STORAGE-BATTERY POINTERS

1. **Learn to prepare the electrolyte.** Use a large earthen crock or lead vessel with burnt seams. One part of chemically pure concentrated sulphuric acid is mixed with several parts of water, proportion of water varying with type of cell.
2. **Prepared electrolyte** may be bought if desired.
3. **Always pour acid into water,** never reverse.
4. **Use pure water,** either distilled or rain water.[1]
5. **Allow the electrolyte to cool** before placing in the cells. The specific gravity should be 1.200 or 25° Baume. Add distilled water if a higher reading is obtained.
6. **Grids should always be at least ½" below the** surface of the solution.
7. **Clothing** is greatly affected by acid.
8. **Ammonia** immediately applied to a splash of acid on the clothes, neutralizes the acid and prevents a hole being burned in the material.
9. **In case a drop of acid splashes into the eye,** wash well with warm water and put into the eye a drop of olive oil.

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[1] **Distilled water:** Artificial ice is not always made of distilled water. Rain water can be used if it does not come from a metal roof or where mineral substances will get into it. Distilled water can usually be obtained at drug stores or battery supply houses. Filtered water will not do. See also page 584.

10. **Avoid the use of an open flame** in a room where a storage battery is being charged, or in which it has been left for some time, as an explosive mixture of air and hydrogen may be formed.

11. **Storage batteries are rated in ampere-hours,** this being based on the steady current the battery will discharge. A battery that will discharge at 5 amperes for 8 hours without the voltage falling below 1.75 is rated as a 40-ampere-hour battery. This does not mean that 40 amperes would be the output of the battery if discharged in one hour. The ampere-hour capacity decreases with the increase in current output.

12. **The current in charging** should be kept within the maker's specified limit. One authority advises for rapid charging, covering a period of three hours, 50 per cent, 33 per cent and 16 2/3 per cent of the total current for each consecutive hour.

13. **The e.m.f. of the charging current at starting the charge** should be about 5 per cent higher than the normal e.m.f. of the battery. After a few minutes, this voltage may be 10 or 15 per cent higher than the normal battery e.m.f. However, the battery is kept in the best condition by using a constant charging current, and, if necessary to maintain this, the voltage may be raised to 25 per cent higher than the normal battery voltage.

14. **Be sure that the positive pole of the charging mains** is connected to the positive side of the battery.

15. **To determine the polarity,** hold the two wires in a glass of acidulated water or electrolyte, keeping them at least ½″ apart. Gas will collect most at the negative lead.

16. **A cell is fully charged:** (a) if, with a constant current, the voltage and specific gravity do not change in one hour; (b) when the plates decidedly increase the quantity of gas given off; (c) when the specific gravity measures 1.275, and the voltage from 2.5 to 2.7; (d) when the negative plate assumes a light-gray color and the positive plate turns a dark brown.

17. **Never adopt the method of putting a wire across the positive and negative terminals,** to see if there is any "spark." It is almost a dead short circuit, and if the cell be of a small capacity of, say, 30-ampere-hour, and the wire No. 16 copper, the current may be anything from 30 to 100 amperes for a fraction of time, which, when calculated, is a very appreciable amount of the total capacity, if only for a second of time. It is also very detrimental to the cell, assisting the disintegration of the plates or active material thereon.

18. **Lead cells** for starting and lighting purposes should not be discharged below 1.8 volts.

19. **Excessive boiling** will loosen the active material.

20. **If the cells are hot while charging,** reduce the charging current.

21. **If a battery is not in use,** give it a short charge once a month.

22. **If white sulphate is formed on the grids,** it may be reduced by charging at a high rate for a few hours and overcharging at a low rate for two or three days.

23. **Continued sulphating** will buckle the plates, as will also too rapid discharging.

24. **A cell that has been short-circuited** should be disconnected from the battery and charged and discharged several times separately.

25. **Manufacturers furnish directions for keeping batteries when not in use.** One way to do this is to charge the battery fully, then siphon the electrolyte out of the jars, to be kept until used again. The plates must then be removed and stored. See "Storing batteries."

26. **Never allow the cells to stand in a discharged condition,** as it becomes very difficult to get them properly charged if they are left standing any length of time, unless great care is taken during the succeeding charge.

27. **If the terminals begin to corrode,** use vaseline.

28. **Voltage readings** should be taken only when charging or discharging.

29. **Do not let the battery get too warm;** its temperature should never exceed 100° F.

30. **Use only distilled water to replace losses from evaporation.** Add acid only in special cases.

31. **Each time you charge,** bring the gravity up to maximum, or charge until it has remained constant, for at least one hour in every cell.

32. **When charging the battery,** put in at least 20 per cent more current (ampere-hours) than is taken out, and at every third charge give it a 50 per cent over-charge, at the finish rate for the general good of the battery.

33. **Voltage readings are only approximate.** Gravity readings give correct indications.

34. **Keep the box containing the battery perfectly dry.** If any acid is spilled into the box, wipe it off carefully with a piece of waste dipped in ammonia water.

35. **When charging at the finish rate,** or 24-hour rate, leave the battery on until bubbles begin to rise in the electrolyte, and then for at least one hour longer.

36. **Never add acid or electrolyte to the cells** except to replace loss from spilling.

37. **In cases where the specific gravity will not show** any rise during or at the end of its charge, it indicates a short circuit, and the cell has not received its charge.

38. **In cases where the specific gravity comes up to 1.250 at the end of its charge, but falls to a** lower figure during a period of idleness or standing for say twenty-four to forty-eight hours, this also indicates a short circuit, or else local action (or internal discharge), due to contamination of the electrolyte.

Don'ts and Do's—Read Carefully

Always disconnect the wire from the generator terminal before disconnecting the battery, and reconnect the battery before reconnecting the terminal. Otherwise the lamps may all be burned out if the engine should be started.

Don't use a piece of wire instead of a fuse.

Don't short-circuit your battery with a pair of pliers or a screwdriver, to see if it is charged.

Don't advance the spark, but retard when you start with a starting motor, with the throttle partially open.

Don't use emery paper on your commutator; use fine sandpaper.

Don't forget to see that your ignition switch, spark lever, and gas lever are all in their proper positions, before depressing foot switch to start engine.

Don't fail to push down the button of the foot switch to its limit.

Don't continue to crank your engine, if ignition does not take place after a few revolutions. There is something wrong with your ignition system, or the carburetor. Look for the trouble. Just turning over the engine will not help matters, but it will exhaust your battery, if continued for any length of time.

Don't allow connections on generator, battery, or motor to become loose.

Don't blame the generator for every trouble you may have. As a matter of fact, 90 per cent of all troubles originate in switches or wiring connections, or at the lamps, which are necessarily small and more or less liable to imperfect contact or short circuit.

Don't forget that it requires twenty times as long to restore current to the battery as it takes to start the car. In winter, it is sometimes advisable to use the starting crank to save the battery current.

Don't put oil or grease on the commutator of the generator or motor.

Don't tighten up on the silent chain drive unless the slack becomes excessive from stretching. The chain must be run with a reasonable amount of slack to prevent noise and wear.

Don't fail to lubricate the silent chain drive at frequent intervals. Noise will be eliminated and wear reduced. Keep the chain and sprockets clean, and free from dirt.

Don't run your car, if for any reason the battery is disconnected from the circuit, unless you have disconnected the chain driving the generator, or the generator itself has been removed, or the field-circuit is opened. See also page 366.

Dont' forget to examine your battery at intervals of about two weeks, and make certain that the electrolyte covers the top of the plates in each cell.

Don't allow your battery to become loose in its box or container. Strap or wedge it tightly in position, and make certain that the terminals cannot come into contact with anything which may cause a short circuit.

CARE OF A BATTERY IN SERVICE

The care of a battery in service, or where there is a generator on the car to recharge it, is summed up in the four following rules, which, if observed with reasonable care, will result in the best service being obtained:

1. **Add nothing but pure water to the cells,** and do it often enough to keep the plates covered.
2. **Take frequent hydrometer readings.**
3. **Give the battery a special charge whenever the hydrometer readings show it to be necessary.**
4. **Keep the filling plugs and connections tight, and the battery clean.**

Adding Water

Water must be added often enough to keep the plates covered. If the plates are exposed for any length of time, they may be seriously damaged.

The length of time a battery can go without the addition of water will depend upon the season of the year, water being required more frequently in summer than in winter.

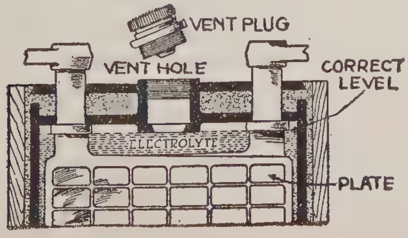

Fig. 1. Section of cell, showing correct level of electrolyte.

The best plan is to make it an invariable rule to remove the filling plugs once each week and to add water if the level of the electrolyte is below the bottom of the filling tube.

Never bring an open flame, such as a match or candle, **near the battery.**

Always add the water regularly, though the battery may seem to work all right without it.

In freezing weather, when necessary to add water, always do it just before running the engine.

If temperature is extremely low, start the engine so that the **battery is charging before adding water.**

The reason for this is that water, being lighter than electrolyte, **will remain on the surface and will freeze** in cold weather. If the engine is run, however, the gassing, owing to the charging current, will thoroughly mix the water with the electrolyte; also the motion of the car when running will have a similar effect. Thoroughly mixed electrolyte will not freeze solid, except at very low temperatures. See page 531.

The reason why the solution (electrolyte) falls below the top of the plates is that when the battery is being charged it gasses or bubbles. This action changes some of the water into gas, which escapes, or evaporates. Thus the water evaporates when the battery is in service, and the acid does not. Therefore it will be necessary to replace the water—but don't add too little, and don't add too much. Many a case of apparent leak has been blamed to an over-indulgence of water.

Replace evaporation, but do not add enough water to any cell to raise the electrolyte above the indicated level.

Electrolyte Level

Note that for each battery there is a well-defined level, up to, or nearly to, which you should endeavor to keep the surface of your electrolyte, but above which you must never raise the level of the solution when you add water to your battery.

In the U. S. L. type EDC battery, for example, the level is 1 inch above the plate tops. In the type

EL the level is ⅝ of an inch. In many other types of U. S. L. batteries the electrolyte level is ½ inch above the plates.

Not only should the electrolyte level be at the same height in all cells, but **there should be the same amount of acid in the electrolyte in each cell.** Therefore always restore the electrolyte from the syringe, when testing, to the cell from which it was taken.

Before water is added to the cells, take a hydrometer reading of each cell to see whether all cells are equally healthy. No cell can live unto itself—if it goes wrong, it affects the others.

How to add water: Remove the filling plugs by turning to the left, and if the level of the electrolyte is found to be below the bottom of the filling tube, add water by means of the hydrometer syringe (Fig. 2) or a very small pitcher, until the level begins to rise in the tube.

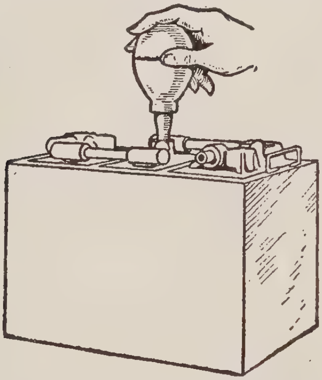

Fig. 2. Adding water to a storage-battery cell.

After adding water, be sure to replace the filling plugs and tighten by turning to the right. **If the filling plugs are not tightened, the electrolyte will flood out of the battery and cause damage.** Also wipe off the top of the battery.

Kind of Water

The water used must be of reasonable purity, as the use of impure water, if persisted in, will injure the plates. **Distilled water,** melted artificial ice, or rain water collected in clean receptacles is recommended.

Water collected in rain barrels from **metal roofs** would contain a trace of the mineral—therefore avoid it.

Nothing but pure water must be put into the cells. If acid of any kind, alcohol, or in fact anything but water, is added to the cells, it will result in very serious injury to the plates and may ruin them.

There being no loss of acid, **it is never necessary, during normal service, to add any acid to a battery.**

If electrolyte has been spilled from the battery by accident, the loss may be replaced with electrolyte. See pages 585, 530.

Finding Level of Electrolyte

A method recommended by the U. S. L. Battery Co., is shown in Fig. 3.

Unscrew the vent from its well, push a glass tube (Fig. 3) with both ends open, straight down, as shown, through the well and against the tops of the plates. Then close the top end of the tube with your thumb and remove the tube with the top end still closed. The height of liquid in the tube equals the height of the electrolyte level above the tops of the plates. Be sure to restore the electrolyte to the cell from which it was taken. If you persistently take electrolyte from one cell and put it into another, you will gradually get your cells unbalanced. Be sure to test the levels in all cells.

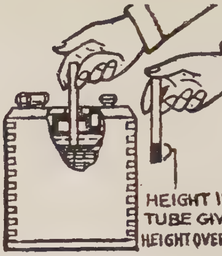

Fig. 3. Testing the level of electrolyte in a cell.

Miscellaneous

Take frequent hydrometer readings, for they show whether the battery is receiving sufficient charge.

Care of battery case: If water or electrolyte is spilled upon the battery or in the compartment, wipe dry with waste. If electrolyte is present in any quantity, use waste moistened with weak ammonia in order to neutralize the acid in the electrolyte. Do not allow electrolyte to collect upon the woodwork, as it will cause deterioration.

Once a week, when adding water, inspect all the battery connections and make sure that they are tight and clean. **A loose or dirty connection** may cause trouble when least expected.

Care of connections: If signs of corrosion of any brass or copper parts should appear, clean the parts thoroughly with weak ammonia and apply vaseline. Don't fail to examine the ground connection of the battery (see page 428) for the result of an open circuit.

Connections throughout the system must be examined periodically and kept tight and clean. Sometimes a connection, even if tight, will give trouble, due to foreign matter such as paint or varnish on the contact surfaces. This must be removed with a file or sandpaper. The connections to the generator and the grounding connections to the frame of the car must not be neglected.

Locating Battery Trouble in Service

1. **Take a hydrometer reading in each filling tube** of each cell (see page 531 on how to use a hydrometer). If all readings are within 50 points of each other and all below 1.200 (1.130)[1], give the battery a bench charge, following the instructions on page 573. Locate the cause of trouble and remove it.

If the readings are all above 1.200 (1.130)[1], or if one cell differs from the others by 50 points or more, make the high-rate discharge test.

If the solution is too strong, it indicates that acid or electrolyte has been added to the cell.

If it is too weak, the cause is sloppage of the battery solution and replacement with water, or else a broken, cracked, or leaky jar, or internal trouble.

2. **Just before replacing the battery in service,** make the high-amperage discharge test, **to be sure** the battery is in good condition.

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[1] Applies to tropical climates.

3. **Hydrometer readings less than 1.225** (1.155),[1] but more than 1.150 (1.080)[1], indicate a battery less than half charged. If the car is equipped with an electric starting motor, use lamps and starter sparingly until readings become more than 1.250 (1.180)[1].

Readings less than 1.150 (1.080)[1] indicate complete discharge. In such a case the battery should be removed and given a bench charge.

If readings in one cell differ from the others by 50 points or more, it indicates loss of electrolyte, wrongful addition of electrolyte, or internal trouble in the battery.

If the car is laid up, put the battery into proper storage.

4. **Go over all connections.** A loose or dirty connection is often the cause of trouble. If the connections between battery and cable terminals are not kept well coated with vaseline, they may corrode, causing a poor connection, or else opening the circuit altogether. If the connector is causing the trouble, remove it and clean the parts thoroughly with weak ammonia. Then remove all dirt, apply vaseline, tighten the connections perfectly, and give the whole connection a heavy coating of vaseline.

5. **There may be a leak or ground in the wiring.** Test for this by turning on all lamp switches and then removing the bulbs from the sockets. Disconnect one of the cables at the battery, and in its place tightly hold a file against the battery post, making sure there is good electrical contact between the file and post. Then rub the cable terminal along the file; if sparks are noticed, there is a ground in the wiring, which must be looked for and removed.

6. **If the engine will not crank,** turn on the lights and attempt to start in the usual manner. If lights become dim, the battery is in poor condition and should be given a bench charge and the cause of trouble should be investigated and removed. If lights continue to burn brightly, the trouble is elsewhere than in the battery.

7. **If the generator of the starting system is not in proper adjustment,** the battery will not be kept supplied with the proper amount of current. If the supply is insufficient, the battery will become discharged; if it is too much, the battery solution will become hot (110° F.). The generator should be readjusted to deliver more or less current, as the case may require. On all cars, the generator is originally adjusted to supply an amount of current which experience has shown to be the most satisfactory for average running conditions. If the car is run only at nights, more current is naturally required because the lights use a large part of the current which would otherwise go to the battery. If long daylight runs are the rule, the opposite is true, because then almost all the current goes into the battery.

When a Battery Needs Recharging

On systems where a storage battery is kept charged by a generator run from the engine, the system is supposed to be automatic, but for various reasons the generator may not keep the battery charged, or the battery itself may be defective and so will not hold a charge for any length of time. The indications would be a **weak starting motor, or dim lights.** The battery, however, in this case ought not to be allowed to become weak.

There are several causes for a battery becoming discharged: in fact, so many that it is advisable to refer to the "Digest of Battery Troubles" (page 556).

The usual and common causes are failure of the battery to receive sufficient current from the generator, or permitting the level of the electrolyte to fall below the level of the plates (see "1. Examine battery," page 478).

When the battery is used in connection with a charging generator system, the system is so designed and adjusted that the amount of charging current received by the battery from the charging generator (dynamo) should about compensate for the discharge current used when starting the engine, or when lighting the lamps from the battery. At medium or high speeds, the current for lamps does not come from the battery, but from the dynamo.

It sometimes happens, owing to conditions, such as excessive use of lamps, especially when the car is driven at low speed, or when the car is driven mostly at night, with all the lights on, that the current is taken up by the lights and the **battery receives but a small portion of the current from the generator,** or that when the weather is cold, the starting motor is used more than usual.

In cases of this kind, the **output of the generator should be increased,** if not already up to its capacity, and the least amount of current possible should be used.

It is advisable to see that a **primer is used in order that the engine may start easily.** Be sure that the battery is kept charged, even though it be necessary to have it charged at an outside source occasionally, as a full voltage of the battery is also required for good ignition, which is also necessary in starting an engine. By this means, too, **current is saved.**

To tell when a battery needs recharging, there are two methods: (1) Test the battery with a voltmeter when it is discharging, as when all lights are on. Test each individual cell, and if any is as low as 1.8 volts during discharge, the battery needs recharging. (2) Test with a hydrometer, as directed on page 531. This latter test is the one used most.

See page 545 under **"The first step is to test the entire lot of cells."** See also, "Digest of Storage-battery Troubles," page 556, and also page 478.

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[1] Applies to tropical climates.

INSTRUCTION No. 50

STORAGE-BATTERY CHARGING EQUIPMENT

STORAGE-BATTERY CHARGING EQUIPMENT

Kind of current: For charging a battery only **direct current** can be used.

Connections: Connect the positive (+) wire of the charging circuit with the positive (+) terminal of the battery and the negative (−) terminal of the battery with the negative (−) wire of the charging circuit.

Storage batteries are usually connected in series when being charged. This subject will be dealt with farther on.

Finding polarity: To determine which is the positive and which is the negative terminal of a charging circuit, the best plan is to use a voltmeter and place it across the line. If the meter needle moves to the right, the wire connected to the (+) terminal of the voltmeter, which is usually marked, will indicate the (+) or positive wire. The same test can be made on storage-battery terminals. If the charging circuit is 110 volts, the voltmeter should have a corresponding capacity. If a voltmeter is not at hand, there are several simple methods which can be resorted to, as shown in the illustrations below.

Storage-battery terminals are usually marked "+" and "−" or "Pos." and "Neg." The storage battery positive (+) terminals can also usually be determined by their dark color whereas the negative (−) is of a light color.

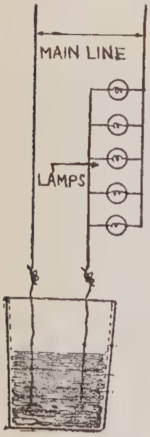

Fig. 1

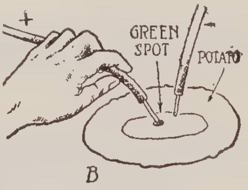

Fig. 2

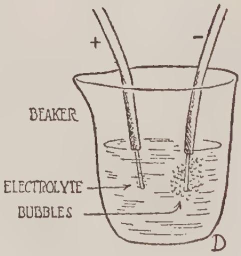

Fig. 1A

Fig. 1. To find the **polarity of charging wires,** or of any direct current source, dip the ends of the wires into a glass of water in which a teaspoonful of salt has been dissolved, care being taken to keep the wires at least one inch apart. When current is on, fine gas bubbles will be given off from the **negative** wire.

Another method is to use a beaker (see **(D)** (Fig. **1A)**, in which a small amount of electrolyte is added to water. The negative pole will have the most gas bubbles around it.

Fig. 2. A potato can be used as shown in the illustration.

The charging wires from a rectifier, if connected wrongly (use a regular dash-type ammeter), will show 30 amperes. If connected correctly, they will show about 6 amperes.

Charging Methods

As already stated, only direct current can be used to charge storage batteries. There are **several methods** of doing this, which are classified as follows:

1. From a 110, a 220, or a 500-volt **direct current** power and lighting line.
2. From an **alternating** current power and lighting line, by the use of a **motor-generator.**
3. From an **alternating** current power and lighting line, by means of a **rectifier.**

Charging Resistance

Charging resistance is a suitable apparatus inserted in series with the charging circuit. By varying the resistance, the current can be regulated.

Resistance may consist of **lamps** or of **resistance** wire.

An Explanation of Resistance

Resistance can be in the form of a bank of lamps (Fig. 6), of resistance wire (Figs. 3 and 4), of water (Fig. 5), of carbon and other resistance metals. Lamps or resistance wire is generally used, the latter being termed a "rheostat."

Principle of a Rheostat

By way of illustration, we will use a wire resistance unit (Fig. 3). German silver, nichrome, iron wire (some others also), offer resistance to the flow of electric current. The **smaller the wire,** for the same amount of current, the **greater the resistance.**

If, for example, a coil of iron wire of 1/32″ diameter and of sufficient length is wrapped around an insulated cylinder, such as porcelain or stone and connected to a 110-volt circuit, by connecting one wire, say, from the (+) side of the 110-volt circuit to **(X,** Fig. 3), the current would then flow down the rod **(T)** to the sliding contact **(C).**

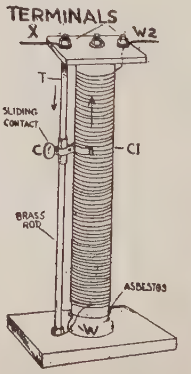

Fig. 3. Principle of a rheostat or resistance unit

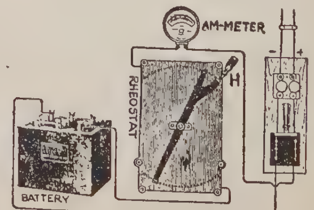

Fig. 4. A rheostat of standard construction

If one terminal of the battery is then connected with (W2), which is one end of the wire coil (C1), and the other battery terminal is connected with the other, or (—) side of the 110-volt circuit, this would form a circuit, and the amount of resistance wire in the circuit would depend upon the position of the sliding contact (C).

By moving the sliding contact (C) down, **more** resistance is thrown into the circuit; by moving it up, **less** resistance will be in the circuit. This is the principle of a rheostat, and is similar to that of "resistance units," as used for charging batteries, which will be discussed farther on. In some instances an ordinary stove pipe, covered with asbestos and wrapped with iron wire has been used.

A rheostat of a more modern construction is shown in Fig. 4. The principle is similar to that shown in Fig. 3, except that the construction is different. It consists of wire resistance mounted on the back of a slate base. The resistance can be iron wire, German silver, nichrome, or any other kind of resistance wire.

The amount of resistance which can be cut into or out of the circuit is regulated by movement of the handle (H), and it serves the same purpose as the sliding contact (C) in Fig. 3.

A rheostat might be termed a device for absorbing some of the electrical pressure.

For example, suppose you desired to charge a 6-volt storage battery from a 110-volt circuit. It would be necessary to absorb approximately 104 volts in some sort of resistance or rheostat.

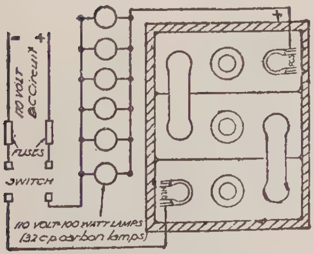

Fig. 6. A lamp bank resistance

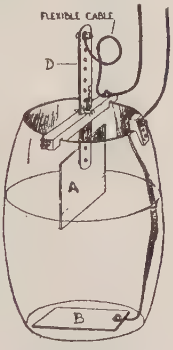

Fig. 5. A water rheostat

Principle of a Water Rheostat

A simplified illustration (Fig. 5) gives the principle of a water rheostat. A 5-gal. stone jar is partially filled with salt water (or acidulated water), with one metal contact (B) in the bottom, and the other (A), which is a sheet, immersed more or less in the barrel. The movement of (D) regulates the resistance, i.e., the nearer the plates are together the **less** the resistance; the farther apart they are the **greater** the resistance.

The construction and action of an acidulated water rheostat is as follows: Let us suppose that current is to be taken from a 500-volt direct current, to pass 3 to 9 amperes; use a 5-gallon stone jar and mix 1 part sulphuric acid with 3 gallons of water. Use two plates of lead or soft metal as electrodes, the main requisite being that they have sufficient area to keep the heating effect down as low as possible. Current applied at one terminal leaves the plate and passes through the water to the other plate. One of these is made stationary and the other movable, and the resistance is regulated by changing their relative distance apart. The farther they are apart, the greater the resistance. During the action of the rheostat, the water is decomposed into its natural elements, oxygen and hydrogen, and the loss must be made up occasionally by the addition of more water.

The prime object of a rheostat is to cut down the voltage.

Charging a Battery from a 110-Volt Direct-Current Circuit Using Lamp Resistance

The amount of resistance to use depends upon conditions as will be explained.

If only one battery is to be charged from a direct-current circuit, the most convenient resistance is a combination of lamps of proper size and rating. An arrangement for charging from a 110-volt circuit is shown in Fig. 7.

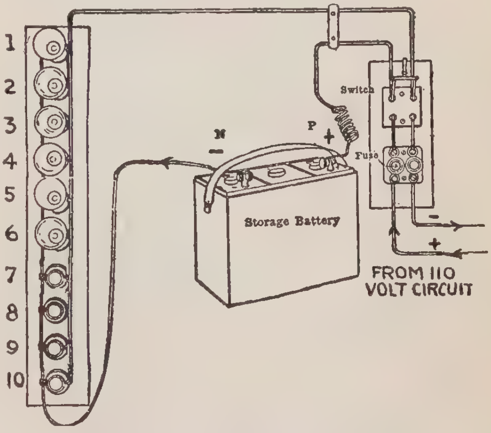

Fig. 7. Diagram of connections for charging one 6-volt battery from a 110-volt direct-current line. Note that the bank of lamps is arranged so that any number of lamps from 1 to 10 can be screwed into or taken out of the sockets. 110-volt, 100-watt, 32-c.p. lamps which draw 1 ampere each are used above. Remove the filler plugs to permit frequent hydrometer readings during charging and also for gases to escape.

The lamps used are carbon filament lamps rated at 110 volts and of 32 candle power. As shown, they are arranged parallel with each other and the combination is in **series** with the battery.

The amount of current or amperes passing to the battery will be determined by the number of lamps used, the watt capacity of the lamps, and the method of connection.

A 32 c. p. 110-volt, carbon filament lamp will pass approximately 1 ampere and is a 100-watt lamp. Watts are found by multiplying the voltage of the circuit (100 volts used instead of 110, which is near enough in this instance) by the ampere capacity, as 100 volts × 1 amp. = 100 watts.

A 16 c. p. 110-volt carbon filament lamp will pass ½ ampere and is a 50-watt lamp.

With the arrangement shown in Fig. 7, **each lamp will allow 1 ampere** of charging current to pass through the battery, so that the number of lamps will depend upon the charge rate of the battery.

Fig. 7 shows six lamps screwed into sockets, which will, therefore, allow **6 amperes** to flow (suitable for a Type XC-13 Exide battery, as shown in the "bench charge" table, page 573).

If 32 c.p. lamps are not available, then use 16 c.p. carbon filament lamps. When using the 16 c.p. lamps it will be necessary to **double** the number, because a 16 c.p. lamp, being a 50-watt lamp, draws but a ½ ampere at 110 volts.

If tungsten or other high-efficiency lamps are used, more will be required than if carbon filament lamps are used, because they draw less current.

Charging a Battery from a 220-Volt Direct-Current Circuit

If a battery is to be charged from a 220-volt circuit, it will be necessary to place two 32 c.p., 110-volt lamps in series, as shown in Fig. 8, because, as the voltage increases, the amperage decreases. Therefore if two 32 c.p., 110-volt lamps are placed in series, the two lamps would draw 1 ampere.

If there are four of these series groups connected in parallel, as shown in Fig. 8, then there would be 4 amperes passing to the battery; if five groups, 5 amperes; if six groups, 6 amperes, and so on.

If two 16 c.p., 110-volt lamps are placed in series, instead of two 32 c.p. lamps, then the two in series on a 220-volt circuit would draw a ½ ampere. Therefore, in order to draw 4 amperes to the battery, it would require eight groups connected in parallel.

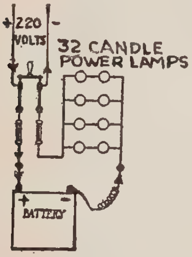

Fig. 8.

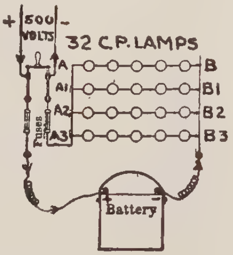

Fig. 9.

Charging a Battery from a 500-Volt Direct-Current Circuit

To charge a battery from a 500-volt direct-current circuit, use 32 c.p., 100-volt lamps. In order not to burn out the lamps, place five in series, as (A) to (B) (Fig. 9).

The five lamps, however, owing to the series connections, will allow but one ampere to pass. In order to pass **two amperes,** another group of five are placed in a parallel or multiple connection as at (A1) to (B1). For **three amperes,** another row from (A2) to (B2) would be necessary; for four amperes, another row (A3) to (B3). If **five amperes** were desired, **five more lamps,** connected as in Fig. 9, would have to be used.

Lighting a Garage with the Charging Current

A current economy in charging storage batteries can be effected by utilizing the current that is ordinarily consumed by the lamp resistance shown in Figs. 7, 8, and 9, while lighting the garage at the same time. The banks of lamps can be placed separate from where the charging is being done, if the correct size of wire is used.

Use of the Ammeter and Voltmeter when Charging

The ammeter can be connected in series with the charging circuit and will indicate the amperes flowing to the battery.

The voltmeter must not be placed in series. It is generally used to test the voltage of the battery during charge or discharge, by placing its terminals across the battery terminals from time to time during the charge or discharge.

A hydrometer is used repeatedly during the time a battery is on charge, as it is important to observe the specific gravity during the charge. Directions for using the voltmeter and hydrometer during the charging of a battery are given farther on.

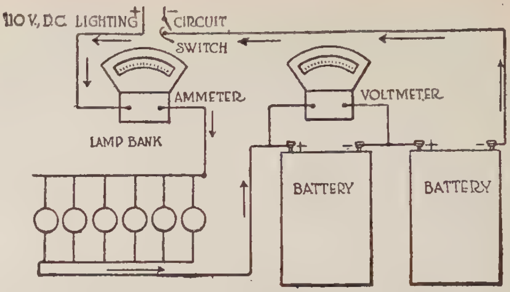

Fig. 10. Method of connecting voltmeter and ammeter when charging.

A 2 to 30-Ampere Lamp-Charging Outfit

If the number of batteries to be charged varies from time to time, the lamp bank shown in Fig. 11 is very convenient when charging from a 110-volt direct-current source.

Thirty ordinary lamp sockets are mounted to a board (Fig. 11) and wired up to snap switches in groups containing two, four, eight, or sixteen lamps. A suitable main switch, fuse cut-out, ammeter, and terminal block complete the connections.

With this equipment, from one to twelve 6-volt batteries can be charged in series at one time. Different combinations of switches on and off permit regulation of the current through the batteries.

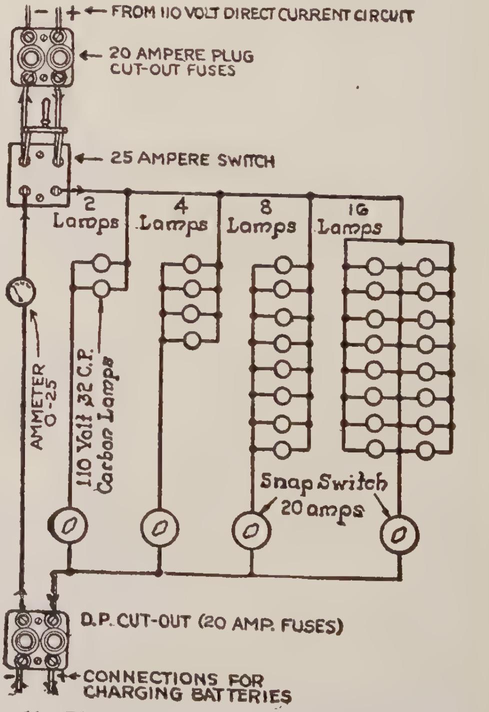
- + ← FROM 110 VOLT DIRECT CURRENT CIRCUIT
← 20 AMPERE PLUG CUT-OUT FUSES
← 25 AMPERE SWITCH
2 Lamps
4 Lamps
8 Lamps
16 Lamps
AMMETER 0-25
110 Volt 32 C.P. Carbon Lamps
Snap Switch 20 amps
D.P. CUT-OUT (20 AMP. FUSES)
← CONNECTIONS FOR CHARGING BATTERIES

Fig. 11. Diagram of connections for charging one to twelve 6-volt batteries from a 110-volt direct-current source, using lamps.

Construction and connections of Fig. 11: A base of hard wood and No. 12 wire is used. Various charging rates can be had by switching on banks of lamps instead of unscrewing lamps. Note that banks of 2, 4, 8, or 16 32 c.p. lamps can be used singly, or **all together,** which would make **30 amperes** total. Each 32 c.p. 110-volt lamp gives 1 ampere.

To obtain 20 amperes, switch on the 4 and 16 bank: for **10 amperes,** switch on the 8 and 2 bank; for **5 amperes,** put 2, 16 c.p. ½-ampere lamps in 2 bank, which would give 1 amp., and use this with the 4 bank.

The ammeter indicates the quantity of current in amperes passing to the battery. It can be connected in series, as shown in Figs. 11 and 10. An ordinary dash-type ammeter can be used if the rate of charge is not over the capacity of the meter. If in connecting the meter the hand points in a wrong direction, reverse the connections to the meter.

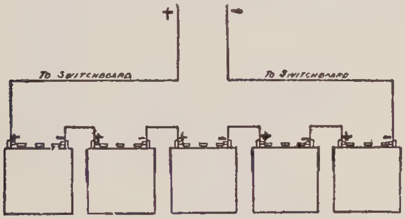

Fig. 12. Method of connecting batteries in series to be charged. If there is a 12-volt battery in series with the 6-volt batteries, consider it as two 6-volt batteries. If an 18-volt battery is in series, consider it as three 6-volt batteries.

Table Giving the Amperage or Rate of Charge Used When Charging from 1 to 11 Batteries

Place the batteries in "series," as in Fig. 12. Then use the number of lamps as indicated in the table below. We are assuming that the charging circuit is a 110-volt direct-current circuit.

Number of Batteries	No. of 32 c. p. 110 v. Lamps at "start" and amp's.	No. Lamps for "finish" rate
1	10L—10a	3L
2	10L— 9½a	3L
3	11L— $9\frac{4}{10}$a	3L
4	12L— $9\frac{6}{10}$a	4L
5	13L— 9¾a	4L
6	15L—$10\frac{2}{10}$a	4L
7	17L—$10\frac{4}{10}$a	5L
8	19L—10⅜a	6L
9	21L— $9\frac{9}{10}$a	6L
10	25L—10a	8L
11	30L— $9\frac{9}{10}$a	9L

L designates lamps in circuit and **a**, amperes passing to battery.

It will be observed that, **to charge more than one battery, more lamps are used** in order to obtain the same amperage rate of charge, or nearly the same. This is due to the fact that as each battery is connected in series with another, the battery voltage is increased .

When charging several batteries, the practice is to charge at 6 amperes during the day and 3 amperes at night. This permits watching during the day and avoids overheating at night.

The table given above is figured for a discharged 90 to 100 ampere-hour 6-volt starting and lighting battery.

If smaller batteries are on the line, or if some are **partially discharged,** charge at the 24-hour rate until smaller ones or partially discharged ones are charged, then remove them.

Resistance Units Instead of Lamps for Charging Batteries

Instead of lamps, "resistance units" of approximately 35 ohms resistance and 3.3 amperes capacity each may be used. or as shown in Fig. 13. This equipment will occupy less space than the lamps and serve the same purpose, each resistance unit replacing two lamps.

Instead of either a lamp resistance or unit resistance panel, a special form of **rheostat** may be used. The size and type depend upon the conditions.

When ordering a rheostat, it will be necessary to give the following information:

1. The voltage of the charging mains.
2. The number of cells to be charged in series.
3. The lowest and highest current rate desired.

Resistance of some sort must be used when charging batteries, except where the voltage of the charging mains is exactly the voltage required to charge the battery or batteries. Within certain limits, a motor generator set can be regulated to deliver the voltage required. Where much charging is done, a motor generator set is more economical in operation than a charging resistance.

When resistance, or a rheostat, is used instead of lamps, the resistance should be such as to produce, when carrying the proper charging current, a voltage drop equal to the difference between the voltage or pressure of the charging circuit and that of the battery being charged.

Example of a Charging Battery Using Resistance Units, and Method of Construction

The **parts necessary** to construct this 5-battery charging outfit are:

1 Double-pole single-throw switch.
2 10-amp. plug cut-outs (fuses).
1 Ammeter, reading 0 to 30 amperes.
40 ft. of No. 16 rubber-covered flexible wire.
1 Resistance unit with two taps.
1 Resistance unit with nine taps.

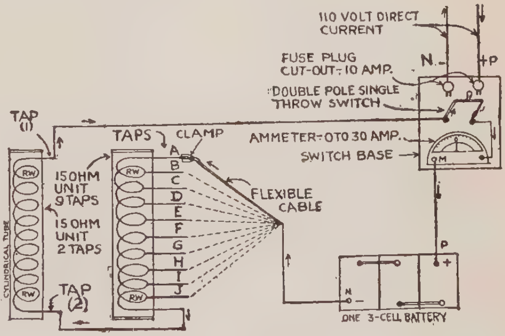

Fig. 13. Resistance charging circuit.

Construction: The resistance units can be obtained of the General Electric Co., of Schenectady, N.Y., or Ward-Leonard Co., Bronxville, N.Y. They are merely coils of wire (spiral resistance wire) wound on cylindrical tubes over asbestos and baked on the cylinder. The tubes are encased in porcelain and measure approximately 22″ long and 2″ diameter.

Taps: There are two taps from each single resistance unit in the left-hand coil of Fig. 13. The coil in the center of Fig. 13 has 11 taps or connections. Each resistance unit in this illustration has 15 ohms capacity, and is known as the 15E form P (General Electric Co. designation).

These resistance units are inexpensive, costing in the neighborhood of about two dollars each.

Charging: Batteries are referred to generally, as 3-cell, 6-volt batteries. If a battery has 6 cells, it is treated as two 3-cell batteries; if it has 9 cells, it is treated the same as three 3-cell batteries, etc.

To figure the amount of resistance necessary to charge 1 to 5 batteries, that is, 3-cell batteries, on a 110-volt direct-current line, note the following:

Resistance is always referred to as so many "ohms." If one 3-cell battery is to be charged at a 3-amperage rate, figure the resistance necessary to put it in series with the battery as follows: **N×SV =TV,** in which **N** stands for number of cells, **SV** stands for single voltage, or the voltage of one cell, and **TV** stands for total voltage. Substituting figures for the symbols (letters), we have: 3 cells (N) ×2.1 volts (SV)=6.3 volts (TV); i.e., the total voltage required for a 3-cell, 6-volt battery at the beginning of a charge is 6.3 volts, and **the resistance to use for a 3-ampere charge is:**

$$\frac{110\text{v}-6.3\text{v}}{3\text{ amp.}}=34.6\text{ ohms}=\text{resistance required.}$$

Arrived at as follows: 110—6.3=103.7÷3=34.6.

If two 3-cell batteries are to be charged at a 3-ampere charge, multiply the 6.3v in the foregoing example by two—for instance:

$$\frac{110\text{v}-12.6\text{v}}{3\text{ amp.}}=32.5\text{ ohms}=\text{resistance required.}$$

If three 3-cell batteries are to be charged at a 3-ampere charge, multiply the 6.3v in the first example by 3; if four 3-cell batteries are to be charged multiply by 4, etc.

If battery is to be charged at 5 amperes, divide by 5, instead of by 3. For instance:

$$\frac{110\text{v}-6.3\text{v}}{5\text{ amp.}}=20.7\text{ ohms}=\text{resistance required.}$$

To charge two 3-cell batteries at 5 amperes:

$$\frac{110\text{v}-12.6\text{v}}{5\text{ amp.}}=19.5\text{ ohms resistance required, etc.}$$

To increase the amperage of a charge, to say, 10 amperes per hour, divide by 10 instead of by 3 or 5 amperes, and cut out enough units to give the required resistance necessary.

To operate on a higher voltage than 110 volts, as explained in the example above, say, 220 or 500 volts, in order to find resistance necessary, use 220 or 500 instead of 110 volts, as used in the examples.

How to charge: The two resistance units (Fig. 13) at the left and center of the diagram, give 15 ohms each, or a total of 35 ohms (actual addition shows 30 ohms, but will give 35). One of the units (that in the center of Fig. 13) has 11 taps, so that the entire 11 resistance coils (RW) can be thrown into the circuit, or only part of them, as shown in the diagram. The resistance unit (at the left of Fig. 13) is connected at all times, and is 15 ohms. The other 15 ohms in the center can be subdivided:

By merely connecting the wire from the battery (—negative) to (A), all resistance (30 ohms—will give 35) is in the circuit. When connected with (J) only the resistance in the unit at the left of Fig. 13 is in circuit. The table (Fig. 14) will explain how and why the resistance units are added or cut out.

By following the arrow points on the diagram, from the + P wire, over the switch from the main wire, the circuit can easily be traced. The dotted lines represent the connections at different taps on the center unit of Fig. 13.

Number to Charge of Batteries 3-cells	To Charge Batteries at 3 Amps.		To Charge Batteries at 5 Amps.	
	Ohms of Resistance Necessary	Tap to Which to Connect Battery—	Ohms of Resistance Necessary	Tap to Which Connect Battery
1	34.6	A	20.7	F
2	32.5	B	19.5	G
3	30.3	C	18.2	H
4	28.3	D	16.9	I
5	26.2	E	15.7	J

Fig. 14. Table showing ohms resistance required for battery charging, using resistance as in Fig. 13.

When connection is at (A), this gives the least current, as the entire 30 ohms is in circuit. When at (F), 22½ ohms resistance is in the circuit.[1]

The ampere current flowing may be read on the ammeter. The actual current will depend upon the number of batteries in series, as in diagram (Fig. 15). If the current obtained at (A) is not sufficient, then cut out resistance by connecting with (B) or (C), and so on, each giving a greater current than the one preceding, the maximum being at (J).

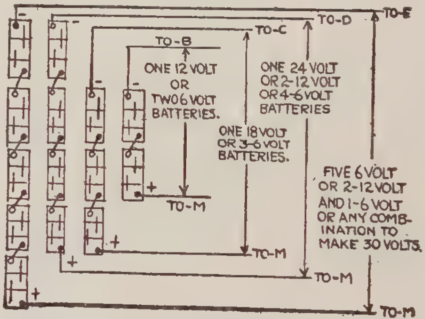
TO-E
TO-D
TO-C
TO-B
ONE 12 VOLT OR TWO 6 VOLT BATTERIES.
ONE 24 VOLT OR 2-12 VOLT OR 4-6 VOLT BATTERIES
ONE 18 VOLT OR 3-6 VOLT BATTERIES.
FIVE 6 VOLT OR 2-12 VOLT AND 1-6 VOLT OR ANY COMBINATION TO MAKE 30 VOLTS.
TO-M
TO-M
TO-M
TO-M
-
+

Fig. 15. Method of connecting more than one battery to charge. Note that batteries are connected in series—the positive pole of one battery to the negative pole of another, etc. Letters (B), (C), (D), and (E) refer to taps. (M) refers to the connection on the ammeter. Thus "B to M" would include all resistance, except coils (A).

As the batteries become charged, the rate will become less, but may be increased again to 3 amperes, by proceeding with the next operation of cutting out resistance. Charge until the specific gravity has reached a maximum and remained there for five hours. This is the standard, indicating completion of charge. The cells should gas at the same time. If they do not, the maximum gravity has not been reached.

The important point to watch in charging is, not to let the temperature of the cell get above 110° F. If it does, the charge must be temporarily stopped, until the cell cools down, and then be continued at a lower rate. But be sure to charge until the specific gravity has remained at a maximum for five hours. In case one battery becomes charged first, it should be taken out of circuit and the remaining batteries charged at 5 or 6 amperes until charge is completed.

Charging Batteries from an Alternating-Current Circuit Using a Rectifier

Alternating current flows alternately in opposite directions, and is used to a great extent for house lighting. Only **direct current,** which is constant, or a continuous current, is suitable for charging storage batteries.

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[1] If each unit (Fig. 13) is 15 ohms, the two would represent 30 ohms, and when the tap is made at (F) this would cut out one-half of the resistance of the center unit of Fig. 13, leaving 22½ ohms in the circuit. Although the table (Fig. 14) calls for 20.7 ohms at (F), this would be near enough for practical purposes.

Alternating current can be rectified so that it will flow in one and the same direction. It can then be used for charging storage batteries. A device for such a purpose is called a **rectifier.**

There are several types of rectifiers, as follows:

1. Chemical rectifier.
2. Mercury arc rectifier.
3. Synchronous commutator type.
4. Tungar rectifier.
5. Vibrator type.

Chemical Rectifier

A chemical rectifier is not very efficient and is seldom used. There is a tendency for liquid in jars to get hot and boil if too high a current is passed through it, otherwise water is not necessary (see Fig. 16).

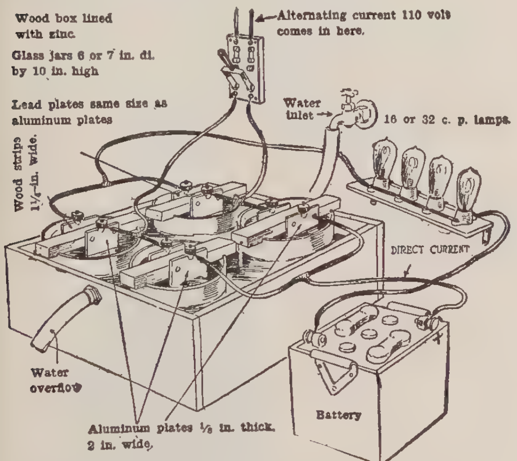
Wood box lined with zinc
Glass jars 6 or 7 in. di. by 10 in. high
Lead plates same size as aluminum plates
Wood strips 1½-in. wide.
Alternating current 110 volt comes in here.
Water inlet
16 or 32 c. p. lamps.
DIRECT CURRENT
Water overflow
Battery
Aluminum plates ⅛ in. thick, 2 in. wide.

Fig. 16. A home-made chemical rectifier.

The amount of charging current is regulated by using 16 or 32 c.p. lamps. One-half of 1 ampere will pass through a 16 c.p. lamp and 1 amp. through a 32 c.p. lamp. Therefore the more lamps, the more amperes flowing. About 2 amperes or four 16 c.p. lamps is best with this outfit, which of course would require a long time to charge a 100-ampere-hour battery if the latter is entirely exhausted.

The solution consists of a concentrated solution of common baking soda in pure water. (*Motor Age.*)

Synchronous Type Rectifier

The synchronous commutator type of rectifier is merely an alternating-current motor with which a commutator is used to change the alternating current to direct current.

Vibrator Type Rectifier

The vibrator type of rectifier is divided into two classes: one, whereby the storage battery being charged determines the polarity of the charge, and the other, whereby a permanent magnet determines the polarity of the charge.

With this last-mentioned type and previously mentioned rectifiers, it is **important that positive and negative poles of the battery be connected** to the positive and negative poles of the rectifier.

On one other type of vibrator rectifier, which is similar to that shown in Fig. 17, but minus the permanent magnet, there is **another winding on the electromagnet,** which is "shunted" across the battery terminals and which takes the place of the permanent magnet.

With this type it does not matter which of the terminals connects with the battery, as the voltage from the battery will set up its polarity in the electromagnet. The disadvantage, however, is that if the battery is almost totally discharged there will not be sufficient voltage to excite the electromagnet which should determine the polarity of the charge.

Vibrator Type of Rectifier with a Permanent Magnet

The vibrator type of rectifier transforms the alternating current from 110 volts to 10 or 12 volts. The current then passes through an electromagnet, the amount of current to operate the vibrator being regulated by resistance (RE) (Fig. 17).

The purpose of the electromagnet, vibrator, and permanent magnet is as follows: If the alternating current flowing through the electromagnet is 120-cycle waves per second, the core (N) of the electromagnet would change its polarity with each cycle wave.

If, however, some means were employed to **cut out 60 of the cycle waves,** and utilize only **one-half of the waves,** or only every other cycle wave which **flows in one direction,** and which would be a direct flow of current, then the vibrator would close the circuit to the battery at (VS), and charge the battery.

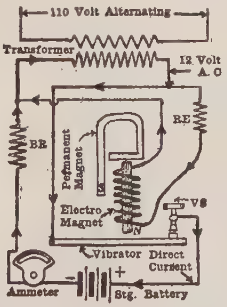

Fig. 17

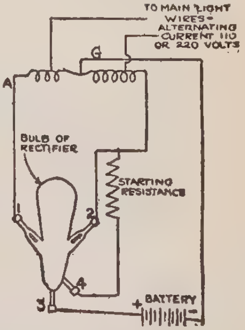

Fig. 18

Fig. 17. Vibrator type of rectifier.

Fig. 18. Mercury arc rectifier for 60, 50, 40, 30, or 25 cycles, 110 volts.

This is made possible by placing a "permanent magnet" at the end of the electromagnet, as shown in Fig. 17, which keeps the electromagnet core definitely (N) and (S). During the time the 60-cycle waves per second are flowing one way, or in harmony with the permanent-magnet polarity, the vibrator "cuts in" the battery, and during the time the 60-cycle waves flow in the other direction, the vibrator is not attracted by the core (N), because current is flowing in an opposite direction to the polarized magnet core, and magnetism is not set up.

A spring, not shown, is attached to the vibrator which is adjusted to hold the vibrator away from the core (N) until current flowing in harmony with the permanent magnet polarity, both combined, draws the vibrator to the core. The resistance **(BR)** is used to limit the amount of charging current to the battery, say 6 amperes.

Positive and negative wires must be connected correctly, but on another type of vibrator rectifier, as explained above, this is not necessary.

This kind of rectifier (Fig. 17) and most other rectifiers of this type are only suitable for charging one 6-volt battery at a 6-ampere rate, or a 12-volt battery at a 3-ampere rate.

The Mercury Arc Rectifier

The mercury arc rectifier (Fig. 18) is used considerably for charging electric vehicle batteries. A maximum of 30 amperes is the average. A large glass tube contains mercury in its base. Graphite terminals (1) and (2) are the "anodes." Terminal (3) is the "cathode" for negative wire, there being only one. (G) is the transformer. A small electrode (4), connected to one side of the alternating current, is used for starting the arc across the mercury.

Tilting the tube causes a mercury bridge between the terminals and produces an arc when the tube is turned in a vertical position.

When the current alternates, first one, and then the other "anode" (1) and (2) becomes positive, and a continuous flow is towards the mercury "cathode" (3), thence to the battery, back to the opposite side of supply.

The Tungar Rectifier

The Tungar rectifier (Fig. 19) consists of a hot argon low-pressure gas-filled bulb (**B**) (Figs. 19, 20), with a "cathode" (**F**) (tungsten filament) and an "anode" (**A**), a transformer (**T**) for exciting the filament, a rheostat (**R**), and the load which is shown as a storage battery. The connections in Fig. 19 show the half-wave rectifier in its simplest form.

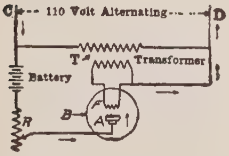

Fig. 19

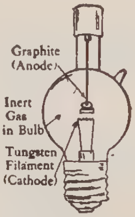

Fig. 20

Principle: Assuming an instant when the side (**C**) of the alternating-current supply is positive, the current follows the direction of the arrows through the load, rheostat, bulb, and back to the opposite side of the alternating-current line. A certain amount of alternating current, goes through the transformer (**T**) to excite the filament, the amount depending on the capacity of the bulb.

When the alternating-current supply reverses, and the side (**D**) becomes positive, the current is prevented from flowing. In other words, the current is permitted to flow from the "anode" (**A**) to the "cathode" (**F**), or against the flow of emitted electrons from the cathode, but it cannot flow from the cathode to the anode with the flow of electrons. This type of rectifier is extensively used.

The General Electric Co., Schenectady, N.Y., supplies a Tungar rectifier for public garage use. It has a charging capacity of 6 amperes and will charge any combination of 3, 4, 5, 6, up to 30 cells at 6 or 7 amperes or less from alternating current. Smaller outfits are made for private garage use. Booklets numbered as follows will be sent to readers of this book who are interested: Large outfit, booklet B-3487; for private garage use, booklet B-3532. Address General Electric Co., Schenectady, N.Y.

The Motor-Generator Set, for Charging Batteries

Only direct current can be used to charge storage batteries, but in most towns and cities only alternating current is available.

There are three methods of charging batteries where only alternating current is available:

1. **By the use of a rectifier,** as explained.
2. **By the use of an electric motor operating on alternating current and driving a dynamo or** generator which will generate "direct" current, from which current the battery is charged. This motor and generator is then "direct connected" on one base, and called a "motor-generator set."
3. Instead of an electric motor being used to drive the generator, this **direct-current generator can be driven by belt power** from a line shaft, or gasoline engine, or other power.

Where a limited amount of battery charging is to be done, the rectifier (Fig. 17) is recommended.

Where many batteries are to be charged, motor-generator sets, shown below, are recommended

Description of a Motor-Generator Set

As an example we will use a type 6-G Valley Electric Co.'s motor-generator (Fig. 21).

Names of parts: (**M**), motor, operates from alternating current and drives a direct-current generator (G); (T), terminals; (S), motor switch; (**R**), rheostat to regulate charging current to battery; (**A**), amperemeter; (**B**), generator switch; (**C**), automatic cut-out.

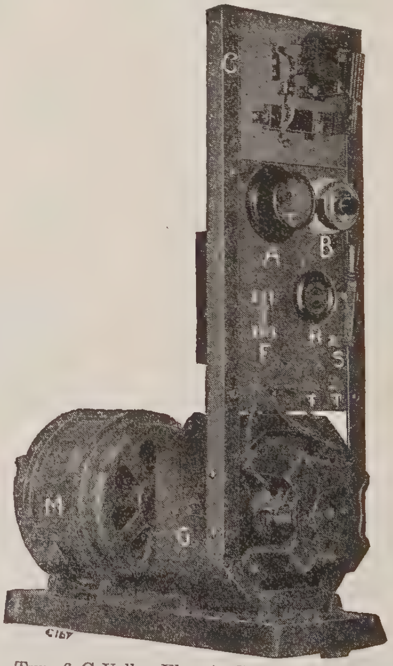

Fig. 21. Type 6-G Valley Electric Co.'s motor-generator set.

This set will charge **1 to 10 batteries in series at 8 amperes; generator, 75 volts, 8 amperes, 600** watts. This same type 6-G set will charge 20 batteries at 4 amperes, if two auxiliary rheostats are used as shown in Fig. 23.

Auxiliary Rheostat

The purpose of this device will be understood better after reading the explanation of its use that follows.

Construction: Resistance coils wound on asbestos board are placed about ¾″ apart lengthwise on the back of a slate slab. This resistance can be cut in and out of the circuit by a handle (**H**) (Fig. 23).

The ammeter (A) on the rheostat indicates the charging rate on that particular rheostat line, whereas the ammeter on the switchboard indicates the total amperes to all lines, or to 1 or 5 batteries if charged without this auxiliary rheostat. The maximum carrying capacity of the auxiliary rheostat is 10 amperes.

Refer now to Fig. 22. Note that there are ten 6-volt batteries connected in series with the type 6-G motor-generator set, **without** the use of the auxiliary rheostat. The charging rate is 8 amperes and this is the capacity of the 6-G motor-generator.

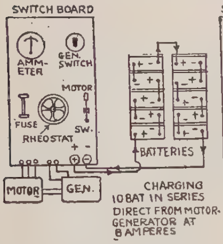

Fig. 22

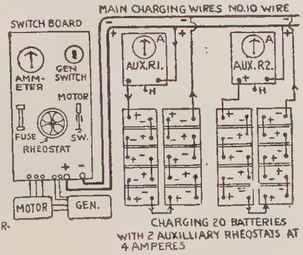
MAIN CHARGING WIRES NO.10 WIRE
SWITCH BOARD
AMM-ETER
GEN SWITCH
MOTOR
FUSE
SW.
RHEOSTAT
+ -
A
AUX.R1.
A
AUX.R2.
H
H
MOTOR
GEN.
CHARGING 20 BATTERIES WITH 2 AUXILLIARY RHEOSTATS AT 4 AMPERES

Fig. 23

Now refer to Fig. 23. Note that there are two sets of ten batteries connected with two auxiliary rheostats (AUX. R1 and AUX. R2). Each set with its auxiliary rheostat, instead of being in series with the main charging line from the generator, is connected **parallel** to the line.

Therefore, instead of each set of ten batteries (Fig. 23) drawing 8 amperes, as in Fig. 22, they only draw 4 amperes, or, in other words, **the rate of charge is reduced one-half,** in order to charge as many as twenty batteries.

When charging with the use of the two auxiliary rheostats, place each rheostat handle (H) of (AUX. R1) and (AUX. R2) so that all resistance is cut out.

Then set the charging rate of the generator by moving its shunt-field rheostat (on the switchboard) until ammeter on switchboard shows 8 amperes.

Then note the reading on each of the ammeters (A) on the auxiliary rheostats. A little resistance can then be cut in or added to the line that is taking most of the current until each of the two auxiliary lines is cut down to the proper amount of current at which it is desired to charge each lot of batteries.

The highest rate at which the twenty batteries can be charged, as shown in Fig. 23, is 4 amperes.

When inquiring about a motor-generator of a manufacturer, the following information will be required:

1. The number of cells to be charged.
2. The highest and lowest charging rate.
3. The voltage of the supply mains.
4. If this is alternating current, give, in addition,
5. The frequency in cycles per second, and
6. Whether it is single phase or three phase.

How to Change the Polarity of Shunt-Wound Generator

It is possible to change the polarity of shunt-wound generators, and since this is the type of generator used for battery charging, it is well to know how to correct the polarity, which is easily done by the following method:

Cut out all the field resistance by turning the rheostat handle to "high" (the resistance of the rheostat is in series with the shunt field-circuit), and connect on a charged battery to the panel board (Fig. 22) (−) to (−) and (+) to (+). Close the battery switch, which will start the generator as a motor, and cause the ammeter to indicate "discharge"; then throw in the main line switch, and the meter will show "charge," and the polarity will be corrected. The polarity will never change while the set is operating. A change of polarity is caused by connecting the batteries wrong when the set is not running.

A Direct-Current Generator Driven by a Belt

A direct-current generator can be driven by a belt from a line shaft, engine, or any other source of power. A type 3-G generator with switchboard, cut-out, and belt pulley can be purchased (Fig. 24).

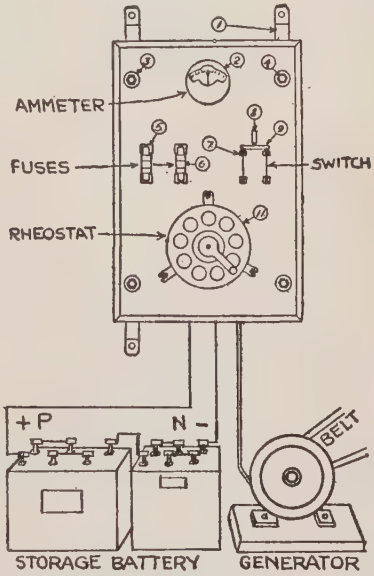

Fig. 24. **Belt-driven generator and switchboard.** **Parts:** (1) bracket for support; (2) ammeter; (3, 4) bolts; (5, 6) fuses; (7, 8, 9) double-pole, single-throw switch; (10) slate slab; (11) rheostat.

The speed of this particular type of generator is 1,800 r.p.m., and the outfit sells for $88. It is a 300-watt capacity, 30-volt 12-ampere generator. This generator will charge 6 batteries at 6 amperes if two auxiliary rheostats are used, or 1 to 3 batteries in series at 12 amperes.

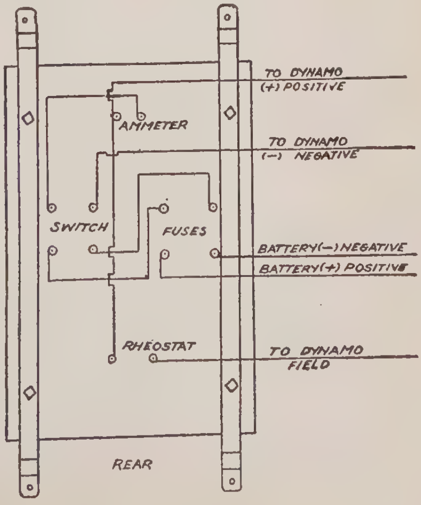

Fig. 25. Rear of switchboard showing connections.

INSTRUCTION No. 51

CHARGING BATTERIES: Putting Batteries in Storage

The different charging methods were explained in the preceding instruction. We shall now deal with the charging of the battery.

When a Battery Charge Is Necessary

A battery charge is necessary:

1. When discharged, that is, when each cell is as low as 1.8 volts and the specific-gravity reading is 1.200 or less.
2. When a battery is received new and in a dry condition.
3. When a battery is received new and in a wet condition.
4. When defective.
5. When repaired.
6. When stored.

A battery may be charged:

1. When on the car.
2. When removed from the car.

Charging and Discharging Action

There are two chief points to consider when charging a battery. In other words, the proper charging of a battery depends upon two points, namely, **gassing** and **temperature,** explained as follows:

To charge a battery, direct current is passed through the cells in a direction **opposite** to that of discharge. This current, passing through the cells in the reverse direction, will reverse the action which took place in the cells during discharge (explained under the "Principle and action of a storage battery," page 539). It will be remembered that during discharge, **the acid of the electrolyte went into and combined with the active material,** filling its pores with sulphate and causing the electrolyte to become weaker (merely water).

Action of current: Reversing the current through this sulphate in the plates restores the active material to its original condition, and **returns the acid to the electrolyte.**

Thus, during charge the electrolyte gradually becomes stronger, as the sulphate in the plates decreases, until no more sulphate remains, and all the acid has been returned to the electrolyte. It will then be of the same strength as before the discharge, and the same acid will be ready to be used over again during the next discharge. **Since there is no loss of acid, none should ever be added to the electrolyte.** There is, however, a loss of water from evaporation.

Object of charging: The acid absorbed by the plates during discharge is, during charge, driven from the plates by the charging current and restored to the electrolyte.

Gassing: When a battery is fully discharged, it can absorb current at the highest rate. As the charge progresses, the plates can no longer absorb current at the same rate, and the excess current goes to form gas. In a battery which is charged, or nearly charged, the plates can absorb current without excessive gassing only at a low rate, and a high charging rate will be almost entirely used in forming gas, resulting in high temperature and wear on the plates.

In starting and lighting systems, the aim is to provide sufficient current under average running conditions so that the battery will not be "starved," and yet that the charge will be at a rate which will not cause injurious gassing.

Normal and abnormal sulphate: The sulphating which takes place during an ordinary discharge is entirely normal. If, however, charging is insufficient, the sulphate increases and becomes hard, and the plates become lighter in color, lose their porosity, and are not easily charged; this is the abnormal condition usually referred to as "sulphated." This condition is usually the result of "starvation" of the battery.

Overdischarge: It is not **discharge** at any rate which injures a battery, but **overdischarge,** or, what in time amounts to the same thing, undercharge or "starvation."

"Starvation": If a car is so run that the battery gets insufficient charge and is "starved," it cannot be expected to do its work properly.

Overcharge: Persistent overcharging not only tends to wash out the positive active material, but also acts on the positive grids, giving them a scaly appearance.

Low temperature: Temperature has quite a marked effect on a battery. Low temperature (temporarily) both lessens the ampere-hour capacity which can be taken out of the battery and lowers the discharge voltage. It is as if the battery were numbed by the cold and unable to make the same effort as at normal temperature. The effect of cold is only temporary, the battery returning to its normal state upon its return to normal temperature, even without charge.

Starting batteries are usually designed with sufficient margin over the ordinary requirements so that they will still perform their functions under reasonably low temperature conditions. It is just as well, however, to bear in mind the effect of cold weather and to aim to keep the battery unusually well charged in winter, and not to expose it unnecessarily to low temperatures.

There is no danger of the electrolyte freezing in a fully charged cell; but in one which is over-discharged, or has had water added without subsequent charging, this is liable to occur.

High temperature: High temperature is to be avoided from the standpoint of the life of the battery; 110° F. is usually given as the limiting temperature, and even this would be harmful if maintained steadily.

Heating is ordinarily the result of charging at too high a current rate. If the temperature of the electrolyte in a battery is found to run excessively high, the system should be inspected; it may be out of adjustment and be charging the battery at too high a rate.

The effects of continued high temperature are to distort and buckle the plates, to char and weaken the wood separators, to soften and sometimes injuriously distort the jars and covers.

Charging a Battery on the Car

If a battery is charged on the car, the chief points to determine are whether it is getting too small a charge, or whether it is getting too much of a charge.

If it is not getting a sufficient charge, this is attributable to the following causes:

1. Car is run mostly at night with lights on, and does not run enough in daytime with lights off.
2. Overloading, such as additional electrical apparatus drawing on it.
3. Battery is old and probably sulphated.
4. Loose connections, or sulphated battery terminals, or ground causing leaks, the latter causing the battery to discharge.
5. Cut-out not opening and closing properly.
6. Generator third brush, or main brushes not seating properly.
7. Generator output set too low.
8. Cold weather driving caused excessive use of starter.

If it is getting too much charge:

1. The temperature of the battery is raised. The connectors will probably be found to be hot. Test the cells with a hydrometer and do not permit the temperature of the electrolyte to rise above 105°. Lower the charging rate.
2. If the charging rate cannot be lowered, then allow the lamps to burn in the daytime.

A Bench Charge (Battery Removed from Car)

A bench charge is a method of charging the battery from a source outside of the car.

If the car is not equipped with an electric generator, a "bench charge" will be required periodically, depending upon how often or how long the lighting or the ignition system has been used.

If the car is equipped with a generator, a "bench charge" will be necessary only in case of trouble, such as the battery being run down on account of the generator output being insufficient, or caused by driving too much at night with the lights on, or by excessive use of the starting motor.

Indications of the battery requiring a "bench charge" will be as follows:

1. When the hydrometer readings of the specific gravity of the cells show less than 1.200, or as great a difference as 25 to 50 points.
2. When the cell voltage falls below 1.8 volts per cell, the test being made when lights are on.
3. When the starting motor revolves, but lacks speed and power.
4. When the lights are dim while the engine is idle.
5. When the electrolyte is below the level of the top of the plates and the battery is discharged. First, fill with water.
6. When the battery is "doped," that is, when acid has been added in place of water. In this instance the battery may be discharged to where the cell voltage is but 1.8 volts per cell, yet the specific gravity readings will be 1.200 or more.

How to Give a Bench Charge

Use **direct current** only, never alternating.

Connect the battery correctly to the charging source, the positive battery terminal to the positive charging wire, and the negative battery terminal to the negative charging wire. The positive battery terminal is marked POS or (+), or is painted red; the negative is marked NEG or (−), or is painted black.

Limit the charging current to the amperes given in the table below, by connecting suitable resistance in series with the battery (see Fig. 6, page 565, showing a method of charging a 6-volt type XC-13 Exide battery from a 110-volt lighting circuit; direct-current only).

Remove the filling plugs and add distilled or other "pure" water until the level reaches the bottom of the filling tubes.

It will be necessary to take hydrometer readings while charging. If the plugs are left out or loose, the solution will flood out unless the valves (Fig. 28, page 528) are each given a quarter turn, bringing them into the position shown.

As quite a few hydrometer readings are required, turning the valves after removing the filling plugs is less work than removing and tightening the filling plugs before and after every reading, as would otherwise be necessary.

Charge at the rate shown in the following table until all cells are gassing or bubbling freely and evenly, and until the hydrometer reading of every cell goes as high as it will. Then charge for five hours longer.

If, on charge, the hydrometer reading of any cell continues to rise above 1.310 (1.240)[1], dump the solution, refill with "pure" water, and continue to charge at about two-thirds of the earlier rate until the hydrometer reading of every cell goes as high as it will. Then charge for ten hours longer.

Keep the temperature of the solution below 110° (125)[1] F., interrupting the charge if necessary.

After the charge is complete, adjust the strength of the solution to between 1.270 and 1.300 (1.200[1] and 1.230[1]) as explained under "Adjusting the strength of the solution," page 535.

Just before putting the battery back into service, make the high-amperage-discharge test, as explained on page 553.

TYPE AND SIZE OF CELL	CHARGING RATE AMPERES
KZ-3 ZA-5	1
ZA-7	1½
LX-5 LXR-5 LXRE-5	3
KXD-5 XC-9	4
JX-11 SX-9 XC-11 XE-11	5
JX-13 KXD-7 LXR-9 LXRE-9 XC-13 XE-13	6
JX-15 SX-13 XC-15 XE-15	7
KXD-9 LXR-11 XC-17	8
JX-19 LXR-13 LXRE-13 XC-19 XE-19	9
KXD-11 LXR-15 LXRE-15 LXRV-15 XC-21 XE-21	10
XC-23	11
LX-17 LXR-17 LXRE-17 XC-25	12
MHA-11 PHA-13 PHC-13	8

Fig. 1. **"Bench charge" table,** applying to Exide batteries. Note that an XC-13 battery requires 6 amperes. To facilitate comparing other batteries with this table, see page 523, giving the meaning of XC-13, and also the capacity.

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[1] Readings for tropical climates.

U. S. L. 6-Volt Lighting Batteries

Lighting Batteries Cannot be Used for Starting

*Catalogue Numbers	"L" in Inches	"W" in Inches	"H" in Inches	Wts. Lbs.	LIGHTING CAPACITIES Number of Hours Batteries will Sustain Ampere discharges of				CHARGING RATES IN AMPERES		
					1 Ampere	5 Amperes	7½ Amperes		Starting Rate	Finishing Rate	24-Hour Rate
AL-307	6¾	7⅜	8⅞	30	50 Hrs	7 Hrs	4 Hrs		6	1½	2¼
AL-309	8 1/16	7⅜	8⅞	36	70 "	10.5 "	6 "		8	2	3
AL-311	9⅜	7⅜	8⅞	43	90 "	14 "	8 "		10	2½	3¾
AL-313	10 11/16	7⅜	8⅞	49	110 "	18 "	10.5 "		12	3	4½
AL-315	12	7⅜	8⅞	56	130 "	21.2 "	13 "		14	3½	5¼
AL-319	14⅝	7⅜	8⅞	69	170 "	28.8 "	18 "		18	4½	6¾
CL-307	6¾	7⅜	9½	31	60 "	8.5 "	4.8 "		7	1¾	2⅝
CL-309	8 1/16	7⅜	9½	39	85 "	12.6 "	7.2 "		9	2¼	3½
CL-311	9⅜	7⅜	9½	47	105 "	16.8 "	9.9 "		11	3	4¼
CL-313	10 11/16	7⅜	9½	55	130 "	21.2 "	12.6 "		14	3½	5
CL 315	12	7⅜	9½	63	150 "	25.2 "	15.5 "		16	4	6
FL-307	6¾	5⅞	10⅜	30	50 "	7 "	4 "		6	1½	2¼
FL-309	8 1/16	5⅞	10⅜	36	70 "	10.5 "	6 "		8	2	3
FL-311	9⅜	5⅞	10⅜	43	90 "	14 "	8 "		10	2½	3¾
FL 313	10 11/16	5⅞	10⅜	49	110 "	18 "	10.5 "		12	3	4½
FL 315	12	5⅞	10⅜	56	130 "	21.2 "	13 "		14	3½	5¼
FL-319	14⅝	5⅞	10⅜	69	170 "	28.8 "	18 "		18	4½	6¾
K-307	9 1/32	6⅜	8⅞	35¼	70 "	10.2 "	6 2 "		6	3	4½
K-309	11⅜	6⅜	8⅞	46¼	92 "	15.5 "	9 "		8	4	6
K-311	13 11 32	6⅜	8⅞	55¼	120 "	20 "	12 "		10	5	7½

U. S. L. Starting and Lighting Batteries, 6-Volt

Catalogue Numbers	"L" in Inches	"W in Inches	"H" in Inches	Wts. Lbs.	LIGHTING CAPACITIES No. Hours batteries will Sustain ampere discharges of			STARTING CAPACITY Minutes Batteries will sustain ampere discharge of	CHARGING RATES IN AMPERES		
					1 Ampere	5-Amperes	7½ Amperes	120 amperes	Starting Rate	Finishing Rate	24-Hour Rate
A-311-B	9⅜	7⅜	8⅞	43	90 Hrs	14 Hrs	8 Hrs	11.5 Min.	10	2½	3¾
A-313-B	10 11/16	7⅜	8⅞	49	110 "	18 "	10.5 "	15 "	12	3	4½
A 315 B	12	7⅜	8⅞	56	130 "	21.2 "	13 "	18.8 "	14	3½	5¼
A-319 B	14⅝	7⅜	8⅞	69	170 "	28.8 "	18 "	27.2 "	18	4½	6¾
C-311-B	9⅜	7⅜	9½	47	105 "	16.8 "	9.9 "	14.2 "	11	3	4¼
C-313-B	10 11 16	7⅜	9½	55	130 "	21.2 "	12.6 "	18.7 "	14	3½	5
C-315 B	12	7⅜	9½	63	150 "	25.2 "	15 5 "	23.5 "	16	4	6
C-317-B	11 5/16	7⅜	9½	71	175 "	29.5 "	18.1 "	28.5 "	18	4½	6¾
G-311-B	9⅜	7⅜	11⅛	62	130 "	22 "	13 5 "	20.5 "	14⅛	3⅝	5½
G-315-B	12	7⅜	11⅛	80	185 "	33.2 "	20.5 "	33.5 "	20⅛	5	7⅝
F-311-B	9⅜	5⅞	10⅜	43	90 "	14 "	8 "	11.5 "	10	2½	3¾
F-313-B	10 11/.6	5⅞	10⅜	49	110 "	18 "	10 5 "	15 "	12	3	4½
F-315-B	12	5⅞	10⅜	56	130 "	21.2 "	13 "	18 8 "	14	3½	5¼
F-319-B	14⅝	5⅞	10⅜	69	170 "	28.8 "	18 "	27.2 "	18	4½	6¾
12-Volt Batteries											
A-607-B	12⅜	7⅜	8⅞	57	50 Hrs	7 Hrs	4 Hrs	5.1 Min.	6	1½	2¼
A-609-B	15	7⅜	8⅞	70	70 "	10.5 "	6 "	8.4 "	8	2	3
A-611 B	17⅝	7⅜	8⅞	84	90 "	14 "	8 "	11.5 "	10	2½	3¾
A-613 B	20¼	7⅜	8⅞	97	110 "	18 "	10.5 "	15 "	12	3	4½
C-607-B	12⅜	7⅜	9½	63	60 "	8.5 "	4.8 "	6.5 "	7	1¾	2½
C-609 B	15	7⅜	9½	79	85 "	12.6 "	7 2 "	10.1 "	9	2¼	3½
C 611-B	17⅝	7⅜	9½	95	105 "	16 8 "	9 9 "	14.2 "	11	3	4¼
C-613-B	20¼	7⅜	9½	111	130 "	21.2 "	12.6 "	18.7 "	14	3½	5
G-607-B	12⅜	7⅜	11½	86	80 "	11.8 "	6 7 "	9.3 "	8¾	2¼	3¼
G-609-B	15	7⅜	11½	104	105 "	17 "	10 "	14.2 "	11⅝	3	4⅜
F-607-B	12⅜	5⅞	10⅜	57	50 "	7 "	4 "	5.1 "	6	1½	2¼
F-609-B	15	5⅞	10⅜	70	70 "	10.5 "	6 "	8.4 "	8	2	3
F 611-B	17⅝	5⅞	10⅜	84	90 "	14 "	8 "	11.5 "	10	2½	3¾
F 613-B	20¼	5⅞	10⅜	97	110 "	18 "	10.5 "	15 "	12	3	4½
F-615-B	23	6	10½	110	130 "	21.2 "	13 "	18.8 "	14	3½	5¼
EL-607-D	10 5/16	7⅜	9	54	45 "	5.8 "	3.1 "	4 "	5	1¼	2
EL-613-B	21 13/16	5 13/16	10 7/16	89	100 "	14.8 "	8.7 "	12 "	10	2½	3¾
LA-613	21¼	7 9/16	9¼	97	110 "	18 "	10.5 "	15 "	12	3	4½
18-Volt Batteries											
A-909-B	22 3/16	7½	9	103	70 Hrs	10.5 Hrs	6 Hrs	8.4 Min.	8	2	3
F-907-A	15 11/16	6⅜	9	84	50 "	7 "	4 "	5.1 "	6	1½	2¼
F-909-A	15 13/16	8 1/16	10⅜	103	70 "	10.5 "	6 "	8.4 "	8	2	3
F-911-A	15 13/16	9⅝	10⅜	122	90 "	14 "	8 "	11.5 "	10	2½	3¾
F-907-B	18¼	5⅞	10⅜	84	50 "	7 "	4 "	5.1 "	6	1½	2¼
EDC-909	15	8½	12⅛	105	70 "	10.5 "	6 "	8.4 "	8	2	3
24-Volt Batteries											
A-1207-A	12⅜	14	9	112	50 Hrs	7 Hrs	4 Hrs	5.1 Min.	6	1½	2¼
A-1207-B	23⅜	7⅜	9	112	50 "	7 "	4 "	5.1 "	6	¾	2¼
F-1207-A	12⅜	11	10½	112	50 "	7 "	4 "	5.1 "	6	1½	2¼
EL-1207	19¼	7⅜	10 7/16	105	45 "	5 8 "	3.1 "	4 "	5	1¼	2
EL-1209	19¼	8¾	10 7/16	127	60 "	8.7 "	4.7 "	6.6 "	6¼	1¼	2⅝

Charging Rates

Charging rates are given by the Exide manufacturers under the head of "Bench Charge," page 573, for all ordinary charging, and under "Initial charge and repair charge," for charging both when the battery is new and when it is to be repaired.

The U. S. L. table gives an ampere-charge rate to start with, termed "starting rate," a "finishing rate," and a "24-hour rate." This will all be found in the foregoing table, page 574.

It will serve to make the table clearer if we explain some of its features. For example, under the heading, "U. S. L. Starting and Lighting Batteries—6 Volt," note that the battery number "A-313-B," meaning a 3-cell 13-plate battery (see page 523 on how to determine) has a 90-ampere-hour capacity at 1 ampere discharge. The **starting** rate, to charge this battery is 10 amperes; the **finish** at 2½ amperes.

For example: Start the charge at the "starting rate," or lower, as shown in the table, and continue the charge until the cells **gas freely.** This will ordinarily take about six hours. Then continue the charge for six hours at the normal rate (finish); see table.

A battery charge is complete when, with charging current flowing at the **finish rate** given in the tables, all cells are gassing (bubbling) freely and evenly and the gravity of all cells has shown no further rise during one hour.

The 24-hour rate is the one used for charging through the night, and cells charging at this rate may be left on continuously.

If you have no voltmeter nor hydrometer, it is possible to determine when the battery is fully charged by observing when gas bubbles begin to rise from the solution while the battery is charging at the 24-hour rate.

Procedure of Charging

Commence the charge at the current rate given under **"Starting Rate,"** (see table, page 574). Be sure that the rate is correct for the particular type of battery. Continue to charge at the maximum rate until the cells begin to gas or bubble freely, at which time the voltage will be approximately 2.5 volts per cell (7.5 volts for a 6-volt battery). When one or both of these conditions are obtained, reduce the charging current to the value given under **"Finishing Rate,"** by unscrewing the proper number of lamps (if charging with lamp resistance), and continue to charge at this rate until the cells again gas freely, and the specific gravity of the electrolyte ceases to rise, as indicated by successive half-hour readings taken after the cells begin to gas.

At the end of charge, the voltage will be approximately 2.5 volts per cell with the current flowing at the minimum rate, but on a new battery this voltage will be greater, reaching as high as 2.65 volts per cell.

The specific gravity of the electrolyte at the end of charge should be at a maximum between the value 1.275 and 1.285. Correct all specific-gravity readings for temperature as described under "Specific Gravity," page 532. Make sure that the battery is full, but do not overcharge.

The temperature of the electrolyte should not be allowed to exceed 100° F. during charge. If this temperature is exceeded, cool the battery by reducing the charging current, or by temporarily stopping the charge.

Hurrying a charge: This is not recommended, but when unavoidable, put the battery on **double** the "starting rate" given for the particular size of battery in the table on page 574.

Charging Small and Large Batteries

It is not advisable to place small batteries in series with large-capacity batteries and then give the small ones the rate of charge required for the large ones. This practice will cause the temperature of the small ones to rise more quickly than in the large ones, and will thus cause overheating.

If charging more than one size in series is unavoidable, then charge all at the rate required for the smaller battery; then when the latter is charged, take it off the line. It is best to have separate charging lines for series circuits of different sizes of batteries, for then the charging rate can be controlled accordingly.

Charging and Discharging Sulphated Batteries

With the sulphated battery, the charging should begin at about a 2 or 3-ampere rate and should not be allowed to rise beyond 5 or 6 amperes. A thermometer reading should be made often, and the temperature of the solution should never be much over 100° F. Never let it heat more than 110°.

When the cells begin to gas and give off bubbles, take the battery off the charger and discharge the battery by connecting some lamps on it or some resistance across its terminals (see tests on pages 546 and 547). Put in just enough lamps or resistance to draw a discharge current equal to 1/10 the ampere-hour capacity (if you have 80 ampere-hour batteries, discharge at an 8-ampere rate, or a 10-ampere rate); discharge the battery until each cell has a voltage of 1.7 or 1.8 volts while the battery is discharging. Repeat this process from two to three times and the sulphate will be well broken down and the battery will be in good condition. In some instances it may be necessary to charge and discharge for a week or more.

See also item 2, page 589, relative to the "water treatment" of sulphated cells.

When discharging the battery, observe as suggested above, the discharge rate and the time it requires for the battery to discharge to 1.8 volts. Multiply the two together and you have the ampere-hour capacity of the battery. Compare it with the rated ampere-hour capacity of the battery, and if your result is considerably less, the cell or cells should be opened for inspection.

If the **temperature rises** in the cells, yet **does not gas freely,** then there is trouble inside of the battery. Open it for inspection.

Charging a "Doped" Battery

Where a battery has been doped with acid, it should be given an immediate charge. Then remove some of the electrolyte and add water during the time the cells are freely gassing, while on charge, until the hydrometer test shows about 1.275 or 1.280, but do not take the hydrometer reading for at least an hour after the water is added.

The length of time to charge will depend upon the amount of acid added and the condition of the battery resulting from the acid. If the plates are not badly sulphated, a long-time charge at a low rate may bring the battery back to normal.

If the acid has caused sulphation, see above. The battery may also require new separators if the battery has been doped often (see also pages 535, 543, 544, 588).

Reversed Charge

Should a reversal occur, put the battery on charge at the 24-hour rate, and leave it on for several days. Do not take it off until its voltage and gravity have both reached a maximum, with the battery at normal temperature, 70° F.

Charging Repaired Batteries

This subject is dealt with farther on, under the subject of "Battery Repair."

What to Do when Receiving a New Battery from the Factory

Batteries are shipped from the factory either "charged" or "bone dry."

Receiving a Battery Filled or Wet

When a "charged" battery is received, it is one which has had the solution added and which has been given its initial charge at the factory. It leaves fully charged, and contains the proper amount of solution and is intended to be put into service.

Before putting it into service, however, it should be examined by testing the strength of the solution by taking a hydrometer reading (see page 531, Fig. 1) in each cell. All readings should be more than 1.250 (1.180).[1] Add distilled water through each filling tube until the level reaches the bottom of the tube (Fig. 1, page 561), and replace and tighten the plugs.

In freezing weather, charge the battery for an hour at the proper rate (see page 577), in order to mix the water with the solution.

If all cells, or some cells read less than 1.250 (1.180),[1] give the battery a "bench charge" (see page 573).

If there is not enough solution to give a hydrometer reading, and if there is no evidence that the solution has been spilled in shipment, add distilled water to the proper level, and replace and tighten the filling plugs. Then charge for an hour at the proper rate (see "bench charge," page 573). Then test the strength of the solution.

If the solution has been spilled in shipment, then use electrolyte having a strength of 1.250 (1.180)[2] instead of water to make up the loss (see "Mixing Electrolyte," page 534).

Just before putting the battery into service, make the "high-amperage discharge" test (see page 552).

Receiving a Battery Dry or Unfilled

Batteries are often shipped unfilled, or "bone-dry," as it is termed. A "bone-dry" battery is one which has never had solution added and which, therefore, has not been given an initial charge at the factory. To it is attached a tag, reading "unfilled" or "dry."

A bone-dry battery may stand a considerable length of time before being put into service, the time limit being given on the tag.

Bone-dry batteries are shipped to all foreign countries and many battery distributors order batteries dry, preferring to give them their initial charge when sold, thus preventing the deterioration that would result if a fully charged battery was kept on their shelves over a long period of time.

Care of Battery When Received Dry

1. Store it in a dry, clean location and keep the temperature above freezing and below 110° F.

2. Put it into service before the expiration of the time limit given on the tag attached to the battery. The process of putting into service will require about five days.

3. If the battery has been allowed to stand beyond the time limit, a cell must be opened up and the separators examined just before putting the battery into service. If the separators are cracked, warped, or split, the entire battery must be provided with new separators; otherwise, reassemble the cell and put the battery into service.

Putting a Bone-Dry Battery into Service

The following instructions are taken from the Exide instruction book:

1. Fill with electrolyte of the proper strength and give a long initial charge at the proper rate.

2. Remove the filling plugs and pour electrolyte of the proper strength carefully into the cells until level with the bottom of the filling tubes, using china or glass vessels or a rubber syringe. The proper strength for filling varies with the different types of Exide cells and should be as follows:

For Types JX, XC, and XE, it is 1.360 (1.260)[1]
For Types LX, LXR, LXRE, LXRV, and SX, it is 1.340 (1.260)[1].
For Types MHA, PHA, and PHC, it is 1.320 (1.260)[1].
For Type ZA, it is 1.320 (1.240)[1].
For Types KXD and KZ, it is 1.300 (1.240)[1].

If electrolyte of proper strength is not on hand, it can easily be made as explained on page 535.

3. After filling, allow the battery to stand ten to fifteen hours before starting the initial charge. It is important that the full time be allowed.

4. Arrange charging circuit.

   (a) Direct current only must be used, never alternating.

   (b) The positive terminal of the battery must connect with the positive of the charging circuit, and the negative of the battery with the negative of the charging circuit. The battery positive terminal is marked POS or (+), or is painted red; the negative is marked NEG or (−), or is painted black.

   (c) Arrange the resistance in series with the battery, so that the charging rate will be that given in the table below. Use either lamps in parallel or a rheostat for resistance.

5. Not sooner than ten to fifteen hours after filling the battery with electrolyte, add more electrolyte to restore the level, if it has fallen, and replace the filling plugs, screwing them tight. Never charge with filling plugs out or loose.

Start charging, and **continue at the amperes shown in the table** (Fig. 2) until the battery has received at least the number of ampere-hours shown. If the rate is maintained, the time required will be ninety-six hours (four days). The initial charge is not complete until the hydrometer reading of every cell goes as high as it will and then remains there for ten hours. Be sure to make the charge absolutely complete, as the entire future of the battery depends upon it.

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[1] The readings in parentheses apply to batteries used in tropical climates. The term "tropical climates" is applied to conditions where the temperature is never low enough to freeze water—or warm climates.

[2] Applies to tropical climates.

[1] Applies to tropical climates.

6. Keep the temperature of the solution below 110° (125°)[1] F., interrupting the charge if necessary.

7. After the charge is complete, the strength of the solution should be between 1.270 and 1.300 (1.200[1] and 1.230[1]). If it is not between these limits, adjust as explained on page 536.

8. Wipe off the top and sides of the battery case with a rag dampened with ammonia to remove any electrolyte that may have been spilled.

9. Just before putting the battery into service, make the "high-rate discharge test" (page 552).

The following instructions are those on the tag of all Witherbee batteries which are shipped dry:

Remove the vent plugs and fill with 1.300 electrolyte (approximately 2½ parts by volume of distilled water and one part by volume of chemically pure sulphuric acid); allow to stand for twelve hours, adding 1.300 electrolyte, if necessary to obtain the proper level in the cell.

Then charge at the rate specified on a name plate for not less than sixty hours, or until the gravity stops rising, adjusting the gravity at the end of the charge to 1.300 sp. gr. at 70° F.

The temperature during the charge should be kept below 110° F.

While charging, add distilled water to replace any electrolyte lost by evaporation. After charging, insert the vent plugs.

Important: If the temperature exceeds 110° F. during charge, the current should be reduced and the time lengthened proportionately.

Never fill with acid, the temperature of which is over 90° F.

It is very important that the instructions be followed carefully, as too much acid or improper charging rates will ruin the plates.

TYPE AND SIZE OF CELL	Charging Rate Amperes	Minimum Ampere Hours
KZ-3 ZA-5	½	50
ZA-7	¾	70
LX-5 LXR-5 LXRE-5	1½	145
KXD-5	2	190
XC-9 SX-9	2½	240
JX-11 KXD-7 LXR-9 LXRE-9 XC-11 XE-11	3	290
SX-13	3½	340
JX-13 KXD-9 LXR-11 XC-13 XE-13	4	385
JX-15 LXR-13 LXRE-13 XC-15 XE-15	4½	430
KXD-11 XC-17	5	480
LXRV-15 LXR-15 LXRE-15	5½	525
JX-19 LX-17 LXR-17 LXRE-17 XC-19 XE-19	6	575
MHA-11 PHA-13 PHC-13	6	575
XC-21 XE-21	6½	625
XC-23	7	675
XC-25	7½	720

Fig. 2. **Table for initial charge and repair charge** of Exide batteries.

BATTERIES IN STORAGE[1]

It is necessary to put batteries into storage:

1. When a car is to stand idle for a considerable period, as when it is held for future delivery.
2. When a car is laid up for the winter.
3. When batteries are kept in stock.

Should it be "dry" storage or wet storage? That depends on the condition of the battery.

Any battery which is to be out of commission should, if possible, be put into **wet storage,** providing it will not soon require dismantling, in which case it should be put into **"dry"** storage.

"Dry" storage requires no attention during the storage period. The battery must, however, be dismantled and reassembled, and if its condition is such that this will soon be required, anyway, dry storage is obviously the better method.

Putting a Battery into Dry Storage

1. Provide a dry place for storage, free from dust.

2. Have on hand enough "pure" water to fill all the cells.

3. Empty the battery solution by tilting and turning over the battery, and immediately replace the solution with the water.

4. Allow the battery to stand filled with water for approximately ten to fifteen hours.

5. Give the battery a charge, as outlined in the first five items of "Charging a Battery after Repairing" (page 590).

6. Unseal the cells and pull out of the jars the elements complete with covers, that is, without removing the sealing nuts.

7. Remove the separators.

8. Wash the plates by dipping them several times in water.

9. Replace the separators, using new ones for the wood separators. Be sure these are thoroughly saturated (see page 588: "When New Separators Are Necessary"). Where there are rubber separators, they may be used again, if they are not broken or cracked.

10. Pour the water out of the jars.

11. Put the elements back into the jars and reseal before the negatives dry out.

12. Put a tag on each battery, giving the date put into storage.

13. Replace and tighten filling plugs.

14. Within twelve months put the battery into service, as outlined on page 576 ("Putting an Unfilled or Bone-Dry Battery into Service"). (It is preferable to do this immediately and then keep in wet storage on "trickle charge.")

15. If it is impossible to reseal the cells, proceed as in items numbered 1 to 6 inclusive (above). Then remove the wood separators and throw them away. Where there are rubber separators, replace them between the plates. Allow the plates to drain and to become thoroughly dry. Pour the water out of the jars. Put the elements back into the jars, but do not seal.

Putting a Battery into Wet Storage

1. Provide a bench or shelf in a convenient location and of sufficient size to allow a little air space all around each battery.

2. Place the batteries upon wood strips in order to keep the bottom of the batteries clear of the bench.

3. Install the necessary wiring, switches, and charging resistance, so that batteries can be easily connected up and charged where they stand on the bench.

4. Apply vaseline freely to the battery terminals and to the exposed copper wires.

5. Batteries may be kept in wet storage by means of either the "trickle charge" or "periodic charge" method.

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[1] From the Exide instruction book.

Trickle Charge

When a number of batteries are to be held in wet storage, the most satisfactory results can be obtained by **charging continuously at a very low rate,** which is so low that gassing is avoided and yet gives enough charge to maintain the batteries in good condition.

This charge is termed a "trickle charge," and in many cases will be found more convenient to arrange for than the "periodic charge." It has the added advantage of keeping the batteries in condition for putting into use at any time on short notice.

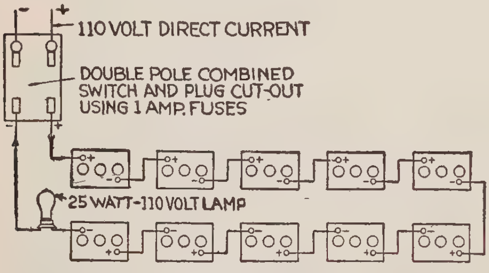
110 VOLT DIRECT CURRENT
DOUBLE POLE COMBINED SWITCH AND PLUG CUT-OUT USING 1 AMP. FUSES
25 WATT-110 VOLT LAMP
-
+

Fig. 3. Diagram of connections for "trickle charge," showing ten 6-volt type XC-13 batteries.

How to Apply a Trickle Charge

1. Give a bench charge.

2. Connect a tungsten lamp or lamps of appropriate resistance in series with the cells, across a charging system adapted for continuous charging.

Fig. 3 gives an example of connections for a "trickle charge," and the table below gives suggested lamp resistances to provide proper rates for various numbers and sizes of cells of the Exide make.

3. Every two months interrupt the "trickle charge," remove filling plugs, add water to the bottom of the filling tubes, replace and tighten the filling plugs, and continue the "trickle charge."

Type and Size of Cell		KXD-5 or 7 LX or LXR-5 SX-9 XC-9	JX-11, 13 or 15 KXD-9 or 11 LX or LXR-9 to 13 LXRE-9 or 13 SX-13 XC-11, 13 or 15 XE-13 or 15	JX-19 LX or LXR-15 or 17 LXRE or LXRV-15 or 17 MHA-11 PHA or PHC-13 XC-17, 19 or 21 XE-19 or 21
Approximate Current		0.05 Ampere	0.10 Ampere	0.15 Ampere
Number of cells. (Usually three cells to a battery)	3	5 15-watt lamps in series	3 25-watt lamps in series	2 25-watt lamps in series
	30	2 15-watt lamps in series	1 25-watt lamp	1 25-watt lamp
	45	1 15-watt lamp	2 25-watt lamps in parallel	3 25-watt lamps in parallel

Fig. 4. Tungsten lamps to use for a "trickle charge." Lamps are rated at 110 volts. Combinations given are to be used in series with batteries across a bus of 105 to 115 volts.

Periodic Charge

This is a method of wet storage in which the batteries are given charges **periodically,** and is used where it is not practicable to arrange for the "trickle charge" method.

How to Apply a Periodic Charge

1. Give a bench charge.

2. Store in a dry, clean location, and keep the temperature above freezing and below 110° F.

3. Once every month remove the filling plugs, add distilled or other "pure" water to the proper level, replace, tighten the filling plugs and charge for five hours at the proper rate given in the "bench charge table" (Fig. 1, page 573).

4. Before putting the battery into service, add "pure" water and give a bench charge.

QUESTIONS AND ANSWERS ON CONNECTING A 6 AND 12-VOLT BATTERY

Q. 1: If a 12-volt battery is connected to a 6-volt battery: positive (+) to positive (+) and negative (−) to negative (−), as in Fig. 1, what would be the voltage?

Ans.: The resultant voltage impressed on the circuit would be 6 volts in the direction of the 12-volt battery and opposed to the direction of the 6-volt battery. The 6-volt battery would be charged at 6 volts.

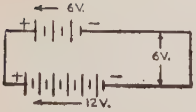

FIG.1

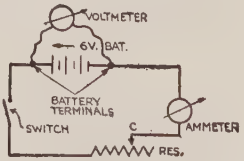

FIG.2

Q. 2: What amperage would flow to the 6-volt battery?

Ans.: This would depend upon the resistance of leads, internal resistance of the 6-volt battery, and internal resistance of the 12-volt battery.

First, it will be necessary to find the ohms resistance of the 6-volt battery; therefore we will insert a resistance wire into the circuit as in Fig. 2.

On an open-circuit test of the 6-volt battery we will assume that it tests 6.25 volts with a voltmeter across the (+) and (−) terminals with the switch open.

We will now discharge the battery by closing the switch and cutting in resistance. At (C) we will say the discharge is 302 amperes and the voltage drops to 2.98 volts.

Thus at a 302-ampere discharge the voltage has dropped from 6.25 to 2.98, or a drop of 3.27 volts. (These are only approximate figures.)

The ohms resistance would then = volts dropped ÷ amperes, or 3.27V ÷ 302A = .0108, or approximately .01 of an ohm resistance of the 6-volt battery.

We will assume, for the purpose of explanation, that the ohms resistance of the 12-volt battery is twice that of the 6-volt battery, or .02 of an ohm.

Therefore, to find the amperes that would flow to the 6-volt battery from the 12-volt battery (not considering the resistance of the leads, connections, etc., which is negligible), we will proceed as follows:

Amperes = volts ÷ resistance, thus:

$$\text{Amp.} = \frac{6 \text{ volts}}{.02 \text{ ohms (R)} + .01 \text{ ohms (R)}} = \frac{6 \text{ volts}}{.03 \text{ ohms (R)}} = 200 \text{ amperes.}$$

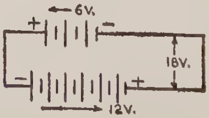

FIG.3

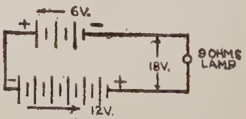

FIG.3A

Q. 3: What would be the voltage of battery if the 6-volt and 12-volt battery were connected together (in series) as in Fig. 3: (+) to (−), as shown?

Ans.: The resultant voltage would be 18 volts. in the direction of both batteries. Both batteries would discharge. If the 6-volt battery was **discharged,** it would be charged in an opposite direction, thus reverse-charging or depolarizing the plates.

Q. 4: At what ampere rate would the 12-volt battery charge the 6-volt battery if the 6-volt battery was completely discharged?

Ans.: Considering the ohms resistance as .02 ohms for the 12-volt and .01 for the 6-volt battery, it would figure approximately thus:

$$\text{Amperes} = \frac{12 \text{ volts}}{.02+.01(\text{R})} = \frac{12 \text{ V}}{.03(\text{R})} = 400 \text{ amperes}$$

Q. 5: Suppose a lamp of 18 volts, drawing 2 amperes, was placed across the circuit (Fig. 3A). What would be the ampere discharge and voltage?

Ans.: The voltage would be the same as in Fig. 3: 18 volts. The ohms resistance of the lamp would be found as follows: 18 volts÷2 ampere=9 ohms (or R). Therefore,

$$\text{Amperes discharge} = \frac{18 \text{ volts}}{.02+.01+9\text{R}} =$$

$$\frac{18 \text{ V}}{9.03(\text{R})} = 1.9933 \text{ amperes.}$$

Thus it is observed that there is quite a difference in the rate of discharge, where **batteries** are connected together as in Fig. 3, and where a **lamp** or other equal resistance is placed in the circuit.

We have assumed in these examples that the internal resistance of a battery while being charged is the same as its internal resistance while being discharged. This is not strictly true.

Q. 6: Isn't it the usual plan to connect batteries together as in Fig. 3, that is, to connect (+) to (−), and to connect several batteries together to charge them. Then how could a battery be charged in the wrong direction?

Ans.: By referring to Figs. 4 and 4A, the explanation will be made clear. In these illustrations only one set of plates is shown to make the explanation clear. One set of plates, to the right, represents the internal circuit of the 12-volt battery, and the set of plates to the left, the 6-volt battery.

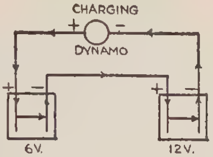

FIG.4

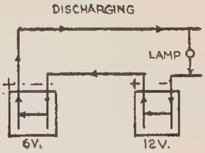

FIG.4A

Referring to Fig. 4: When batteries are being **charged,** connected (+) to (−), as shown, the current from the charging source must flow from (+) of the dynamo to (+) of the battery, and through the battery, (+) to (−), then to (+) of the next battery and (+) to (−) internally, to (−) of the dynamo, forming a complete circuit. This is as it should be.

When on a **discharge,** however, as in Fig. **4A,** note that if both batteries start fully charged, then the discharge current from the 12-volt battery would pass from (+) of the 12-volt battery to (−) of the 6-volt battery, and it is clear that the 6-volt battery would discharge in the same direction as the 12-volt battery, and depolarizing is not probable.

If, however, the 6-volt battery was **discharged,** the rule is to connect the (+) terminal of a charging source to (+) of the battery, and in this case, the direction of charging would be as in Fig. 4 (note the arrow in the 6-volt battery). However, as the (+) of the 12-volt battery (Fig. **4A**) is connected with the (−) of the 6-volt battery, it is clear that the current would flow in the **wrong** direction internally of the 6-volt battery, and the (−) plate of the 6-volt battery would become a (+) plate, and the (+) plate a (−) plate.

This is why we frequently find one cell in a battery having become depolarized, owing, probably, to internal troubles which discharged it, whereas the other cells are charged, and thus, as current is passing through this discharged cell in the wrong direction to charge it, it will be depolarized or the plates will be reversed in polarity.

Note. It is not advisable to charge a battery from another battery. The explanations given above are used for the purpose of making clear how one cell of a battery can sometimes be depolarized and then show opposite polarity from that of the other cells, if defective internally.

CONSTANT POTENTIAL BATTERY CHARGING

The method previously treated in this book might be termed a "constant current" system. It consisted of connecting a sufficient number of batteries in series to approximate a voltage of 110 or 220 volts supplied by a direct current charging line, there being an adjustable resistance so that the amperes can be properly adjusted to the battery requiring the lowest ampere charge. **The amperage is usually kept constant and the voltage varies** according to the state of charge of battery. This results in it being necessary to have the batteries on the line anywhere from 12 to 48 hours in order to charge them properly.

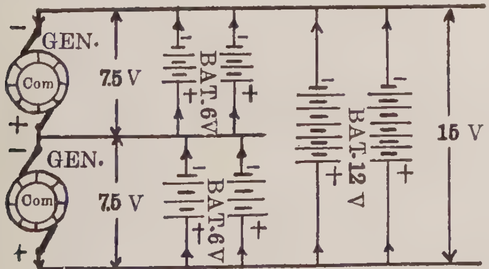

Fig. 5. Circuit of the Marshall-Chandeysson constant potential system (Marshall Electric Co., 3225 Locust St., St. Louis, Mo.).

The constant potential, or constant voltage method of charging storage batteries consists of connecting the batteries **in parallel** across the low-voltage 7½ and 15-volt circuit, instead of using a 110 or 220-volt line, and the **voltage, or potential, is held constant** regardless of load. Each battery will draw current from the constant potential bus bars in accordance with its counter-electromotive force or the amount to which the battery has been discharged. In other words, a battery fully discharged will draw more current than one which is only partially discharged. **No resistance is used.** The batteries are connected to the bus bars with as low a resistance as possible. Batteries can be charged in from 6 to 8 hours by this method.

In practice, a three-wire generator is usually employed, this generator having two commutators, one at either end of a single armature, and two separate and distinct windings, one connecting to each commutator. Such a generator will give a three-wire system, as shown in Fig. 5, the negative brush of one commutator being connected to the positive brush of the other. Such a system is capable of giving 7½ volts for charging 3-cell batteries and 15 volts for 6-cell batteries. In the smaller sizes a single-commutator, 7½ volt, two-wire generator is often used for charging 3-cell batteries. These generators are built in sizes from 125 to 200 amperes, 7½ volts rating, and also 300 amperes to 600 amperes, 7½ to 15 volt rating. Larger machines can be had if required.

The generator is shunt wound with an automatic voltage regulator in series with the shunt fields. This regulator is very sensitive in operation and insures a constant voltage at all times, regardless of load conditions. The shunt-wound generator also has the advantage that if current supply to the driving motor is accidentally shut off, the generator will operate as a motor in the same direction of rotation (on the battery current) and will not injure the batteries, whereas the compound-wound generator will reverse the direction of rotation with probable serious results.

Question 1: Why can a battery be charged at a high rate by the constant potential system, whereas by the series method it would cause heating and gassing which is injurious to a battery?

Answer: The charging of a battery by the constant potential method is tapered. The amount of current drawn by each battery will be dependent upon the condition of the batteries and how much they have been previously discharged. The ampere charge starts at a high value and tapers off rapidly as the battery builds up its counter voltage (c.e.m.f.) as it becomes charged. By the series method the current or amperage is constant, and the voltage varies and a certain amount of current is forced through a string of batteries. Under these conditions, if an accurately reading voltmeter is placed across the individual terminals of the several batteries in series, it will be found that there is quite a difference in the voltage or potential of each individual cell, this being due to the fact that some of the batteries are more run down than others. A battery that is almost charged, if in series with other batteries that are run down, will be forced to take a higher current than it should, and this current will be dissipated in heat and gassing

INSTRUCTION No. 52

EQUIPMENT FOR STORAGE-BATTERY WORK: Layout of a Shop for Storage-Battery and Electrical Work; Tools and Supplies; Charging Equipment

LAYOUT OF SHOP FOR BATTERY AND ELECTRICAL REPAIR WORK

The following layout for a storage-battery repair shop is taken from *Motor Age* and was prepared by Mr. B. M. Ikert. The layout is one that has many advantages, as will be noticed by a study of the illustration.

The space is divided into two sections (A) and (B). The dimensions are given on the illustration.

(B) shows the layout of the room for battery work, such as for charging, putting in new plates, new separators, new jars, burning-in straps, discharging and testing.

The room is 12′ x 19′ and is a part of the "Service Station," as shown on page 691.

(A) shows layout of a room for the electrical department for starting, lighting and ignition work, such as putting in new brushes, new windings, testing and repairing armatures (if the job is not too complex), undercutting mica in the commutator, recharging magneto magnets, putting in new condensers in magnetos, timers and coils, regulating the charging rate of generators, testing and repairing electric horns. Each of these subjects is explained in this book. See the Index under the appropriate captions.

Supplies should be carried in the electric department, such as lamp bulbs, spark plugs, fuses, condensers, generator and motor brushes, timer points for Delco, Atwater-Kent, and Connecticut ignition timers.

A Wiring Diagram Book for tracing circuits is very important. On the subject of electric testing instruments, see Index.

Tools and Spare Parts for Storage-Battery Work

Anyone undertaking to care for or repair batteries will in time gather together the equipment he considers necessary or desirable for the work. Many of the tools are questions of personal taste or present equipment, but there are four things absolutely essential:

1. Suitable charging equipment (see "Charging Apparatus").
2. A hydrometer syringe.
3. A battery thermometer.
4. A lead-burning outfit.

In addition, tools and equipment must be available for the following purposes, and suggestions are here given along with the list of purposes.

1. To read battery or cell voltage: a portable voltmeter, such as a Weston, model 280, or model 301, or model 45.
2. To remove connectors: a brace with 5/8″ and a 3/8″ wood bit.
3. To tighten or loosen sealing nuts: a special wrench. There are three sizes.
4. To tighten or loosen tie bolts: a screwdriver, or else a special spanner bit.
5. To unseal covers: a putty knife. See Fig. 2 (9).
6. To remove element from jar: two pairs of 6″ or 8″ gas pliers. See Fig. 2 (10).
7. To prepare surfaces for lead burning: knife, scraper, wire brush, file or end-cutting pliers.
8. To handle sealing compound: receptacles in which to heat and from which to pour.

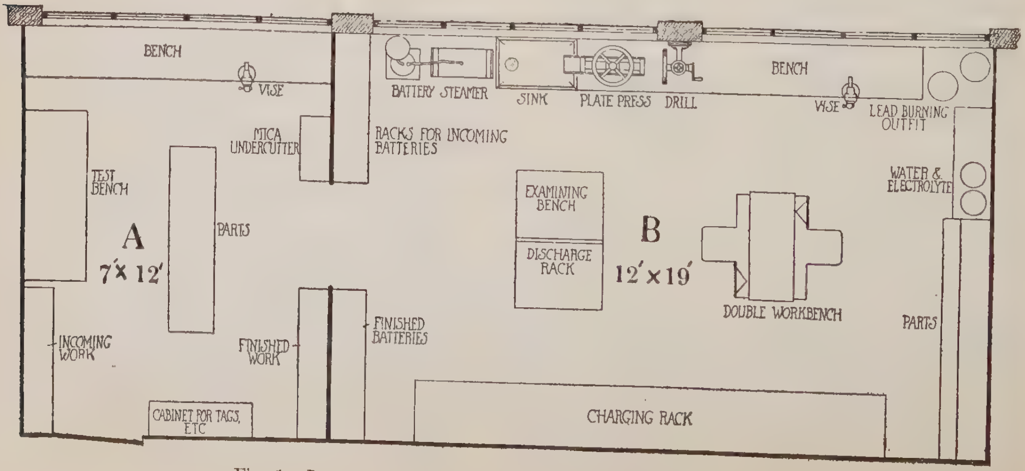

Fig. 1. Layout for a shop for battery and electrical repair work.

. To handle electrolyte: non-metallic or lead vessels for storing, mixing, and pouring; rubber gloves or fingers for protection; soda or ammonia solution for neutralizing effects of spillage or sloppage.

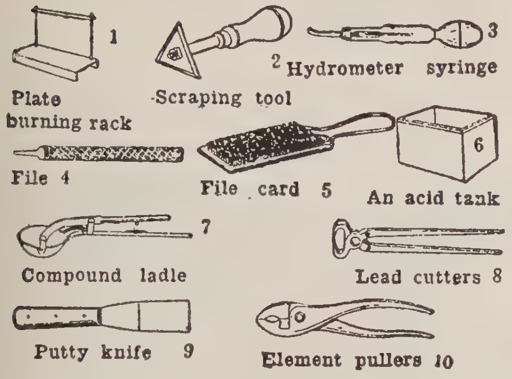

Fig. 2. Small tools for battery work, as follows:

1. **Plate-burning** rack.
2. **Scraping tool** for cleaning parts to be burned.
3. **Hydrometer syringe** for testing and mixing electrolyte.
4. **File for cleaning lead** before burning, 10″.
5. **File card** for cleaning lead from file.
6. **An acid tank,** lead-lined for mixing acid, storing and soaking separators 24″ x 36″ x 24″. Separators, when new, are usually dry and should be soaked in a weak solution of electrolyte before using.
7. **Compound ladle** for melting sealing compound.
8. **Lead cutters** for cutting excess lead and for cutting post straps to necessary size.
9. **Putty knife** for scraping sealing compound.
10. **Element pullers,** or regular gas pliers.

Rubber gloves (not illustrated).

Thermometer for determining temperature of electrolyte in cells.

Lead funnel for filling batteries with electrolyte.

Supplies, Parts, and Instruments for Battery Work

A stock of spare battery parts should, of course, be kept on hand, and with these should be included:

1. **Compound for sealing jars** and surrounding jars. This can be made of gum asphaltum 50 per cent, paraffine wax 25 per cent, and resin 25 per cent, melted together. Battery stations usually buy this compound in bulk.
2. **Solution for making battery box acid proof** (see page 585). This can be purchased at battery supply houses.
3. **Electrolyte** 1.400 or 1.300 sp. gr. test should be kept in a closed stone or glass vessel. Electrolyte is sold by manufacturers. Electrolyte is mixed with water to the density required when using.
4. **Distilled water:** A supply should be kept on hand for battery use.
5. **Extra battery connectors** should also be kept on hand, as well as other connections and parts, such as extra jars, covers, vents, separators, etc.
6. **Pure lead** (10 lbs.) for burning connections together.
7. **A 10 lb. bundle of antimony** and lead bars for burning to straps.
8. **Burning strip** for lead burning.
9. **Glass tube** for testing the acid level.
10. **Volt-ammeter** with a scale 0-30 volts and 0-3-30 amperes is indespensable to the battery repairman.
11. **Cadmium voltmeter.**

Equipment for Battery Work

The following illustrations and itemized list suggest an equipment suitable for battery work.

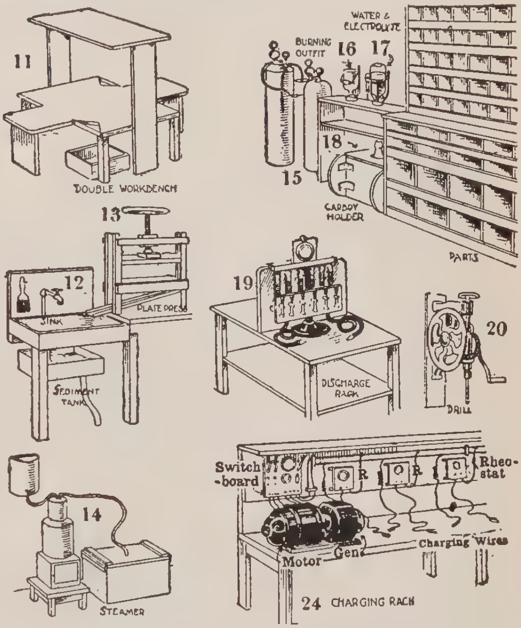

Fig. 3. Equipment for storage-battery work (suggested by *Motor Age*) as follows:

11. **Work bench** and seats.
12. **Sink** for washing plates, etc.
13. **Plate press.** In discharged negative plates the active material is bulged out and must be pressed back flush with the grids. As the acid is pressed from the plates, it flows into lead-coated troughs. Length of jaw of press, 19″.
14. **Battery steamer** for softening the sealing compound so that it can be opened.
15. **Lead-burning outfit.**
16. **Distilled water.**
17. **Electrolyte.**
18. **Carboy of acid.**
19. **Battery-discharging outfit** for discharging battery.
20. **Post drill** to drill top of connectors.
24. **Motor-generator battery-charging outfit.** A rectifier or other methods could be used.
25. **Shelf and bins** for spare parts.

LEAD-BURNING

The parts of a battery which must be burned together by melting the parts to be joined are the post-straps to the plates, connecting links to the post and terminals to the posts, and lead terminals on the battery cables.

Methods for lead-burning are as follows:

1. By an **electric arc.**
2. By **gas,** or a combination of gases.
3. By a well-tinned **soldering iron,** with pure lead as a solder.

The Electric Arc for Lead Burning

The electric arc method consists of one terminal of a spare 6-volt battery connected to the terminal to be burned on the battery being repaired. Clamp (C) (Fig. 4, page 582) is connected to other terminal of the spare battery, or on one of the connectors of the adjoining cell, depending upon whether the battery is partially discharged or fully charged. In the latter case, 3 cells will give too much voltage. The number of cells should be sufficient to heat the carbon (CR) to at least a bright cherry red while it is in contact with the joint.

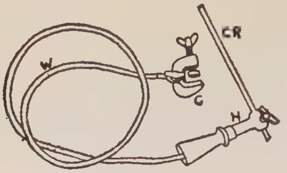

Fig. 4. An electric arc lead-burning outfit.

At the end of cable (W) a carbon holder (H) should have a piece of carbon (CR) sharpened to a long point like a lead pencil which should project not more than 3″ from the holder. When contact is made at the terminal to be burned, this completes the circuit and an "electric arc" is formed. This outfit is not meant to be used where considerable lead-burning is done.

Although this is called the "arc burning outfit," more satisfactory results can be obtained by using the carbon, after it becomes heated, like a soldering iron, without actually drawing an arc.

The carbon should be cooled off occasionally by plunging it, carbon and all, into a pail of water. After being used for a short time, it will be found that the carbon will not heat properly, because of a film of scale that will be found to have formed on the surface. This should be cleaned off with a knife, or file, as occasion requires.

As in the case of flame-burning, additional lead to make a flush joint should not be added until the metal of the pieces to be joined has melted. The carbon should be moved around to insure a solid joint at all points. The electric arc outfit can be secured of the Electric Storage Battery Co., Philadelphia, Pa.

Lead-Burning with Gas

Where there is considerable work of this sort to be done, gas or a combination of gases should be used. Different methods are explained on this page. In addition to using the flame for lead-burning, it can be used for welding light metals.

Gases which can be used, other than as stated on this page, are hydrogen and oxygen, hydrogen and compressed air. The combinations most used, however, are those shown in Figs. 5 and 6 following. The illuminating gas and compressed air can be used, but it does not give as intense or hot a flame as the combinations shown in Figs. 5 and 6.

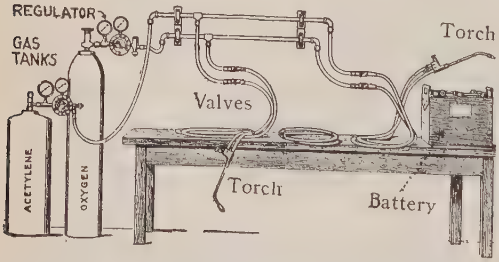

Fig. 5

Fig. 5. Imperial **lead-burning outfit for use with acetylene and oxygen.**[1] Consists of type F oxygen regulating valve with 15 lbs. pressure gauge; type 10R acetylene constant pressure regulator; 35′ 3/16″ rubber hose; bench-block with 2 needle valves; type L lead-burning torch with 4 tips; 1 wrench ($25). A torch with 4 tips, bench-block, 16 ft. hose can be had for $9, where one is already equipped with a welding outfit using oxygen and acetylene. This method gives four times the intensity of heat that is provided by the method shown in Fig. 6.

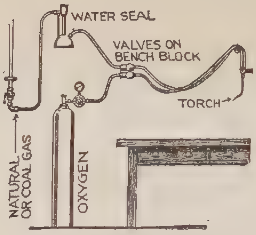

Fig. 6

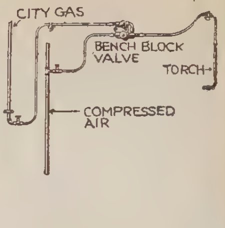

Fig. 7

Fig. 6. Imperial **lead-burning outfit for use with illuminating (hydro-carbon) gas or natural gas and oxygen**[1] in high-pressure tanks. Consists of same outfit as shown in Fig. 5, except that an Imperial hydraulic back-pressure valve and purifier for coal gas or natural gas takes the place of the acetylene regulator and type L-2 lead-burning torch is provided ($25).

Fig. 7. Imperial **lead-burning outfit for use with illuminating (city) gas and compressed air.** On account of the relatively lower temperature of this flame, this outfit works much more slowly than the others, but costs less to operate. Air pressure is obtained from a compressed-air tank which is used in most garages for filling tires. The outfit consists of a type O Imperial torch; type O bench-block; 17 ft. hose; gas shut-off cock; air shut-off cock ($12)[1].

The gases, therefore, which can be used for lead burning are:

Acetylene and oxygen.
Illuminating or natural gas and oxygen.
Illuminating gas and compressed air.

Acetylene and oxygen, as illustrated in Fig. 5, are used most.

To use gas, it is necessary to have the proper kind of lead-burning torch, and also two valves for properly mixing the gases to control the size of flame, called the "bench block." In addition, rubber hose and regulators on the gas tanks are necessary. See Index, under "Gas torches."

Soldering Iron

In the absence of a lead-burning outfit, a fairly good job can be done by using a very hot, well-tinned soldering iron, with pure lead as a solder. This however is not advised, except for temporary work.

Pointers on Lead-Burning

Cleaning surfaces: In all lead-burning, absolutely clean surfaces are essential to good workmanship. Lead is soft and very readily cleaned with a scraper or file. In the case of a battery which has had electrolyte in it, the surface to be burned should first be wiped with ammonia to neutralize the acid, and then allowed to dry before scraping.

Before starting to burn,[2] the connector or terminal should be lightly tapped to a snug fit on the post. The top of the post should be $\frac{1}{8}$″ below the top of the connector to allow space for burning. If the post is too long, remove the connector and trim off the post.

Method of burning: The top of the post should be melted first, then fused to the connector, after which lead from a piece of burning strip can be run in until the joint is flush.

The color of the flame, when using gas and air, should be greenish. If too much air is being used, the color will be blue, and the flame will gradually become invisible and deficient in heating power.

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[1] Can be secured of the Imperial Brass Mfg. Co., 1200 W. Harrison St., Chicago, Ill.

[2] In order to avoid the possibility of an explosion of the gaseous mixture when using a flame near a battery, place the filling plugs in the battery and cover the entire battery with a wet cloth, pressing it down over the vents of the cells, except on that part on which the burning operation is to be performed. The gases can also be removed from the cells by blowing them out with compressed air.

Questions and Answers on Lead Burning with a Blow Torch

Q. 1: Can a blow torch generating 1,500° F. be used for lead burning on a storage battery?

Q. 2: If not, can a double-jet torch generating 3,000° F. be used for the burning?

Ans.: Lead melts at approximately 600° F., from which note that either of the torches mentioned produces sufficient heat for lead burning, but it is also necessary that the torch produce an extremely small and concentrated needle-point flame for successful lead burning on storage-battery work. Note therefore that heat alone is not sufficient for lead burning, but the required heat must be combined with the needle-point flame.

MISCELLANEOUS BATTERY REPAIR DEVICES

Moulds for battery parts: Junk lead can be used for making connectors, terminals, pillar posts, etc., with moulds as shown in Fig. 8.[1]

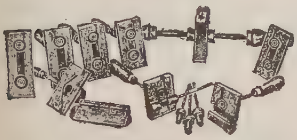

Fig. 8

Fig. 9

Battery clips: The battery clips shown in Fig. 9 are handy for snapping over battery terminals. They can be secured of the Muller Electric Co., Cleveland, Ohio.

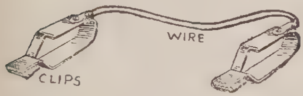

Fig. 10

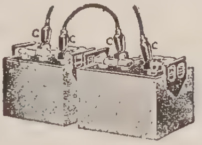

Fig. 11

Flexible service connectors: A very serviceable jumper lead or connector is shown in Fig. 10. It is handy for connecting batteries when charging, testing, etc., as shown in Fig. 11. They can easily be made by soldering cable to two of the battery clips.

Lead-Burning Rack

When burning post straps to the plates, great care should be exercised that the plates are kept a proper distance apart. The Ambu plate-burning racks are shown in Fig. 12.

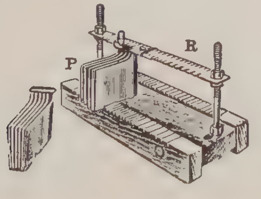

Fig. 12

In the work of burning-in plates, great care must be exercised to see that the plates are kept the proper distances apart. The Ambu plate-burning racks accomplish this work in half the time required with ordinary racks; the plates are held at exactly the correct distances apart. The single plates are set in the rack and rest in the slotted grooves of their particular size. Special fittings are used to simplify the work and to hold the plates in position. These fittings also prevent the hot lead from running away when burning, and permit of puddling the lead.

There are two types of plate-burning racks:

Type "A," the small rack, will take care of practically all 1/8″ plates, such as Exide 3XC, Willard, Gould, Philadelphia, and U. S. L. On this rack there are two slot groups, one group having slots of 5/32″ and 7/16″ between centers; the other has slots of 1/8″ and 3/8″ between centers. Price $8.00.[1]

Type "B," the large rack, is designed to care for over 95 per cent of all types of plates made. There are six slot groups on this rack, as follows: 5/32″ and 29/64″ between centers; 7/32″ and 5/8″ between centers; 5/32″ and 31/64″ between centers; 5/32″ and 7/16″ between centers; 1/8″ and 3/8″ between centers; and 3/16″ and 3/4″ between centers. Price $12.50.[1]

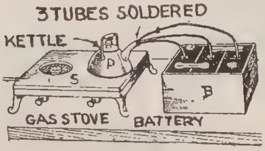

Fig. 13

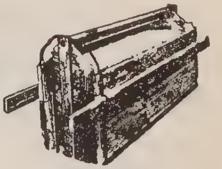

Fig. 14

Fig. 13. A home-made steam generator for softening the composition, so that the battery top may easily be removed. Consists of kettle (P), gas stove (S), and tubes. Steam is generated and passed into the cells. The acid should first be removed with a syringe.

Fig. 14. Crating a battery for shipment; note its shape in illustration. Inside diameter should be 2″ larger than the battery and the crate should be stuffed with excelsior. Label: "Handle with care—ACID."

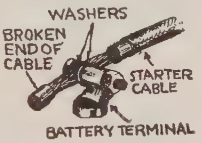

Fig. 15

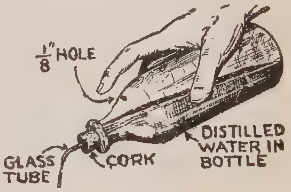

Fig. 16

Fig. 15. Method of making a temporary battery terminal.

Fig. 16. Method of refilling a battery with distilled water. Note the 1/8″ drilled vent-hole in the bottle. A glass or quill can be used for a spout.

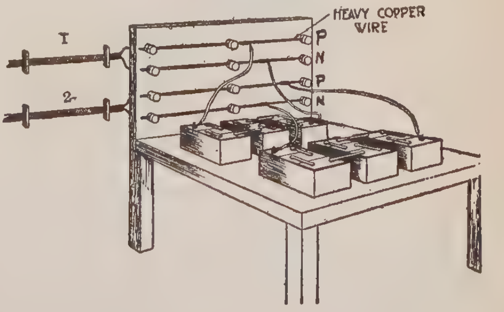

Fig. 17. Simple method of connecting many individual batteries to one pair of supply wires. (P) and (N) are large bare wires; (1) and (2) are separate circuits. Smaller leads to individual batteries can be made.[2]

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[1] The Campbell Engineering Corpn., Kansas City, Mo., supplies moulds as shown.

[1] Can be secured of A. L. Dyke, Electrical Dept., Granite Bldg., St. Louis, Mo.

[2] From *Motor Age* and *Motor World*.

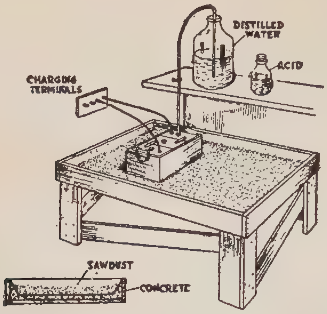

Fig. 18. **A special battery bench** with concrete basin filled with sawdust serves to make the battery work cleaner. The sawdust absorbs the acid.

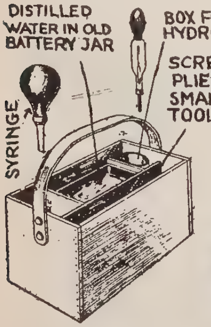
DISTILLED WATER IN OLD BATTERY JAR
BOX FOR HYDROMETER
SCREW DRIVER PLIERS AND SMALL TOOLS
SYRINGE

Fig. 19

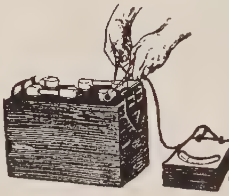

Fig. 20

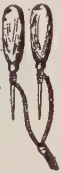

Fig. 21

Fig. 19. **Battery service kit.** A rectangular box is divided into four compartments, as shown. One contains the hydrometer, in a cylindrical pasteboard box for testing; the second contains distilled water, in an old battery jar for replenishing water; a third holds a syringe for placing the water in the battery. The fourth space runs the entire length of the box, and is used for miscellaneous tools, such as screwdriver, pliers, meter, etc.

Figs. 20 and 21. **Voltmeter and copper contact, or test-points for testing voltage of cells.** The points can easily be made by using file handles and heavy copper cable ground to a point, with flexible leads wrapped around the upper part of the points (Fig. 21), and sweated on with solder.

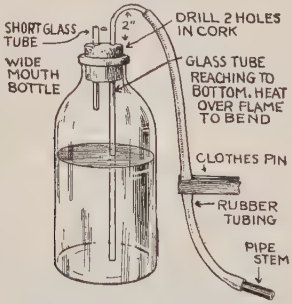

Fig. 23

Fig. 23. **The principle of the syphon** may be used in many places in repairshop work. For example, it provides a simple method of drawing distilled water for the storage batteries. A glass tube extending to the bottom of the bottle is inserted in the cork and a rubber tube is attached as shown. The end of the rubber tube must extend below the bottom of the bottle; consequently it is advisable to place it on a shelf. The tube may be made long enough to reach to the storage batteries. The flow of water is controlled by a simple spring device which pinches the tube. This may be made, or purchased at a drug store.

To put the syphon in operation it is merely necessary to suck on the tube until it is filled with water. Once this is done the water will remain in the tube and the syphon will always be ready for instant operation until the bottle is emptied. The illustration (Fig. 23) shows how to construct a syphon. This is handy for keeping distilled water ready for instant use and free from dust, etc.

The same **principle may be resorted to for drawing gasoline from a tank, oil from a crankcase, or electrolyte from a storage battery,** and is adaptable to many other uses. Of course, it is usually more convenient to drain a gasoline tank or crankcase in the ordinary way, but sometimes the syphon principle will be found quicker.

Battery Steamer and Water Condenser

Battery steamer. The tubes (P) are inserted in the cells to be opened. The steam will quickly soften the sealing compound and prepare the battery so that the elements can easily be removed. Some of the electrolyte should first be removed with a syringe so as to give the steam a chance to circulate.

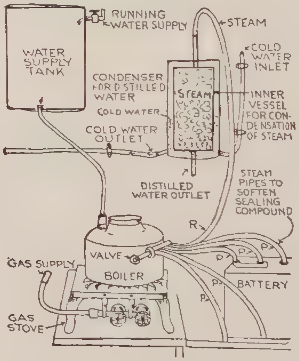

Fig. 22

Water condenser. Only pure water can be used in storage batteries. The best water to use for filling storage batteries is **distilled** water. Distilled water can be obtained at drug stores. Where considerable battery work is done it is best to have a condenser for distilling water, an example being shown in the illustration. Steam passes from the boiler through pipe (**R**), to a copper vessel, lined with bloc tin, inside of an outer vessel. Cold water circulates between the two. As steam passes into the copper vessel it is cooled (due to the circulation of cold water around it) and thus condenses into distilled water which is drawn off into an earthenware or glass vessel (not metal) at the distilled water outlet. This outfit sells for $27.50 and can be secured of American Bureau of Engineering, 2632 Prairie Ave., Chicago, Ill.

Note. All stills must be registered. Any revenue officer will register a still. This is a government requirement.

Melted artificial ice, or rain water can be used if distilled water cannot be obtained, providing it has not come into contact with metal pipes or roof. A good method of collecting rain water is directly into an earthenware vessel during a rain. The use of well or hydrant water or boiled or filtered water should be avoided as it is likely to contain iron or alkali detrimental to the plates.

MISCELLANEOUS STORAGE-BATTERY REPAIR INFORMATION

Corrosion of the terminals or other parts of the connectors should be prevented by coating them with vaseline or petroleum jelly. Sometimes they get so badly corroded that it is almost impossible to unscrew the terminals, and greasing them in this way will prevent recurrences of such trouble.

When overhauling a battery, it is a good plan to put all the connectors, terminals, and other removable pieces at the top in a strong solution of soda and hot water and to let them stay in it for about an hour, so that the solution will have plenty of time to clean them thoroughly. Then put on the vaseline, and no more corrosion should appear. In the first instance, corrosion is usually the result of overfilling the jars or spilling the solution, which in time acts upon the lead and brass terminals.

A Cracked Battery Jar

Never attempt to repair a cracked or broken battery jar, as this is impossible. When the jars get in this condition, they must be discarded as useless.

It is not very much trouble **to remove any cell from a battery,** because the makers have seen to this point. To take apart the connectors on a Willard battery, for instance, the procedure is to drill a 3/4" hole in the end of the connector, directly over the post. This hole should be drilled with any form of drill and about two-thirds through the connector, when the latter will come off readily. The connectors have to be burned back on, and more lead must be used to fill up the drilled-out hole.

To remove a cell from an Exide battery, the top nuts and connections must first be taken off, the nuts unscrewing in the regular manner (see page 586).

Celluloid jars can be repaired by making a cement of celluloid and acetone. Dissolve the celluloid in acid until it is gummy; then clean the seams and coat.

Cracked Compound

Sometimes the tar composition material that is on top of the cells cracks, and very often these become serious points of leakage of the cell solution. The best and simplest way to remedy these is to seal them together with a hot iron, such as an old cold chisel or similar tool. Press the hot iron on the sides of the crack and gradually work them together until the hole is sealed over. If more of the tar material is needed, a big lump of it can be secured from a battery supply house.

To Make a Battery Box Acid Proof

Use 6 parts of wood tar and 12 parts resin; melt them together in an iron kettle, after which stir in 8 parts of finely powdered brick dust. The surface to be covered must be thoroughly cleaned and dried before painting with this preparation, which should first be warmed.

Spilled Electrolyte

If there is evidence that electrolyte has been spilled from the cells, use electrolyte of 1.250 sp. gr., instead of water, to make up the loss.

After adding solution or water, replace and tighten the filling plugs by turning to the right, and give the battery a charge at the proper rate for the particular type of battery in question.

Never add electrolyte to a cell after the gravity has been adjusted to the proper point, unless to replace actual loss by spilling.

Prices to Charge for Battery Work[1]

Price for charging a starting and lighting battery which includes testing ....50c to $1.25

6-volt type	$ .50
12-volt type	.75
16-volt type	.85
18-volt type	1.00
24-volt type	1.25

These prices do not include changing of batteries. All changes not requiring more than 15 min., 25c. Batteries requiring more time to take out and replace will be charged for at regular labor rates.

Price per day for rental of a battery, while your battery is being charged, 10c to 25c.

Starter rental will not be installed until the generating system on the car has been tested and assurance is given that the battery will receive proper charge while the car is in use. A deposit to cover rental batteries is required.

Price for testing the electric system, other than disconnecting and connecting battery, per minute................1c to 2c

Price for repair work, per hour..................60c to $1.00

Notice: Storage batteries left over 30 days will be considered abandoned, and will be junked without recourse.

The foregoing is taken from a printed placard on the wall of a leading storage-battery repair shop.

Where to Obtain Supplies

It is best to order plates and parts of the manufacturer of the battery. Names of some of the concerns who handle supplies are:

General Storage Battery Co., St. Louis, Mo. (supplies and parts of all kinds).

Witherbee Storage Battery Co. (supplies in general), 643 E. 33rd St., New York.

Storage Battery Supply Co. (supplies in general), 239 E. 27th St., New York.

Address of Storage-Battery Manufacturers

Electric Storage Battery Co. (Exide), Philadelphia, Pa.
Witherbee Storage Battery Co., 643 E. 33d St., New York, N.Y.
General Storage Battery Co., 2005 Locust St., St. Louis, Mo.
Prest-O-Lite Co., 30 E. 42d St., New York, N.Y.
U.S. Light & Heat Corporation, Niagara Falls, N.Y.
Willard Storage Battery Co., Cleveland, Ohio.
Marko Company, 1402 Atlantic Ave., Brooklyn, N.Y.
Gould Storage Battery Co., 30 E. 42d St., New York, N.Y.
Amplus Storage Battery Co., 749 E. Van Buren Ave., Chicago, Ill.
Edison Storage Battery Co., Orange, N.J.
Vesta Storage Battery Co., 2100 Indiana Ave., Chicago, Ill.
Aurora Battery Mfg. Co., Aurora, Ill.
Permalife Storage Battery Co., Indianapolis, Ind.
National Carbon Co. (Columbia), Cleveland, Ohio.
Philadelphia "Diamond Grid" Storage Battery Co., Philadelphia, Pa.
E. S. Cowie Electric Co., Kansas City, Mo.
Detroit Storage Battery Co., Detroit, Mich.

Battery Parts

General Storage Battery Co., 2005 Locust St., St. Louis, Mo.
Aurora Battery Mfg. Works, Aurora, Ill.
Campbell Electric Co., 1529 Wyandotte St., Kansas City, Mo.

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[1] Prices vary in different sections of the country. This is an example of prices charged by a concern in the West.

INSTRUCTION No. 53

REPAIRING STORAGE BATTERIES

To be able to repair storage batteries properly, it is necessary to have on hand the tools and supplies, as well as a lead burning outfit, as previously described.

The usual battery troubles are sulphating and buckling of plates, broken down separators, and sediment accumulation in the bottom of the jar.

When Repairs Are Necessary

1. A battery terminal or connector warmer than the others indicates a loose or poor connection, which must be repaired.

2. Broken, cracked, or leaky jars must be replaced; they cannot be mended.

3. A cell leaking around the cover should be resealed.

4. If the cause of trouble is not apparent, take hydrometer readings and make the high-amperage-discharge test, as described on pages 553, 559. If this indicates internal trouble, take the battery or the indicated cell apart and inspect it.

When to Take a Battery Apart

When one or more cells of a battery do not take a charge after being on charge for 24 hours, make a high-amperage-discharge test, and note the indications, as sugested in the "Digest of Troubles" and on page 553. Then make a cadmium test, as directed on pages 547 to 552.

If the tests prove defects to exist inside, then the battery must be disassembled.

Before disassembling, the defective cell should be located by testing, and inasmuch as other cells may be on the verge of a breakdown, it is advisable to disassemble all cells. If other cells are not defective, they should at least be washed, and have new separators added.

DISASSEMBLING BATTERY[1]

As an example, the Exide "3–XC–13" battery will be used.

Removing Connectors

The connectors are solid lead links (Fig. 1) or flexible lead-coated copper strips, and may be removed by taking a wood bit and boring the connectors ¼″ deep centrally over each post as shown in Fig. 2. For all but types KZ and ZA, use a ⅝″ bit, and for these a ⅜″ bit.

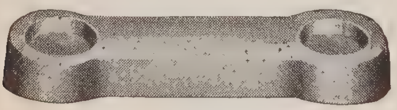

Fig. 1. A lead connector.

Another method is to play a burning flame on the joint, at the same time pulling the connector with a pair of pliers until it comes loose.

Be careful to see that no gas is coming out of the cell when handling a flame about it.

Unsealing Cells

1. Clean any dirt or lead from the top of the battery, taking care that none gets inside the cells.

2. Remove the filling plugs and blow gently into the filling tubes to remove any gas which may be there and which might ignite later when a flame is brought close. Hand bellows are convenient for this purpose.

3. Types JX, LX, LXR, LXRV, PHC, SX and XC have the single-flange type of cover, which has sloping sides flanged outwardly at the base to fit the inside of the jar snugly, while at the top it clears the jar, giving a space of about ¼″ for sealing (Fig. 3).

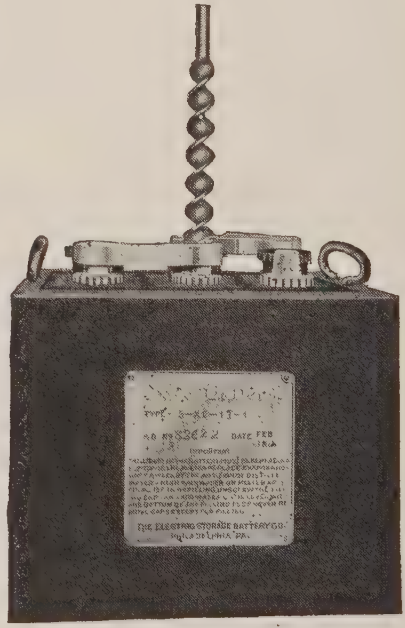

Fig. 2. Boring a lead connector.

To unseal, it is not necessary to remove the cell from the case. Heat a thin-bladed knife, such as a putty knife, and run it through the sealing compound close to the jar wall all the way around. This will loosen the compound and the element with cover attached can be pulled from the jar.

4. Types KXD, KZ, LXRE, MHA, PHA, XE and ZA have the double-flange type of cover, which is made with the two flanges projecting downward, one fitting inside and the other outside of the jar

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[1] From Instruction Book of The Electric Storage Battery Co. (Exide); copyrighted, 1921.

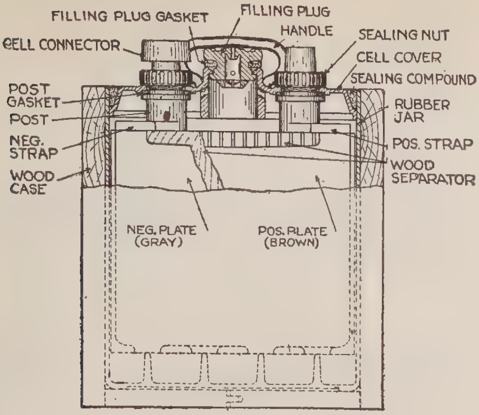

Fig. 3

walls. The two flanges form a channel or slot, holding the jar walls and sealing compound between the flanges (Fig. 3). To unseal, warm the cover all around the edges, and the compound will soften so that the element with cover attached can be pulled from the jar. The warming may be accomplished by passing a moderate flame around the cover, taking care not to hold it on one spot long enough to burn the rubber.

5. **A very effective way of softening the compound** for unsealing any type is to place the cell or battery in a steam box. This consists simply of a box or oven into which live steam is injected at low pressure. By this means, the rubber parts are made somewhat pliable and are much less likely to be cracked in handling, especially in cold weather. Another method is to stand the cell in very hot water, taking care that the water does not get inside of the cell.

Removing Elements from Cell

1. Remove the connections.

2. Unseal the cell. It is unnecessary to remove the cover from the element, but this may be done.

3. Take hold of the two posts with gas pliers and pull the element from the jar. If it should stick, pull the jar along with it and place the cell in very hot water to within an inch or so of the top of the jar. This will soften the rubber and permit the element to be pulled out.

4. Before pulling all the way out, let the element rest a few minutes on the top of the jar at an angle so that the battery solution may drain back.

5. If the element is to be used again, place it in water or in a battery solution until ready to use. This prevents the negative plates from drying out, and will save considerable time during the charge following reassembly.

Removing Jars from Case

1. Remove the connections.

2. Note at which corners of the case the battery terminals are placed, so that they will not be put at the wrong place upon reassembling.

3. Unseal the cells.

4. Remove the elements.

5. Types KXD, LXRE, MHA, PHA, XA and XE have the jars separated in the case by painted wood spacers divided horizontally, and between the two sections runs a tie bolt (Fig. 3). These bolts should be unscrewed one or two turns with a screwdriver, thus releasing the jars.

6. Heat a thin-bladed knife, such as a putty knife, and work it down all around the outside of a jar.

7. Lift out the jars. If they stick, empty the solution and fill the cells with very hot water, allowing them to stand a few minutes. Then pull them out with pliers.

Removing Covers from Cell

1. Remove the connections.

2. Remove the sealing nuts by unscrewing them with the special wrench designed for the purpose. Do not use gas pliers or anything except the proper wrench in removing the sealing nuts, because both the nut and the thread on the post are lead and may be injured.

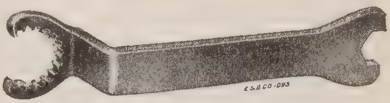

Fig. 4. Sealing nut wrench.

3. Unseal the cells as outlined above, and pull off the covers.

4. If the cell is out of the case and has a double-flange cover, the cover may be removed.

Procure two stout boards about ¼″ longer than the height of the jar and rest the side flanges of the covers on these so that the cell is raised. By warming the cover all around the edges, the compound will soften so that, by pressing down on the posts, the jar with the element in it will readily drop free from the cover.

Taking Elements Apart

1. The cover must be removed.

2. Lay the element down with the plates on edge.

3. Slightly spread the plates and withdraw the separators one at a time, first separating them from the negative plates by running a thin-bladed knife between.

4. The positive and negative groups can then be separated from one another.

5. If the negative plates are to be used again, do not let them dry, but place the group in water or in a battery solution. This will save time in the length of charge after reassembling.

To Tell When New Positive Plates Are Necessary

The positive plates should be examined particularly for washing out of material and buckling (warping).

If the plates are buckled so much that the element will not go back into the jar, the positives should be discarded.

If the plates are only slightly buckled, they can be replaced as they are, since this generally does no harm.

To Tell When New Negative Plates Are Necessary

The negative plates are nearly always in good condition mechanically, as they are not affected by abuse as readily as the positives.

If the positives are buckled, the negatives will be also; but if they are in a charged condition, they can readily be straightened as folllows:

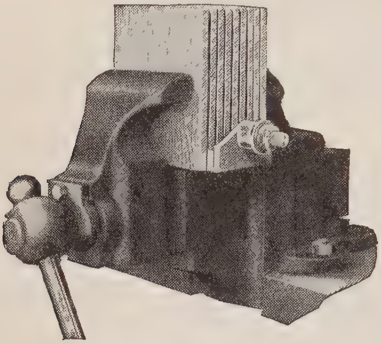

Fig. 5. Straightening plates.

Place boards of suitable thickness between the plates and outside of the group, and slowly apply a gradual pressure. This may be done in a vise, leaving the pile in the vise for some minutes during the operation to give the plates a chance to straighten without undue strain (Fig. 5).

If the battery has been badly abused, "starved," or neglected, the negatives may have shed material. In this case, it is best to use a new group. If the negative material is very hard and not spongy, it is "sulphated," and particular care should be used that the subsequent charge is made complete.

To Tell When New Separators Are Necessary

Unless a battery is new, it will be found advisable to install new separators whenever a cell is dismantled for repairs, since it is of vital importance in a battery to have the separators in good condition.

No wood separators should be used except the specially treated separators furnished by the manufacturer. These should be kept in stock wet, preferably in battery solution.

New separators may be dark, light, hard or soft, according to the kind of wood used. However, none of these qualities affect the value of a separator, which depends on its having been selected and treated properly, so as to have correct porosity and ability to withstand the chemical action of plates and electrolyte.

Before being used, separators should be soaked in battery solution, at least overnight, so that they will be thoroughly saturated before being put into the cell.

Perforated rubber sheets, when used, are nearly always in condition to put back unless broken in handling. It is advisable to carry a small stock of these for emergencies.

Sediment

The sediment in the bottom of the jars will rarely be found to have reached the plates, but whenever a cell is taken apart for any purpose, it is advisable to wash the sediment out of the jar.

In types KXD, LXRE and XE there are four soft-rubber buffers, each resting on one of the ridges in the bottom of the jar. These must be replaced.

Using Battery Solution Over Again

Sometimes impurities get into the solution through carelessness or ignorance, but their detection is not practicable except by an expert chemist. As a precautionary measure, the use of new electrolyte of known purity is recommended when repairing a battery.

When the positive plates are badly disintegrated, it is often a sign of foreign matter in the electrolyte, and in such a case it is safer to discard the negatives and separators as well, since they may hold some of the impurity and be the means of ruining the new positives in a short time.

To Tell When a New Case Is Necessary

Unless the jars have been broken or the battery has been abused in some manner, the battery case will usually be found to be in good condition. If the case has become acid-soaked and rotted, a new one should be used. When the old case is to be used again, it should be soaked in a solution of baking soda and water. This will neutralize any acid and prolong the life of the wood. Rinse with water and allow it to dry thoroughly Repaint the case inside and out with asphaltum or other acid-resisting paint.

REASSEMBLING BATTERY[1]

Replacing Elements

1. Slip the positive and negative groups together without the separators.
2. Replace the covers.
3. Insert the separators.

Replacing Covers

1. Place the covers in hot water for a while. This makes them somewhat pliable.
2. Wipe the posts with a piece of waste moistened with ammonia, rinse with water, and dry thoroughly with clean waste.
3. Place the cover in position, being sure not to omit the soft rubber washers under the cover.
4. Lubricate the sealing nuts with a little graphite mixed to a paste with water; but never use grease or vaseline.
5. Put on the sealing nuts and tighten them, using the special wrench (Fig. 4).

Inserting Separators

1. Place the groups on edge (Fig. 6) and insert the separators from the bottom, one at a time. One separator goes between each positive and negative plate with the flat side of the separator against the negative plate. Separators should be so placed that the grooves will be vertical and not crosswise when the element is in the jar.
2. Types KXD, KZ, LXR, LXRE, LXRV, MHA, PHA and PHC have, in addition, rubber sheets, one of which should be placed against the grooved side of each wood separator before inserting.
3. When all the separators are in place, count them to be sure that none are missing.
4. Stand the element up and tap the edges of the wood separators with a wood block until they project equally on each side of the plates.

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[1] From Instruction Book of the Electric Storage Battery Co. (Exide); copyrighted, 1921.

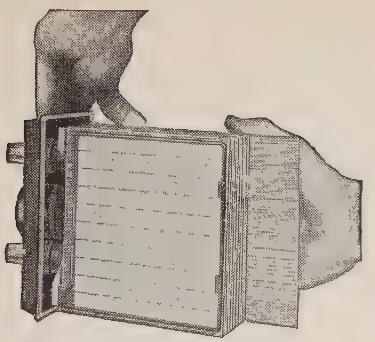

Fig. 6. Inserting separators.

5. Tighten up the sealing nuts, using the special wrench (Fig. 4).

6. Lock the sealing nuts.

Replacing Elements in Jars

1. Place the jars in hot water for a while. This makes them somewhat pliable and less likely to crack under stress.

2. In Types KXD, LXRE and XE be sure to replace first the four soft-rubber buffers in the bottom of the jar, one over each ridge.

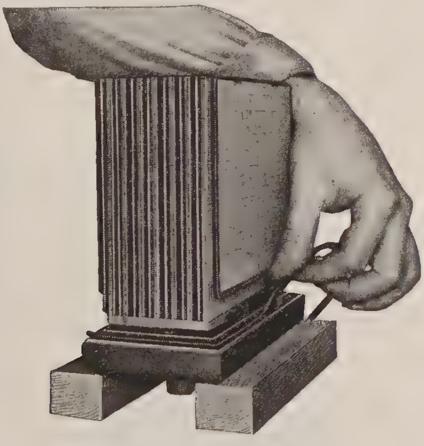

Fig. 7. Applying sealing compound to double-flange cover.

3. For Types KXD, KZ, LXRE, MHA, PHA, XE and ZA, which have the double-flange type of cover, have ready a string or worm of sealing compound about 3/16″ in diameter, made by rolling between boards some of the special compound furnished for the purpose. Stand the element upside down with the cover resting upon two strips (Fig. 7). Lay the string of compound all around the cover channel and then turn right side up.

4. Grip the element near the bottom, in order to keep the plates from flaring out. Take care not to let the outside plates start down over the outside of the jar.

5. The element should fit snugly in the jar. If it does not, place one or more wood separators between the end plates and the jar, taking care that such separators are cut ½″ narrower than the plate, so as not to throw extra strain on the corners of the jar. The ribs of the separators should go against the jar. Do not, however, crowd the jar so that it bulges.

6. Tighten the sealing nuts again and then lock them.

Sealing the Cells

1. Before sealing, always wipe the surfaces to be sealed with ammonia, and then allow them to dry thoroughly, otherwise the compound may not stick, and a leak may result.

2. For Types JX, LX, LXR, LXRV, PHC, SX and XC, which have the single flange type of cover, slowly heat the sealing compound until it runs, but do not get it so thin that it will run down into the cell between the cover and jar. Then pour it into the channel between the cover and the jar walls. Allow it to cool, and finish it off flush with a hot knife. When pouring, be sure the compound is liquid and not lumpy, as in such a case a poor seal will result. A glossy, finished appearance may be given to the compound by passing a flame over it after the job is finished.

3. For Types KXD, KZ, LXRE, MHA, PHA, XE and ZA the sealing compound should already be in the cover channels. Apply heat carefully to the edges of the cover and force the cover down gently. If too much compound has been used, so that it squeezes out around the cover, scrape off the excess with a hot knife while forcing the cover down.

When Cells Should Be Filled with Electrolyte

As soon as the cells are sealed, electrolyte of the proper strength should be added to keep the separators and plates from drying out.

Proper Strength of Electrolyte to Use

1. **After a complete renewal of plates and separators,** fill with electrolyte of the proper strength, as given on page 535.

2. **After a positive plate or separator renewal,** or both, fill with "pure" water instead of electrolyte, since batteries received for repair have the plates in a more or less sulphated condition. This filling with water, together with the proper charge after repairing (see "Charge required after repairing"), is known as the **"water treatment" for sulphated cells.**

How to Fill Cells with Electrolyte

1. Use vessels of glass, china, earthenware, rubber, or lead; never use metallic vessels unless of lead.

2. Carefully pour the liquid through the filling tubes until the level rises in the tubes. If the cover is not on the cell, fill to ½″ above the tops of the plates.

Replacing Cells in Case

1. Be sure to put the cells into the case properly, so that two positives or two negatives will not be connected together, and also so that the battery terminals will not come at the wrong corners of the case.

2. In Types KXD, LXRE, MHA, PHA, PHC and XE, which have wood spacers between the cells, take care that the spacers are in position and then, after the cells are in place, tighten the tie bolts with a screwdriver to clamp the jars.

3. In Types JX, LX, LXR, LXRV, SX and XC, the cells should fit tight in the case; pack them in with thin boards if necessary.

How to Make Connections

1. The cells must all be sealed and in the case.

2. Connectors must be lead-burned. First see that the posts and eyes of the lead connectors are clean and bright. In all lead-burning, absolutely clean surfaces are essential to good workmanship. Lead is soft and very readily cleaned with a knife, file, scraper, or wire brush.

Place the connectors over the posts, lightly tapping them to a firm seat.

Before lead-burning, blow into the filling tubes to remove any gas which may be there.

Lead-burn the joint by first melting the parts to be joined and fusing them together, and then immediately melt in burning strip until the joint is flush. Do not melt in burning strip until the parts have fused together nor after the joint has cooled, and do not use any soldering acid or other flux. A little practice may be necessary before a good joint can be made.

Recharging Battery after Repairing

Note. This method is also used for charging badly sulphated cells, and is known as the **"water treatment"** for sulphated cells.

1. Not sooner than ten to fifteen hours after filling a battery with electrolyte or water, as the case requires, add more to restore the level if it has fallen.

2. With filling plugs out, give the valves a quarter turn, bringing them into a position so that hydrometer readings can be taken. This is to allow of taking hydrometer readings while charging and at the same time prevent flooding, which might occur if the filling plugs were left out and the valves were not turned.

3. If a **complete renewal** has been made, start charging and continue at the amperes shown in the table under "Initial Charge and Repair Charge," page 577, until the battery has received at least the number of ampere-hours also shown. If this rate is maintained, the time required is ninety-six hours.

4. If a **renewal of positive plates or separators** or both has been made, charge at amperes shown in the same table, just mentioned, until all cells are gassing or bubbling freely and evenly, and until the hydrometer reading of every cell goes as high as it will. Then charge for ten hours longer.

5. If the hydrometer reading of any cell continues to rise above 1.310 (1.240)[1], dump the solution, refill with "pure" water, and continue to charge at the same rate until the hydrometer reading of every cell goes as high as it will. Then charge for ten hours longer.

6. Keep the temperature of the solution below 110° (125°)[1] F., interrupting the charge if necessary.

7. After the charge is complete, adjust the strength of the solution to between 1.270 and 1.300 (1.200[1] and 1.230[1]), as explained under "Exide Instructions for Adjusting Electrolyte," page 536.

8. Wipe off the top and sides of the battery case with a rag dampened with ammonia to remove any electrolyte that may have been spilled.

9. Just before putting the battery into service, make high-amperage-discharge test (see page 553).

THE EDISON STORAGE BATTERY

The elements of the Edison storage battery are as follows:

The positive plate, i.e., plates attached to the positive pole, are cylindrical tubes of nickelplated, perforated, spirally seamed thin steel ribbon, filled with alternate layers of a specially prepared nickel hydrate and flakes of pure metallic nickel; the former being the initial state of the positive active material, while the latter is the conductive medium. These tubes are hydraulically crimped at their flattened ends into nickelplated steel grids, a right-hand spiral alternating with a left-hand spiral for equalization of stresses.

The negative plate, i.e., plates attached to the negative pole, are rectangular pockets of nickelplated, perforated steel ribbon, filled with a solid mass of a specially prepared electrochemically active iron oxide and a small proportion of mercury oxide evenly distributed; the former being the initial state of the negative active material, while the latter is the conductive medium. These pockets are hydraulically crimped at their grooved edges into nickelplated steel grids.

The electrolyte is an alkaline solution consisting of specially prepared potassium and lithium hydroxide in distilled water.

Cell and battery voltage: At the 5-hour rate, or the normal rate of discharge, the average voltage per cell is 1.2 volts, while at the 8-hour rate of discharge the average voltage is 1.24 volts. Therefore, when it is desired to discharge at the 5-hour rate, 5 cells would be required for a 6-volt battery.

The advantages of the Edison cells are endurance, reliability, low maintenance, ruggedness, and light weight. The Edison storage battery is the only storage battery made of steel. Its long life is a leading feature in which it is without equal. Its reliability, low maintenance, and ruggedness are proverbial owing to the fact that there is very little sedimentation and, therefore, a very low maintenance, and owing to the fact that it is entirely built of steel, the battery is extremely rugged. There are no jars to break, and the abuses which are common to all types of batteries, which have been the causes of various diseases in the lead-acid type, are almost entirely foreign to the Edison battery, there being no such thing as sulphation, buckling, and growth of plates.

The light weight of the Edison battery is well known, it being for equivalent capacity from 20 to 25 per cent lighter than any other battery on the market, and in the case of the storage-battery vehicle this saving in weight on the battery may be added to the paying load that the vehicle can carry.

The Edison battery is particularly adapted to installations where ruggedness and reliability, not to mention long life, are the main factors. It is used for electric vehicles of all types, including electric trucks, tractors, industrial trucks, storage-battery locomotives, and the more severe classes of station battery work. It is not suited to gasoline automobile starting work, owing to the fact that its inherent characteristics making for reliability, endurance, low maintenance, ruggedness, and light weight prohibit the drawing of tremendous rates of current for short intervals, as is necessary in gasoline automobile starting work. There have been, however, numerous instances of the applications of Edison storage batteries to starting work on gasoline engines up and above the horsepower generally found on automotive vehicles.

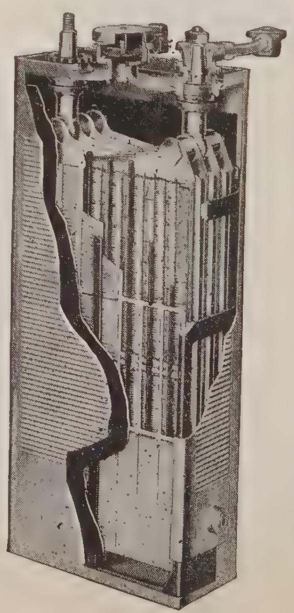

Fig. 8. Part sectional view of the Edison storage battery.

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[1] The reading in parentheses applies to batteries used in tropical climates.

INSTRUCTION No. 54

TIRES

Tires are used on automobiles to overcome the vibration. If the wheels of an automobile were not properly tired, the machine would soon rack itself to pieces. The great weight and speed of the automobile, and its delicate construction, necessitate provision for protection additional to that of the springs alone.

There are two types of tires, the solid and the pneumatic. The **solid tire** is used to a great extent on electric vehicles and trucks, because they are usually slow-speed vehicles. If solid tires were used on high-speed cars, the vibration would be so great that the car would soon rack itself to pieces.

PNEUMATIC TIRES

The pneumatic tire is the type of tire used on all pleasure cars. With pneumatic tires, the car is suspended on air, which is the most elastic of substances. There are two forms of pneumatic tires: the single and the double tube.

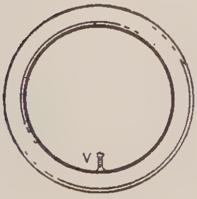


Fig. 1

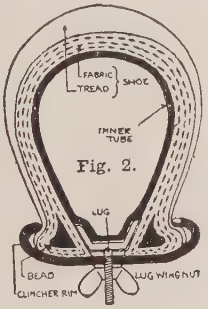


Fig. 2.

Fig. 1. The old-style and original pneumatic tire was a "single-tube tire." The casing itself held the air and did not contain an inner tube.

Fig. 2. The double-tube pneumatic tire. Note that the inner tube sustains the air.

Single-tube pneumatic tire. The first, and now obsolete, method, was a single-tube tire, made air-tight and without an inner tube. This type of tire was merely an outer casing made air-tight, and was fitted with an air valve. It was used extensively during the early days of motoring, but inasmuch as it is now obsolete, we will confine our instruction mainly to the modern type of pneumatic tire.

The double-tube pneumatic tire is the type of tire in general use. It consists of two chief parts: the "inner tube," which holds the air, and the "shoe" or "casing," which retains the inner tube, and protects it from wear (Fig. 2).

A steel rim is placed around the felloe of the wheel, and shaped to fit the tire, its exact shape depending on the design of the tire.

Double-tube tires have projections on the side, called **"beads,"** which fit under grooves or into channels in the side of the rim, the pressure of the air in the inner tube holding them in place.

Inner Tube and Valve Stem

Inner tubes used on automobile pneumatic tires are of the endless type. The only opening into the tube is the **inner valve** (A) (Fig. 3), through which the air is forced. As the tube becomes inflated by air pumped into it, the bead of the tire is forced outward and tightly clinches to the rim channel and can be dislodged only by deflating the tube.

The inner-tube valve-stem is the part shown in Fig. 3. It is the part to which the inner tube is connected as shown in Fig. 4, (T) being the inner tube. The base (G) of the valve-stem is passed through a heavy, tough piece of rubber, called the "valve-stem seat," which is vulcanized to the tube at this point. By stretching the opening in this valve-stem seat, the base (G) is placed inside of the tube and locked by clamp nut (ST) (Fig. 4).

The valve-stem is passed through a hole in the felloe of the wheel when the tire is applied to the wheel and the rim, as in Fig. 27, page 596. The stem is held rigid, after being applied in this manner, by locknut (N) and washer (M) (Fig. 3).

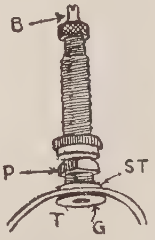
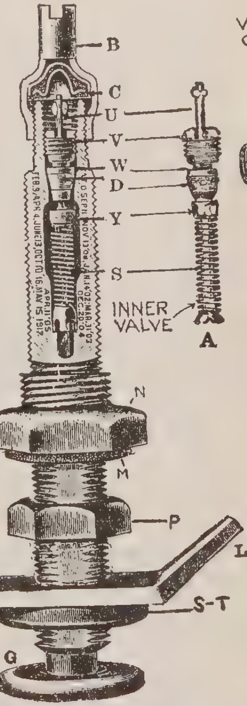


Fig. 4

Note method of clamping the air valve to inner tube.

T, tube; G, base; ST, clamp nut; P, lock-nut.



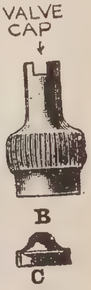


Fig. 3

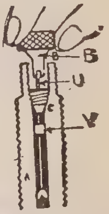


Fig. 5

Fig. 3. Schrader No. 777 inner-tube valve; full size for 3″ tubes and under. No. 725 for 3½″ and over is larger.

(A) inner valve; (B) valve-cap; (C) rubber disk (for cap B) (D) rubber packing; (N) locking nut (for dust cap); (M) leather washer; (G) valve-stem base, goes inside of tube; (P) locknut (for valve-stem); (S-T) clamp disk; (L) valve-spreader.

DUST CAP
PAT. APR. 30 JULY 9 1907 SEPT. 5 1910 REG. U.S. PAT. OFF.
SCHRADER UNIVERSAL DUST CAP No. 2065

Fig. 6. **The dust cap** screws over the valve-cap into the valve-stem, thus protecting the inner parts of the valve-stem from dust, water, etc.

Inner-Valve Principle

The inner valve (A) (Fig. 3), also called the "valve plunger," is an automatic air check valve for retaining the air in the tube. It is screwed into the valve-stem opening, usually by the notched end of the valve-cap (B) as shown in Fig. 5.

(V) is the threaded part which screws into the valve-stem; (W) is metal, with rubber packing (D) around it, which makes an air-tight joint with the walls of the valve-stem; (Y) is a cap holding spring (S) in place, and on its upper part is a rubber washer which is the "valve-seat" which is between the bottom of (W) and the upper part of (Y). This is the seat, or point where the air pressure in the tube is retained because the lower part of (W) is in contact with the rubber washer seat on top of (Y), which is held together by the tension of the spring. This seat is shown open in the illustration.

Pin (U) is firmly attached to (Y), but works freely through enlarged holes in (V) and (W), and these holes also serve as the air passage to or from the valve-seat. The spring holds the valve to its seat, but can be depressed at (U), or air from the air pump will be sufficient to force the valve from its seat.

To inflate the tube, unscrew valve-cap (B) and screw in its place the hose coupling from the air line. Inside of this hose coupling is a projection which presses the pin (U) down against the tension of spring (S), which separates the seat on the upper part of (Y) from the lower part of (W). The air then passes in through the enlarged hole in (V) and (W) and out at the bottom of (W) at the seat, which is now open. When the air-line coupling is removed, pin (U) rises and brings the upper part of (Y) and the bottom part of (W) to a firm seat, and pressure of air in the tube also assists in forcing spring (S) against (Y) and in tightening the seat.

To deflate the tube, valve-cap (B) is removed, turned upside down as in Fig. 5, and pin (U) is pressed down by it, which opens the inner-valve seat. Or the valve-cap (B) can be used to unscrew the inner valve at (V) and can be removed entirely, which is the proper thing to do when removing a punctured tube or when rolling it up as shown in Fig. 13, page 613.

Sometimes the inner valve leaks, owing to the valve cap (B) being screwed down so tight that the rubber disk (C) spreads and forces pin (U) down (see page 613, for inner tube troubles).

Treads of Tires or Outer Casings

The tread of a tire is the part of an outer shoe or casing, which is the part that comes in contact with the road.

The treads[1] **of tires** or outer casings are divided into three types: the **smooth tread,** the **non-skid tread** (Fig. 7), and the **ribbed tread** (Fig. 8). The latter tread is used on "cord tires," as will be explained farther on, as well as on fabric tires.

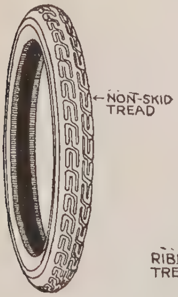


Fig. 7

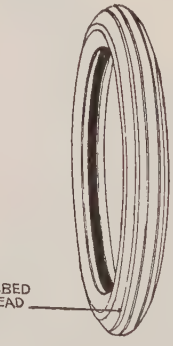


Fig. 8

There are **several different makes of non-skid treads** (as shown in Fig. 9), but the principle or purpose of all is to prevent skidding. The original non-skid tire was the Bailey tread. The Firestone non-skid tread was introduced soon thereafter.

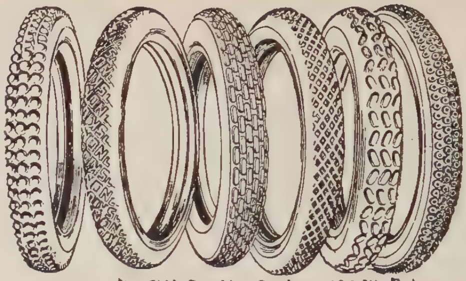


Fig. 9. Some of the different designs of non-skid treads.

The number of accidents which have occurred on account of skidding on slippery pavements has shown the need for some method of prevention.

The original method was by the use of **tire chains** (Figs. 10 to 13) which, so far as the prevention of skidding was concerned, fulfilled their purpose. But the use of chains was found to be detrimental to tires when introduced between the blow-up tire and the hard pavement. And, in addition, chains were found to be hard riding and noisy.

The non-skid tread was introduced to overcome this difficulty, but while they prevent skidding to a certain extent, the chain still remains the only positive preventive of skidding, after all The extra wear and gripping surface, however, obtained with the non-skid tread is well worth the difference in price, and this sort of tire ought at least to be placed on the rear wheels.

The usual tire equipment consists of smooth or ribbed tires for the front wheels and non-skid tread tires for the rear wheels, with rims of the demountable straight side type.

The Non-Skid Tire Chains

For heavy weather and snow time and wet, frozen, or slippery streets, there is nothing equal to a good set of chains: one on each wheel. If only two are used, they should be on the **rear** wheels. If only **one** is used, it should be on the left rear, to avoid being damaged against the curb. Fasten them tightly, but not so tightly that they cannot creep. If they are held rigidly in one place they wear into the tread and ruin it.

The method of applying Weed tire chains over tires is shown in Figs. 10 to 12.

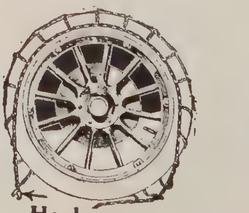


Fig. 10

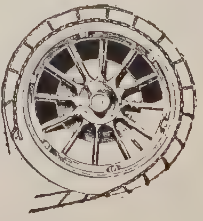


Fig. 11

Fig. 10. Lay the chains over the wheel with the hooks toward the rear, and tuck the slack under the front part of the wheel.

Fig. 11. Start the car forward just enough to run over the slack ends.

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[1] The smooth tread has been discontinued. Fabric tires are now made with "ribbed" or "non-skid" tread, and cord tires are likewise made with "ribbed" or "non-skid" treads.

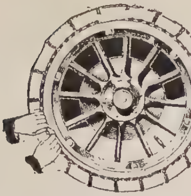


Fig. 12

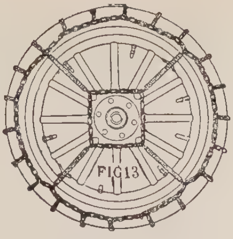


Fig. 13

Fig. 12. Hook the chains as tightly as possible by hand.

Fig. 13. Tire **chain adjusters,** consisting of springs with tempered helical hooks and chain as shown, which automatically takes up any stretch in tire chains, and thus keeps the chain close to the tire. Prevents grinding action and insures silence.

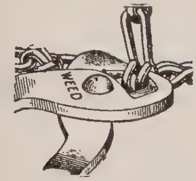


Fig. 14

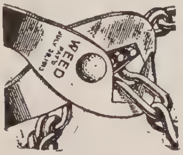


Fig. 15

Fig. 14. Weed **chain pliers** for opening the hooks on Weed cross-chains.

Fig. 15. Weed chain pliers being used to close the hooks. Cutting pliers for repairing chains can also be secured (American Chain Co., Bridgeport, Conn., Mfrs. of Weed Chains).

Tire Protectors

The steel disk type of puncture-proof tire (Fig. 16) consists of three layers of 7/16″ diameter steel disks about 1/64″ thick, imbedded in rubber between the fabric and tread of the tire. The layers of disks are placed in such a manner that it is impossible for a nail to enter the tread of the tire without striking a disk. This tire is called the Lee puncture-proof tire.

The leather-lined puncture-proof tire consists of a specially made tire on the **inside** of which is a puncture-proof strip of chrome leather which is intended to prevent punctures without stiffening the tire. This tire is known as the Woodworth trouble-proof tire.

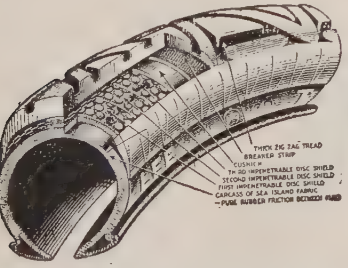

THICK ZIG ZAG TREAD
BREAKER STRIP
CUSHION
THIRD IMPENETRABLE DISC SHIELD
SECOND IMPENETRABLE DISC SHIELD
FIRST IMPENETRABLE DISC SHIELD
CARCASS OF SEA ISLAND FABRIC
PURE RUBBER FRICTION BETWEEN

Fig. 16. Lee puncture-proof tire.

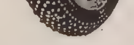


Fig. 17

Another example is **the outer leather cover** made of waterproof chrome leather studded on the tread surface with steel rivets. These covers completely enclose the tire, and are attached to the rim, as shown in Fig. 17. The manufacturer claims that they are particularly valuable to use over old tires or to re-tread and strengthen them, and that they are also valuable to people who have to run over roads that are rough, rutty, and rocky, and who travel at less than 25 miles per hour. (Woodworth Mfg. Corpn., Niagara Falls, N.Y.)

Air Pressure in Tires

There are four ways in which one can save on tire bills: first, by keeping the tires at all times well inflated; second, by using your brakes with caution; third, by not overloading the car; fourth, by repairing small cuts in the tread as they appear, and being sure that the wheels are in alignment.

More than three-fourths of all tire trouble is caused by under-inflation. A soft tire, by having its sides bent at a sharp angle, will soon have its fabric loosened from the rubber, with consequent liability of an early rupture. Besides, a hard tire presents less surface to the road, and is therefore less likely to suffer cuts and punctures.

The most important thing to fix in mind on the subject is that **load** as well as **inflation** must be considered to get good results. These two factors are interdependent. You cannot consider one properly without regarding the other.

If you **increase the load imposed on a given tire, you must increase the inflation pressure**—and vice versa—if you are to maintain the proper degree of flattening.

From this it will be seen that there is no fixed pressure which can be set as a standard for any size of tire, regardless of load.

That the inflation pressure should vary in tires of a given size according to the load they are obliged to carry, is obvious when you consider, for instance, a 4-inch tire used on a heavy touring car and another 4-inch tire used on a light roadster. Obviously the weight on the former is a great deal more than that on the latter, so that the former tire will be flattened or distorted a great deal more, providing tire pressure is the same. In order to prevent this flattening from becoming abnormal and in that way affecting the tire detrimentally, it will be necessary to maintain a higher inflation pressure in the touring car than is used in the tires on the light roadster.

If the tire is inflated so that it does not flatten at all under the load, **more service** will probably be received from it. However, this will cause the car to **ride harder.**

If the tire is underinflated, that is, if the amount of air allows too great a degree of flattening, the constant distortion at its point of contact with the ground as the wheel revolves will generate heat in the side walls of the tire. This heat destroys the rubber between the individual plies of fabric and tends to separate them. Separation of this kind **weakens the tire** so that it is not long able to stand up under ordinary road conditions.

Pressure to Be Carried in Tires and Maximum Load per Tire

The pressure to be carried in tires and the wheel-load that the different sizes are intended to carry is shown in the table (Fig. 18) and is in accordance with the recommendation of the S. A. E.

Tire Size	Fabric Tires for Passenger Cars		Cord Tires for Passenger Cars		Cord Tires for Commercial Vehicles	
	Maximum Load per Tire, Lb.	Air Pressure, Lb. per Sq. In.	Maximum Load per Tire, Lb.	Air Pressure, Lb. per Sq. In.	Maximum Load per Tire, Lb.	Air Pressure, Lb. per Sq. In.
3	375	45	400	40	....	....
3½	570	55	600	50	....	....
4	815	65	850	60	850	70
4½	1100	75	1200	70	1200	75
5	1500	85	1700	80	1700	80
6	....	....	....	....	2200	90
7	....	....	....	....	3000	100
8	....	....	....	....	4000	110
9	....	....	....	....	5000	120
10	....	....	....	....	6000	130

Fig. 18. **Carrying capacities and inflation pressures of pneumatic tires recommended by the S. A. E.** (Society of Automotive Engineers). The difference in construction of the "fabric" and "cord" tire is explained farther on.

To find the wheel load for any particular car: First, it is necessary to know the weight of the car, with all the passengers and accessories, water and gasoline tanks filled and on board. After weighing the whole car, weigh back of car. To do this, the middle of the step of the car should be over the edge of the platform scale—if a regular wagon scale is not available.

Weigh the front of the car in the same way, the middle of the step being over the other end of the platform. If this has been carefully done, the last two weights added together should give within twenty pounds of the total weight of the car when weighed complete. Of course the wheel loads are one-half of the respective axle loads as found in this way. In this way you can see if your car is tired properly by referring to the scale showing the size of tires to use.

Inflation Pressure during Hot Weather

The question of whether or not inflation pressure in tires should be reduced in hot weather is a very interesting one, because it is generally supposed that the pressure should be reduced in the summer time.

A test was made with a 33 x 4 tire on one of the hottest days in June, and it was found, that even if the car was driven at excessive rates of speed, the increase in inflation pressure amounted to only 4 pounds, which of course, is negligible, because many times 4 pounds would not cause the tire to blow out. **It may be assumed, therefore, that the same pressure can be used the year around.**

To Get Better Cushioning: Change to Oversize

If it is desired to increase the durability or mileage obtained from the tires, the inflation pressure should be increased. In extreme cases, where better cushioning effect is desired, this can be done by decreasing the inflation pressure. However, that is bound to cut down the mileage received from the tire. The best way to get better cushioning is to change to oversize tires, because in that case a lower inflation pressure can be used.

For instance: Suppose that a 4-inch tire carrying a weight of 815 pounds per wheel should, according to the table, be inflated to 65 pounds. If the motorist found he wished easier riding, the best thing he could do would be to change over to 4½ inch tires, which, with a load of 1,100 pounds, would need to be inflated only to about 75 pounds.

Oversize Tires

All tire makers agree that a larger size tire, giving a larger air cushion, is better than a smaller tire with a smaller air cushion. If you think your tires are too small, place a larger size tire on the rim, in accordance with the table below.

Standard Oversize Tires

Standard Tire Sizes	Oversizes Made to Fit Same Rims
30 x 3½ C	31 x 4 C
32 x 3½ SS	33 x 4 SS
32 x 4 SS	33 x 4½ SS
33 x 4 SS	34 x 4½ SS
34 x 4 SS	35 x 4½ SS
32 x 4½ SS	33 x 5 SS
34 x 4½ SS	35 x 5 SS
36 x 4½ SS	37 x 5 SS

C means clincher.
SS means straight side.

The oversize tires listed above are made in **fabric** construction. The **cord** tire construction is also to be had in all of the sizes mentioned except 31 x 4C.

You can figure the oversize tire your rim will take by adding one-half inch to the cross-section and one inch to the diameter. For instance, suppose your present tire is a 32 x 3½; by adding one inch to the diameter we have 33 and adding one-half inch to the cross-section we have 4, therefore a 32 x 3½ rim will take an oversize tire 33 x 4.

Transposing Tires

Ruts, curbings, and similar tire destroyers may wear the outer wall of a casing nearly to the fabric, but if the tire is reversed, and that side which has been exposed and most worn is placed nearest the car, it will still be serviceable.

As the rear tires sustain more than half the burden in every movement of the car, they will wear more rapidly than the front tires; they also have to bear the traction strain, that of carrying the car forward, and for these reasons they are subject to more wear than the front tires. Furthermore, whenever the car is stalled in a mud hole, the rear wheels revolve a great many times without the front wheels moving.

Many motorists follow the practice of using repaired tires on the front wheels and new ones on the rear wheels. Increased service can also be had by transposing tires. In ordinary wear it is usually true that tires on the right side become worn more quickly than those on the left. This is due to their being run into ruts and stones, when the car is turned out of the traveled roadway, and because the tires of the right side suffer most from curbings and the like as the driver uses the right side of the street. They also carry more than half of the weight when the car leans, which it does mostly, on the right side.

The right rear tire wears faster because of the curve of the streets and roads. The actual cause is probably that the weight is more on the incline.

Standard Sizes of Pneumatic Tires

The standard sizes of fabric and cord pneumatic tires, as adopted by the leading tire manufacturers, are as given in the list following:

Standard Sizes: Fabric Construction for Passenger Cars

30 x 3 Clincher
30 x 3½ Clincher
32 x 3½ straight side
31 x 4 Clincher
32 x 4 straight side
33 x 4 straight side
*34 x 4 straight side
32 x 4½ straight side
33 x 4½ straight side
34 x 4½ straight side
*35 x 4½ straight side
*36 x 4½ straight side
33 x 5 straight side
35 x 5 straight side
*37 x 5 straight side

* Not technically considered standard, yet are still being made.

Standard Sizes: Cord Construction for Passenger Cars and Trucks

All sizes listed under fabric construction are made in the cord type of pneumatic tires for passenger car work, except 30 x 3 and 31 x 4 clincher.

The Buick "light four" car uses a Jaxon rim 31 x 4 straight side, which is made in cord construction. This size and type of rim is also used on certain models of the Briscoe and Maxwell.

Standard sizes of Pneumatic Commercial or Truck Tires. Made only in Cord Construction and Non-Skid Tread—Giant Tires

34 x 5 straight side
36 x 6 straight side
38 x 7 straight side
40 x 8 straight side
42 x 9 straight side
44 x 10 straight side

Note that all of these tires are for straight-side rims of the one-piece, side-ring type.

The straight side-bead tire is now the popular type of bead. In fact, the clincher tire is now made only in sizes of 30 x 3, 30 x 3½ and 31 x 4, the latter size being an oversize for 30 x 3½, i. e., it can be fitted to 30 x 3½ rims.

Ford Tires

The Ford uses 30 x 3 in front and 30 x 3½ in the rear, plain clincher on one-piece clincher rims permanently fitted to the wheel on the touring car and roadster. On the Ford sedan and coupelet, and also on the 1920–21 Maxwell, Chevrolet "490," and the Overland "4," the 30 x 3½ tire on "one-piece clincher rims" but with the "demountable" feature is employed.

Ford trucks use 32 x 4½ straight-side rear, and 30 x 3½ front-demountable clincher rims; and therefore clincher bead tires are used. 32 x 3½ solid tires can also be supplied for the rear.

METRIC TIRES AND EQUIVALENTS

Metric Sizes	Approximate Size in Inches	Metric Sizes	Approximate Size in Inches
650x 65	26x2½	870x 90	34x3½
700x 65	28x2½	910x 90	36x3½
750x 65	30x2½	960x 90	38x3½
800x 65	32x2½	1010x 90	40x3½
830x 65	33x2½	815x105	32x4
860x 65	34x2½	875x105	34x4
700x 85	28x3¼	915x105	36x4
750x 85	30x3¼	820x120	32x4½—5
800x 85	32x3¼	850x120	33x4½—5
860x 85	34x3¼	880x120	34x4½—5
760x 90	30x3½	920x120	36x4½—5
810x 90	32x3½	1020x120	40x4½—5
840x 90	33x3½	1080x120	42x4½—5

* Figures in first column represent millimeters. See Index for explanation of millimeters.

Beads of Tires and Rims

There are three types of tire beads: (1) plain clincher (Fig. 19), which is **flexible,** and is intended for one-piece clincher rims; (2) quick-detachable clincher, with a clincher bead which is **hard,** and is for use on the quick-detachable side-ring type of rim; (3) straight-side bead (Fig. 20) for use on rims with straight sides.

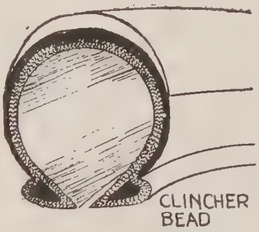


Fig. 19

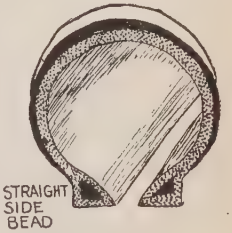


Fig. 20

Note. The **hard-bead clincher tire** formerly used on quick-detachable clincher rims is no longer manufactured.

The **flexible bead clincher** is now made only in 30 x 3, 30 x 3½, and 31 x 4 sizes. The tire in general use is the straight-side bead tire.

THE CLINCHER BEAD TIRE AND RIM

There are three kinds of clincher rims: (1) a **one-piece** clincher rim which is firmly fastened to the wheel felloe, as shown in Fig. 21; (2) a **quick-detachable** clincher rim where one side of the ring is removable, and the tire is removed, as in Fig. 22; (3) a **demountable** one-piece clincher rim, as used on the Ford sedan and coupelet, and other light cars, where the tire can be removed with the rim, and another tire and rim, fully inflated, can be put on the felloe rim of the wheel in its place (see also page 597).

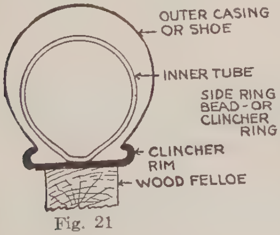


Fig. 21

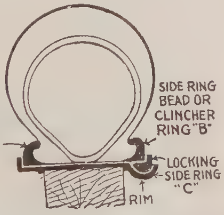


Fig. 22

Fig. 21. Clincher bead tire on **one-piece clincher rim.**

Fig. 22. Clincher bead tire on a **quick-detachable rim.**

To attach or detach a tire on a one-piece clincher rim it is necessary to raise the beads of the tire over the rims as shown in Fig. 21, and that is why the bead is made flexible.

To attach or detach a clincher bead tire on a quick-detachable clincher rim, it is only necessary to remove the "locking ring" and "clincher side ring," as in Fig. 22, and the tire can be slipped on or off without much stretching. For this reason it is not necessary to have a flexible bead.

Therefore a flexible-bead clincher tire can be fitted to either a "one-piece clincher rim" or to a "quick-detachable clincher rim," but it would be a difficult matter to stretch a **hard-bead** clincher tire over a "one-piece clincher rim."

Tire lugs or staybolts This device was formerly used to a great extent when the use of clincher tires predominated, but it is now seldom used. It consisted of a bolt which passed through a hole provided in the felloe of the wheel, as shown in Fig. 2, page 591. The wedge-shaped head was canvas, or rubber-covered, and when drawn tight would spread the beads of the tires firmly into the clincher part of the rim.

The tire lug is still used on some clincher tires, but is usually placed close to the valve-stem, to provide against creeping of the tire on the rim.

When a tire creeps on the rim, or slips, it causes the valve-stem to pull away from the tube, resulting in a bad tear in the tube.

Spreader: The purpose of a spreader (L) (Fig. 3, page 591) is to keep the inner tube from being pinched at the stem hole in the rim, and also to act as a protection in case the dust cap is screwed down too tight. This is very often the case, and as a result, the inner tube is partly pulled or pinched in the rim hole.

Spreaders are not absolutely necessary, but, as stated above, they greatly lessen the chances of tubes "going bad" around the valve-stem, before the rest of the tube has given all the service that has been built into it.

The difference in size of spreaders is necessary, owing to the difference in space between the beads as they set on the rim.

Flaps: These are canvas strips which are placed inside of the tire to insure against pinching of the inner tube by the toe of the bead, and to prevent injury to the inner tube by rim rust. Flaps may be used in all casings, except the flexible clincher type.

To Remove Inner Tube from a Tire on a One-Piece Regular Clincher Rim

Jack up the wheel. Remove the valve cap (**B**) and the inside valve (**A**) by reversing the cap head and unscrewing it, as shown in Fig. 23. Remove the locknut on the valve-stem (see **P**, Fig. 3, page 591).

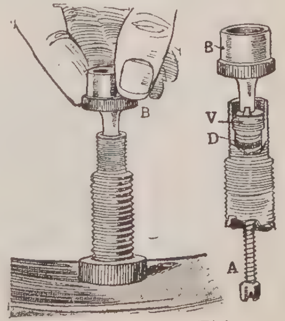


Fig. 23. Shows how the valve cap (**B**) is reversed to unscrew the inner valve (**A**) when the tube is to be deflated.

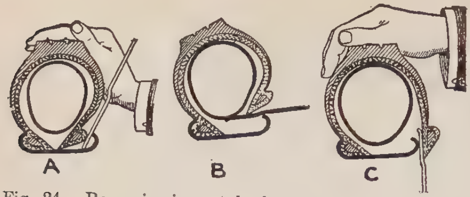


Fig. 24. Removing inner tube from a tire, using a one-piece clincher rim.

Push the edge of the casing from under the lip of the rim with a tire tool as shown at (**A**) (Fig. 24). Pry off as shown at (**B**) and (**C**). This operation must be repeated all around the tire until the outer bead is loosened. The inner tube can then be removed, and the outer casing slipped off, as shown in Fig. 25.

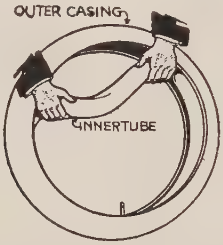


Fig. 25

When taking an inner tube out of a tire, turn the wheel until the valve-stem is at the bottom, as in Fig. 25, then remove the tube, beginning at the top.

Always make it a point to run your hand around the inner tube in the casing until you detect the cause of the puncture, because very often the offending object is hidden in the tire and cannot be seen or felt from outside.

Replacing Inner Tubes

Place powdered soapstone or mica in the case before inserting a tube (Fig. 26). (Too much of this however is likely to work up into little balls and cause inner-tube trouble.)

Then run your hand around the inner tube, smoothing out the creases and placing the tube evenly around in the rim.

Put in a new tube, or patch the old one in accordance with the instruction farther on.

The insertion of the tube may be done with the casing remaining on the rim or with it removed. In either case, it is desirable to turn the wheel until the valve-stem hole is on top (Fig. 27). Before the tire is replaced, the inner tube should be slightly inflated.

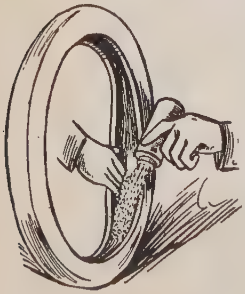


Fig. 26

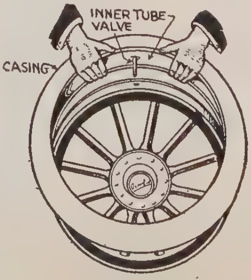


Fig. 27

Do not inflate the tube too much when placing it in a tire, for if you do, you will have difficulty in replacing the locking rim over the bead of the casing.

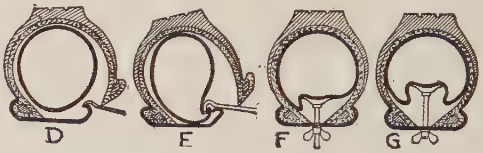


Fig. 28. Replacing an inner tube in a tire, using a one-piece clincher rim and showing precautions to observe to prevent pinching of the tube.

Replacing tire casing on rim: With the inner tube carefully placed in the outer casing, one side of the casing is easily applied. The other side is more troublesome. The hooked end of the lever is used to work the edge of the cover back into the rim, as shown in (**D**) (Fig. 28).

In using this lever, the inner tube may be pinched, as in (**E**); therefore care must be exercised to avoid this.

After the bead of the tire is worked into place, it sometimes happens that the tire lugs or staybolts are not properly placed, as shown in (**F**). Note that the inner tube has become nipped between one of the lug bolts and the cover, and, unless released, this will result in a burst tube. This risk is avoided by taking care to inflate the tube moderately before replacing it in the cover.

The tire lug should be pushed upwards, or towards the inside of the tire as in (**G**), before screwing it down, thus permitting the cover and tube to fit into the correct position. Some tire lugs have a canvas-covered head which sometimes causes inner tube defects, such as nipping and chafing. If bolts with moulded rubber heads be used, these defects are not likely to occur.

The inner tube and tire are properly fitted as shown in (**H**); the tire lugs are in place, and the inner tube snugly in its place, with no nipping at any part.

The inner tube should now be carefully inflated and, when pumped up, should be even all the way round the rim, and run truly when the wheel is rotated.

The air pressure should be in accordance with the table on page 593 (Fig. 18). During the process of inflating, the air pressure can be **tested.** A very handy device for this purpose is a Twitchell air gauge, shown in Fig. 30.

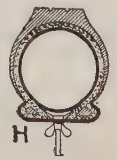


Fig. 29

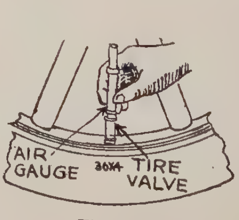


Fig. 30

Note. The instructions for the removal and replacement of inner tubes, as explained above, will apply to all types of inner tubes, except the method of removing and applying the tire to the rim, which varies on different kinds of rims.

THE QUICK-DETACHABLE RIM—SIDE-RING TYPE

The words, "quick-detachable," as applied to a **tire rim,** were originated several years ago, when the one-piece clincher rim, shown in Fig. 21, page 595, was extensively used.

It was a great source of trouble to remove a clincher bead over the clincher part of the rim. Consequently a quicker method was introduced, termed, the "quick-detachable" method, as shown in Fig. 22, page 595. Note that the tire could be removed by removing a "locking ring," (**C**) and a "clincher side ring" (**B**) (see Fig. 22, page 595, and Fig. 31, this page). The tire could then easily be removed. This type of quick-detachable rim was termed a "side-ring" type. This type is now almost obsolete for clincher-tire use, but is used for straight-side tires, as on wire wheels, where the entire wheel is removable.

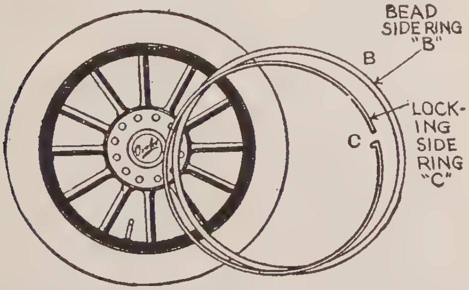


Fig. 31

Quick-Detachable, Demountable Rim—Side-Ring Type

The next improvement to follow was a quick-detachable type of rim, using "side rings," similar to those shown in Fig. 22, page 595, but with **demountable** features, as shown in Fig. 33.

Demountable rims are those rims which are not permanently fastened to the wheel and can be removed with the tire, usually by loosening the clampbolts on the side. This feature, of being able quickly to detach the rim and tire, and thus demounting the tire and rim combined, was a great advancement, as it relieved one of the drudgery of having to remove a tire and repair it on the road. Instead, a spare tire fully inflated on a rim, was carried on a rack, on the rear or side of the car, and was replaced on the wheel instead of the defective tire, and defective tire and rim were placed on the rack to be repaired later.

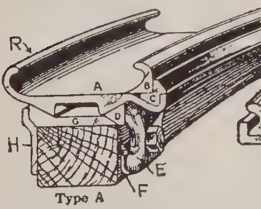


Fig. 32

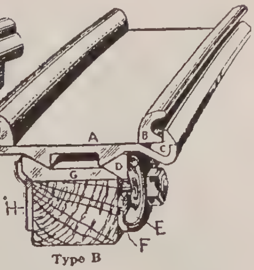


Fig. 33

Fig. 32. A **clincher demountable rim** (not now made for clincher tires) (Firestone, type A).

Fig. 33. A **universal rim;** for clincher or straight side-bead tire (Firestone, type B).

Parts: (**A**) rim base; (**B**) side ring; (**C**) locking ring; (**D**) clamping ring; (**E**) flat clamp; (**F**) clamp bracket; (**G**) felloe band; (**H**) bolt washer.

A quick-detachable, demountable clincher rim of the Firestone make is shown in Fig. 32. Note the difference between this rim and the quick-detachable rim without the demountable feature (Fig. 22, page 595). The difference is, that clamping bolts (**E**) (Fig. 32) and a clamping side ring are provided to hold the clincher rim (**A**) (Fig. 32) in place, and this, when removed, permitted the rim (**A**) to be **demounted** with the tire. At this time, the clincher-bead tire was the type in general use, and the **hard** clincher bead was used for this type of rim.

The universal rim (Fig. 33) was the next type of rim to be used. It was necessary, because the straight-side tire came into existence and proved to be superior to the clincher bead, in that rim cutting, which was a great source of trouble with clincher-bead tires, was eliminated. Therefore, the universal rim would take either a clincher-bead tire, or the straight side-bead tire. Note that the rim (**B**) (Fig. 33) is reversible. By having the rings (**B**) as shown in Fig. 33, the rim would take a "straight side-bead" tire; by reversing (**B**), the rim would take a "clincher-bead" tire.

Side-bead tires on clincher rims: A great deal of complication existed, because the majority of tires in use were clincher-bead tires, and those who had wheels fitted with the clincher rim (Fig. 32) who desired to use straight side-bead tires found it necessary either to have the wheels fitted with straight side rims, or to use **filler beads,** which consisted of strips of fabric like the bead of a tire. These filler beads could be placed in the clincher part of the rim at (**R**), and thus fill up the clinch, and by this means straight-side tires could be used. This type of rims is now obsolete.

The Ford sedan and coupelet, and some other light cars use 30 x 3½ clincher tires on a one-piece clincher rim, which is not quick-detachable, that is, without side rings, but it is **demountable.**

Straight-Side Bead Tires and Rims; Demountable, Side-Ring Type Rim, Q. D.

The clincher bead tire gradually became obsolete, the straight-side bead having taken its place.

An example of a **straight-side, quick-detachable, demountable rim** (Firestone type C) is shown in Fig. 34.

Note that this rim (Fig. 34) is similar in principle to that shown in Fig. 32, but is different, in that it takes a straight-side bead tire only. It is quick-detachable, as in Fig. 32, because there are **side rings,** which can be removed. Thus the tire can be removed from the rim while on the wheel, or the tire and rim can be demounted from the wheel.

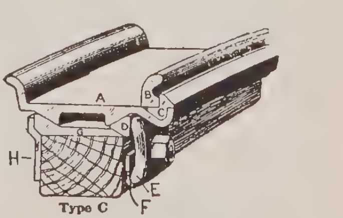


Fig. 34. A **straight-side, quick-detachable, demountable side-ring type of rim** for use with straight-side bead tires only. Note that the tire can be removed from the rim while on the wheel, or the rim and tire can be demounted from the wheel (Firestone type "C" rim).

This type of rim (Fig. 34) is the type, or principle (there are many different makes), used on commercial cars, or trucks.

Example of Demounting Rim and Tire from Wheel and Removing Tire on a Quick-Detachable Side-Ring Type of Rim—Demountable

This example refers to the type of rim shown in Figs. 32, 33, and 34. This rim is not split, but is of the side-ring type.

This type of rim is used quite extensively for commercial cars or trucks, with straight-side bead tires.

It will be found on a great number of older cars with clincher rims, as well as with straight side rims. Note that the rim and tire are demounted from the wheel, and that by removing a side ring, the tire can be removed from the rim; or the tire can be removed from the rim without demounting the rim. An example of this process is as follows:

To Demount Rim and Tire from Wheel

Jack up the wheel and loosen clamp (**E**) (Fig. 35), using the socket wrench (**W**) which accompanies each set of rims. Slide each clamp down as far as it will go; then tighten the nut sufficiently to hold the clamp in that position.

When all clamps have been freed, turn the wheel so that the valve-stem (**A**) is at the top; then swing out the lower side of the rim (Fig. 36), and lift rim, tire, and all off the wheel.

The valve hole in the felloe is tapered, so that this can be done without straining the valve stem. Note: It is not necessary to remove the dust cap when demounting the rim. The dust cap should always be kept screwed tightly against the valve sleeve, except when detaching the tire from its rim.

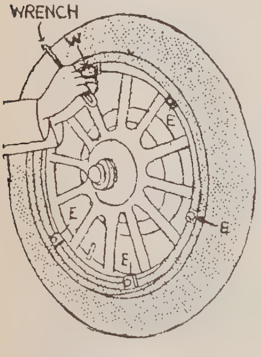


Fig. 35

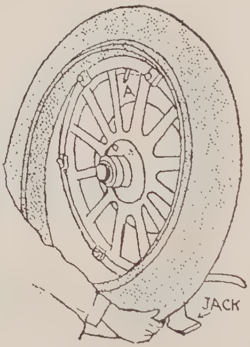


Fig 36

Fig. 35. Loosening clamping bolts.

Fig. 36. Demounting rim and tire from wheel.

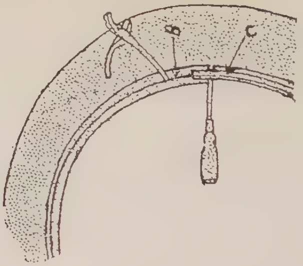


Fig. 37. To remove tire from rim: pry off locking ring (**C**) and remove side-ring bead (**B**).

To Mount the Spare Rim with Inflated Tire

Having taken the clamping ring (**D**) (Fig. 34, page 597) from the rim just removed, place it in the same position (with point toward inside) in the spare rim carrying an inflated tire.

Turn the wheel so that the valve hole in the felloe is at the top; insert the valve-stem (with dust cap and valve sleeve already in place) through the hole and swing the lower part of the rim snugly into place. The ends of the clamping ring (**D**) (Fig. 34, page 597) should come under one of the clamps.

Restore each clamp (**E**) in turn to its original position, overlapping the clamping ring, giving the respective nuts one or two turns with the wrench to hold the clamp fairly tight. Then continue around the wheel again, tightening down all nuts and clamps firmly.

To Apply Tire to Rim

Place the slightly inflated inner tube in the casing, using plenty of soapstone or talc, and set the casing back on the rim.

Put on the side ring (**B**). Apply the locking ring (**C**), by engaging the pin in the notch in the edge of the rim, and then force the locking ring into its groove around the wheel. Inflate the tire to proper pressure. Screw the dust cap on tight against the valve sleeve.

The spreader is held in position in the base of the tire by the pressure of the screw dust cap against the valve sleeve. No locking nut or other device is necessary.

To Remove Tire from Rim

Remove the dust cap and allow the air to escape. Push the valve-stem up into the tire as far as it will go, thereby releasing the pressure of the spreader inside.

Insert the point of [illegible]crewdriver between the side ring (**B**) and the locking ring [illegible] (Fig. 37). Pry downwards, causing an opening between the two rings. Drop a coin or other convenient piece of metal into this opening and hold the opening thus gained. Pry downwards with a screwdriver, which will remove locking ring (**C**). The bead ring and tire may now be removed from the rim. Note that the valve-sleeve will remain in the valve-hole of the rim or felloe.

THE ONE-PIECE STRAIGHT-SIDE DEMOUNTABLE SPLIT RIM

This type of rim (Fig. 38) is a popular type. The illustration shows the type E Firestone rim. There are many other makes. As will be noted farther on, the rim is demountable by loosening the clamp bolt (**E**), which relieves the pressure on (**D**), and thus the rim (**A**) and the tire are demounted from the wheel.

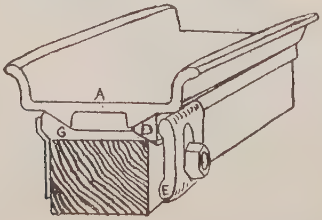


Fig. 38. **A straight-side, demountable, one-piece rim for a straight-side bead tire only.** This rim is a "split" rim. The tire is not removable from the rim while on the wheel. The rim and tire must be removed (Firestone, type E).

Note also that the side rings (**B** and **C**) (as in Fig. 34), which was the so-called "quick-detachable" feature, has been eliminated, and that therefore the tire could not be removed from the wheel while on the rim. When the rim and tire are removed from the wheel, a much simpler method is used to remove the tire from the rim, which is by separating the rim, which is **split** (see Fig. 45, page 600).

As stated, the straight-side, demountable one-piece **split rim** is the popular type of rim. The purpose of having a rim demountable is to permit removing the tire and rim, so that a spare tire, inflated, and on another rim, can be placed on the wheel in place of the defective tire.

If one did not have a spare tire and rim along, then the tire and rim would have to be demounted, and the tire removed. It is easier to remove the **split-rim type,** than is the case with the **side-ring quick-detachable type.**

There are many different types of **one-piece, straight-side demountable split rims.** On some makes, instead of having a **side-clamping ring** (D) (Fig. 38), which is held tight in place by a clamp bolt (E), a **wedged clamp** is used, as shown in Fig. 42.

Principle of the Demountable Split Rim

This type of rim is the rim in general use on passenger cars.

There are **many different makes.** Fig. 38, page 598, shows the Firestone, type E. The one illustrated below is the Stanweld No. 21 or 76. There are many others. The difference is chiefly in the method of seating the rim on the felloe band of the wheel, fastening it to the wheel, and the method of holding the split part of the rim together. Split rims are made demountable only.

An example of how the Stanweld, No. 21 or 76, split rim is held together and separated, so that the tire can be removed from the rim, is shown in Fig. 39.

A split rim is shown with a locking lever (C). The rim is called a "split rim" because it is not endless, but is cut through on one side.

When the rim is removed from the tire, the locking lever (C) is thrown to one side as at (D). The rim is then pried out or lapped as at (E), and the tire is pulled off.

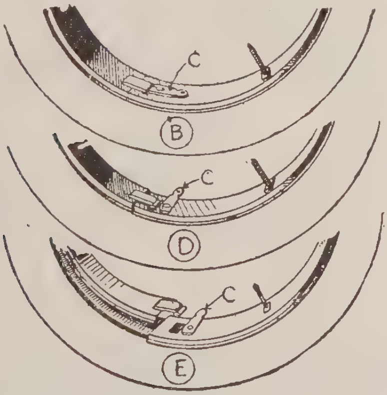


Fig. 39

When the rim is put back in place, the lever (C) is put in place as at (B). The type E rim (page 598) is of the split type, but has a different locking device.

Another type of split rim is shown below in Figs. 40 to 41, and is similar, except for a different locking principle. We will use this type to explain how the rim and tire are demounted, and how the tire is removed from the rim and how replaced. The procedure is very similar on all types of split rims.

How the Demountable Split Rim Is Held to Wheel

The rim is held securely to the wheel by **wedge-shaped clamps** and bolts, as shown in Figs. 40 and 41.

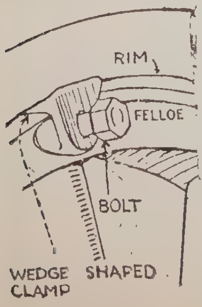


Fig. 40

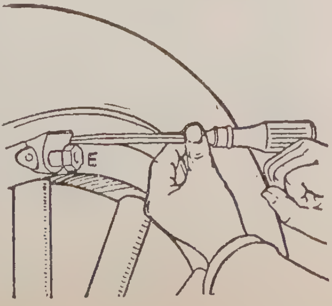


Fig. 41

The difference in construction of different makes of rims of this type is chiefly in the shape, or in the method of applying this clamp, and also in fastening the split part of the rim as explained in connection with Fig. 39.

On the **Firestone, type E,** split rim (Fig. 38, page 598), the clamp (E) is flat, instead of being wedge-shaped. The clamp (E) presses against a triangular-shaped **clamping ring** (D). With the type of split rim shown in Figs. 40 and 42 (the Baker) and many other split rims, the "clamping ring" as mentioned above is not used, the **"wedge clamp"** serving instead.

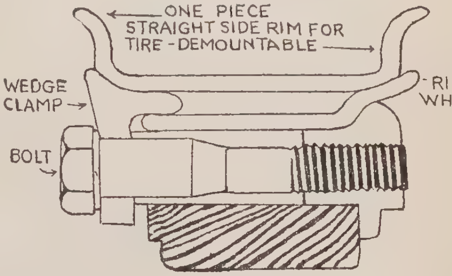


Fig. 42

The **purpose of the wedge clamp** (see Figs. 40 and 42) is to wedge in between the rim and steel rim on the felloe of the wheel. The tighter the bolt is drawn, the tighter it wedges. The wedge clamps are placed equidistant all around the side of the felloe of the wheel, and it is important that they be drawn equally tight all around, else the tire will be thrown out of line and will wabble.

Example of Removing a Demountable Split Rim and Tire from Wheel

The wheel used in this example is what is termed an **"artillery type,"** in which the spokes meet at the center and are bolted between the flanges of the metal hubs. A steel felloe is shrunk on the wooden spokes to carry the demountable rim and tire.

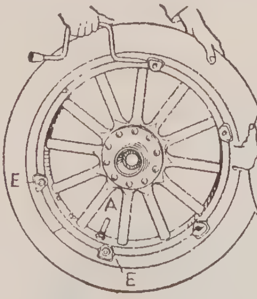


Fig. 43

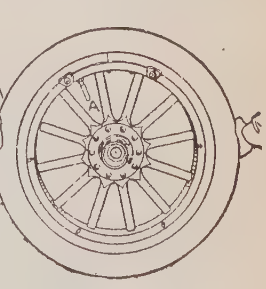


Fig. 44

Procedure: Jack up the wheel. Remove the dust cap and nut from the air-valve stem (A) (Fig. 43). With the rim wrench, remove all of the nuts from the bolts except the ones on either side of the tire valve.

Insert the screwdriver end of the demountable rim wrench between the felloe and wedge clamp, to pry loose and remove (Fig. 43). After the wedges have been removed, turn the wheel until the tire valve is in upper position, and pull the lower portion of the tire toward you until it clears the felloe sufficiently to raise up so as to disengage the valve-stem from the felloe (Fig. 44).

Mounting Spare Rim and Tire

The next procedure is to place on the wheel the spare rim and tire which should be carried on the "tire carrier" at the rear of the car, with the tire fully inflated.

Procedure: Loosen the nut at the lower edge of the "tire carrier" with a rim wrench and turn the lug until it clears the rim. Remove the air-valve stem-cap and nut, and lift the rim off the carrier.

Insert the valve-stem in the proper hole in the felloe, and the driving stud in the driving plate (Fig. 43) and force lower part of rim on the wheel with the foot. Replace the two wedges opposite the valve-stem, drawing them up evenly, but not to their final position; then replace the remainder of the wedges and draw them up evenly until all are tight. Note that the edges of the rim at the split are even and not more than 1/32" apart. If the bolts are not tightened uniformly, the rim will run out of true.

To Remove Tire from the Split Rim

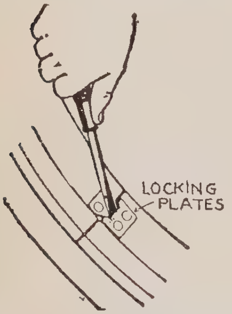
As an example, the Kelsey No. 110 split rim, as installed on the Studebaker cars, will be used. Note that the locking device of the split part of rim on this make is different from the locking device (C) (Fig. 39).

It is not a difficult task to remove a straight-side tire from the rim, as used on Studebaker cars; nevertheless, we outline below the very best procedure in order to reduce this labor to a minimum.

First, be sure the tire is fully **deflated,** then loosen the bead of the tire thoroughly from the rim before proceeding with the following operations:

Operation No. 1: Place a screwdriver between the locking plates of the split part of the rim, as shown in Fig. 45, and force the rim apart, by bearing up on the handle.

Operation No. 2: With the rim slightly forced apart, as shown in Fig. 45, bear down on the handle of the screwdriver, so that one section of the rim will be telescoped into the other, as shown in Fig. 46.



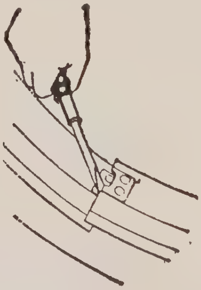
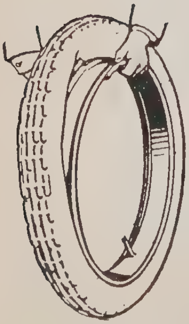


Fig. 45. Forcing split apart

Fig. 46. Lapping split.



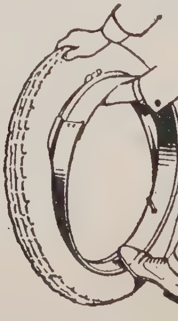


Fig. 47. Starting tire from rim.

Fig. 48. Pulling rim from tire.

Operation No. 3: By means of a screwdriver or a tire tool remove the tire from the rim at the telescoped section (Fig. 47).

Operation No. 4: Supporting the tire between hand and foot, as shown in Fig. 48, pull the rim from the tire with the other hand.

To Mount Tire on Rim

Operation No. 1: In mounting the tire, place the rim on the floor, and, after having installed the tube in the casing very carefully, insert the valve-stem into the rim hole provided (Fig. 49).

Operation No. 2: By following around the tire, pressing with the heel of your shoe, the casing can be forced into position (Fig. 50).

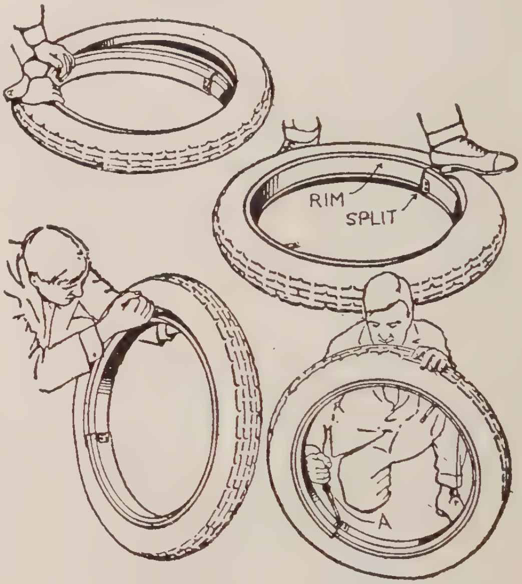


Fig. 49 (upper) Fig. 50 (upper)

Fig. 51 (lower) Fig. 52 (lower)

Operation No. 3: With the rim still telescoped, force a screwdriver, or preferably a tire tool, between the casing and rim (Fig. 51) and slide around the entire rim, noting carefully if the flap is in proper position. If the flap is allowed to become folded over the bead of the tire shoe, a blow-out may result and expanding the rim and removing operation becomes difficult.

Operation No. 4: By using a screwdriver (Fig. 52), and reversing the operation as shown in Fig. 46, the rim can be locked in its proper position.

Additional Pointers on Mounting Tires on the Split Rim

To avoid tire troubles, mount the tire properly on the rim by observing the following:

1. See that the tube is partially inflated when inserting.
2. See that the inner tube valve does not leak.
3. When inserting the tube, use talc to lubricate it.
4. When the rim and tire are mounted on the wheel, draw the wedge bolts evenly, or the wheel will wabble.
5. Before inserting the tube in the casing, see that there is no dirt or other substance in it which might injure the tube. Run your hand all the way around the inside of the casing.
6. If the rim is rusty, scrape off all the rust you can, and then apply a coat of rim paint.

A few pointers as to the method of placing an inner tube in the casing and mounting the casing on the rim are given on the next page.

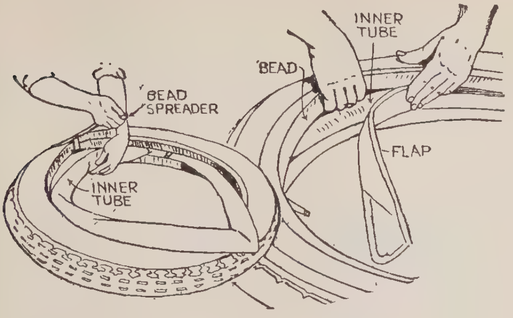


Fig. 53 Fig. 54

Fig. 53. **Inserting tube into casing:** Sprinkle talc inside of casing, being careful not to use too much, or it will form balls. Then inflate the tube just enough so that it will assume sufficient shape to make it easy to handle. The tube is then put into the casing. A very handy tool for spreading the tire when inserting a tube is a "bead spreader" shown in the illustration. Do not permit the tube to touch the ground. Dirt or grit may cut through.

Fig. 54. **Placing flap over tube:** A flap is then placed as shown. Do not stuff it in and permit it to wad, but spread the bead with the hand as shown, and place it evenly and flat over the tube. If it wads, it may cut the tube.

After the inner tube and flap are placed on the casing, then place the casing on the rim. Stand the rim up and insert the valve-stem through the hole in the rim. Next place the rim on its side, as shown in Fig. 55.

Spare Rims and Tires

We often see a spare rim on the rear of a car with an inflated tire on it. This indicates that the rim is of the demountable type, and that the wheels are of wood.

These rims are usually of the one-piece, straight-side, split-type demountable rim. Any other type of demountable rim could be used, as, for instance, the side-ring demountable type.

The Ford uses a demountable clincher rim of plain clincher construction without side rings.

Fig. 55. **Forcing one side of casing over rim:** Use a tire tool. One of the best tire tools obtainable is a piece of spring leaf; the longer, the better. With this tire tool, and by striking the bead of the tire (not the rim) lightly with a hammer, one side of the casing will go over the rim.

When one bead of the tire is over, then start the other bead of the tire into the bead of the rim by means of the tire tool, and a few blows of the hammer. Use the tire tool first and do not use a hammer any more than necessary. When using the tire tool, be careful it does not injure the tube.

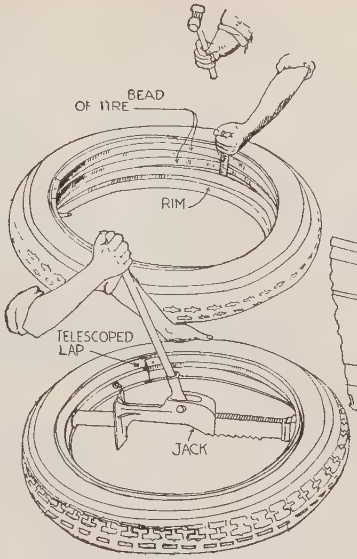


Fig. 55 (upper)
Fig. 56 (lower)

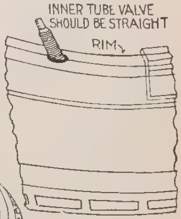

INNER TUBE VALVE SHOULD BE STRAIGHT
RIM

Fig. 57

Fig. 56. **Spreading the rim apart so that it will lock:** There are many methods for joining the lap of the split rim where it telescopes. One method, and a good one is to use a jack as shown in Fig. 56.

Fig. 57. **Inner-tube valve not in correct position:** This is a trouble which often occurs and is one that will not be noticed until the beads of the tire are on the rim. The valve should be perfectly straight. If it is left in the position shown, it will result in the inner-tube valve seat being torn from its base, and this might occur when the telescoped part of the rim is separated, as this will only cause it to be drawn farther. If not, it will tear sooner or later.

The Stanweld Interchangeable Rim

The Stanweld interchangeable rim replaces without alteration of band the following makes of rims:

Stanweld 21 and 22	Dodge Bros.	Standardized-Baker
Stanweld 76	Perlman-Jackson	Baker-Detroit

This rim permits easy and quick tire changing, because the valve-stem does not interfere with the rim when collapsed. A screwdriver is the only tool needed. No new bolts, wedges or nuts are needed.

Some of the popular cars equipped with flat-base rims which interchangeable rim will replace are: Ford (some), Overland, Maxwell, Dodge, Oakland, Oldsmobile, Buick, Paige, Chalmers, Mitchell. For a complete list see pages 603, 604, 605, 606.

WIRE WHEEL RIMS

The wire wheel uses a rim which is not demountable. Instead, the wheel itself is demountable. A spare wheel and inflated tire is usually carried on the tire rack at the rear of the car, and when tire trouble occurs, the wire wheel and tire are demounted from the axle and the spare wheel and tire are placed on the axle in their place.

The type of rim generally used on wire wheels is the plain straight side rim which is permanently fastened to the wheel. The tire is removed from the rim by first removing the side ring (Fig. 58). The removal of this side ring is an operation similar to that shown in Fig. 22, page 595, except that a straight side rim is generally used instead of a clincher rim. If the wire wheel is of 30 x 3½ size, it may have a clincher type of rim.

If a spare wheel and tire are not at hand when tire trouble occurs, then the tire can be removed from the rim by jacking up the wheel and removing the side ring.

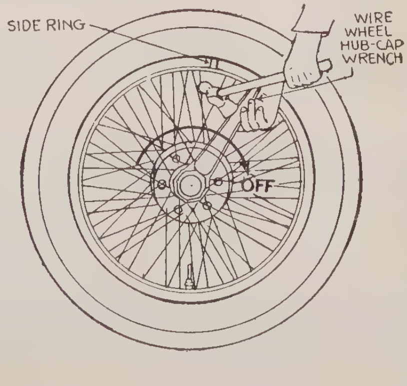


Fig. 58. Illustrating **how a hub cap wrench is always moved** downward toward the **front** of the car when the hub cap is to be taken **off**, and toward the **rear** of the car, when put **on.** Note that the side ring is removed in order to detach a tire. The rim is not demountable.

Wire wheel hub nuts have right-hand threads on the left side and left-hand threads on the right side. A large hub-cap wrench is usually provided for removing wire wheel hub nuts.

To Remove Wire Wheels—Front or Rear

Jack up the wheel until clear of the ground and place the special wrench over the hexagon of the hub cap. Putting on the wrench releases the hub-cap lock-finger, so that the cap can be removed by turning toward the **front** of the car.

The two hubs on the left-hand side of the car have right-hand threads, while those on the right-hand side have left-hand threads. The hub caps are marked with arrows pointing the direction they turn on. To **remove,** turn in the direction opposite to the arrow.

Should the caps be so tight that trouble is experienced in loosening them, let the wheel down until it rests on the ground, to keep it from turning and then tap the end of the wrench forward with a hammer. When the cap is once started, jack up the wheel and unscrew the rest of the way by hand. After the hub cap is removed, the wheel can be pulled straight off the hub.

When replacing the wheel, be sure to push the wheel on the hub all the way, and see that the wheel draws up tightly on the inner hub. To screw the hub cap on, turn towards the **rear** of the car—in the direction of the arrow.

Do not attempt to tighten the hub cap when the wheel is on the ground, as the weight of the car prevents free action of the wrench on the cap, and while the wheel may appear tight, it is only binding and will loosen with driving. When a clicking noise is heard in the wheels, it is generally the result of the hub caps not being drawn tight.

Care of Wire Wheels

It is never necessary for an owner to tighten or touch the spokes unless in case of accident. All spokes have the proper tension when they leave the factory. If new spokes are inserted, do not draw up too tightly with a spoke wrench. The new spokes should be only as tight as the ones already in, of the same length, and ring true with them.

To keep wheels in good working order, they should receive the following **lubrication:**

The taper of the inner hubs, both tapers in the wheel hub shells, and the threaded portion of the hub caps should be wiped clean and covered with light grease every thirty days. Also, occasionally look over the locks in the hub caps; place a few drops of oil in between the spaces provided for clearance. This will assist the locks to work freely and help to counteract the accumulation of dirt, dust, etc.

DISK WHEELS

Different wheel constructions are explained on page 3.

The disk steel type of wheel is now very popular, and in order to explain the advantages of this type of wheel we will use the Disteel wheel as an example.

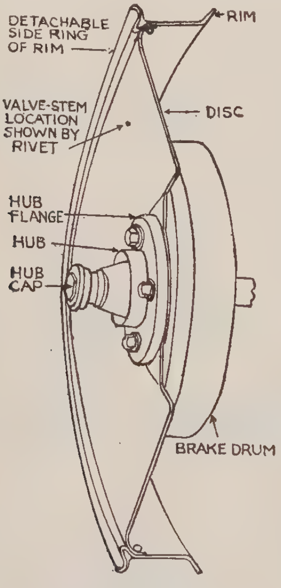

DETACHABLE SIDE RING OF RIM
RIM
VALVE-STEM LOCATION SHOWN BY RIVET
DISC
HUB FLANGE
HUB
HUB CAP
BRAKE DRUM

Fig. 59. The Disteel wheel using the Goodyear type of rim permanently riveted to the disk.

The advantages of this type of wheel are as follows:

Strength: Being disks of steel they have no spokes to break.

Permanent rims: Rims are not demountable, but are riveted to the disk.

Curved and tapered disk: Shocks cannot be transmitted in a direct line to the axle, but are carried at an angle, thus deflecting the full force of the blow. The tapered construction of the disk diffuses the shock on the same principle as in the case of tapered roller bearings and springs.

Proper distribution of weight: The weight of the Disteel wheel is concentrated at the hub, so that the fly-wheel effect is lost and easy starting and stopping results. The contrary effect—throwing the principal weight to the rim—makes stopping and starting less easy.

Convenience: Disk wheels are easy to clean and easy to change.

The Disteel **wheel itself can be removed** by loosening the nuts holding the hub-locking flange.

The method of changing a tire is to remove the side ring, or to carry an extra wheel with the tire mounted ready to replace the other wheel. Manufacturers are Disteel Wheel Corp'n., Detroit, Mich.

The Tuarc Steel Disk Wheel

Another make of steel wheel is the Tuarc shown in Fig. 60. The wheel is made of steel. A patented clamping ring gives a full-circle grip on the demountable rim to be removed. Thus it is only necessary to carry an inflated tire and rim on the rear tire rack instead of a complete wheel and tire. Manufacturers are Motor Wheel Corp'n., Lansing, Mich.

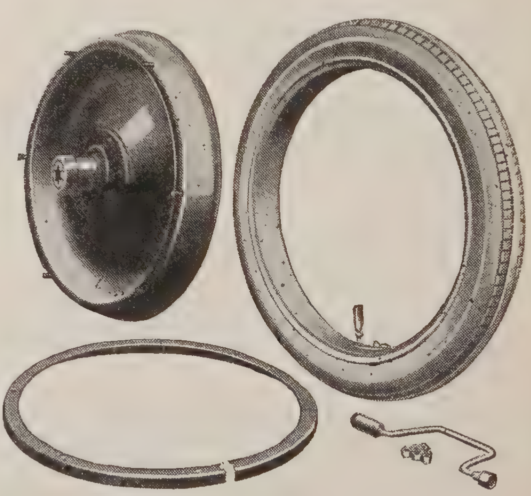


Fig. 60. The Tuarc steel wheel with a demountable rim.

Rim Equipment of Leading Automobiles from 1916 to 1921

The following table gives the name of the car, the year and model, the size of tire, the type of rim, the make of rim, and the catalog number of wedge-clamp, bolts, and nuts. It is a valuable list of data, as it will tell the size and type of tire to order for all makes of cars.

Abbreviations: Fir. for Firestone; Stan. for Stanweld; Stzd. for Standardized; K. for Kelsey; K.U. for Kelsey Universal; K.P.S.S. for Kelsey Permanent Straight Side; Det. for Detroit; Gdyr. for Goodyear; Gdrh. for Goodrich; Perl. for Perlman; Pk. for Parker; J. for Jaxon; B. for Baker; D.B. for Dodge Bros.

Obtained through the courtesy of the Borbein Auto Co., 2109 North 9th St., St. Louis, Mo. This concern carries a complete line of rims and parts, and issues an instructive catalogue on the subject.

Make	Year	Model	Size	Type	Make of Rim	Wedges Clamps	Bolts	Nuts
Abbott	1916	6-44	32x4	SS	Fir. E	6-7	42	3
Abbott	1916	8-80	34x4	SS	Fir. E	6-7	42	3
Abbott	1917	6-44	32x4	SS	Fir. E	6-7	42	3
Abbott	1918	All	34x4	SS	Fir. E	6-7	42	3
Allen	1913-14	36-38-40	34x4	SS	B	21	72	6
Allen	1915	All	32x3½	SS	Det.	24	21	1
Allen	1916-17-18	32-37-41	32x3½	SS	Fir. E	6-7	41	3
Allen	1919	All	32x4	SS	Fir E-C	6-7	42	3
Allen	1920-21	All	32x4	SS	Fir. E-St. 76	6-7	42	3
Apperson	1916-17	All	34x4	SS	Fir. E	6-7	42	3
Apperson	1918	All	34x4	SS	Fir. E	6-7	42	3
Apperson	1919	19-A	32x4	SS	Fir. E	6-7	42	3
Apperson	1919	19	34x4½	SS	Fir. E	6-10	43	3
Apperson	1920-21	20	33x4	SS	Fir. E	6-7	42	3
Auburn	1915	4-36	32x4	SS	Fir. E	6-7	42	3
Auburn	1915	6-40	34x4	SS	Fir. E	6-7	42	3
Auburn	1915	6-47	36x4	SS	Fir. E	6-7	42	3
Auburn	1916	4-36	32x3½	SS	Fir. E-Det.	6-24	41-21	3-1
Auburn	1916	6-38-40	34x4	SS	Fir. E-Det.	6-24	6-22	3-1
Auburn	1917-18	All	34x4	SS	Fir. E	6-7	42	3
Auburn	1919	H-K	33x4	SS	Fir. E	6-7	42	3
Auburn	1920-21	All	33x4	SS	Fir. E	6-7	42	3
Briscoe	1915	B	30x3½	CL	J. 124	34	21	1
Briscoe	1916	4-24	30x3½	CL	J. 124	34	21	1
Briscoe	1916	4-38-8-38	30x3½	Cl.	J. 124	34	21	1
Briscoe	1917-18-19	All	30x3½	Cl.	J. 124	34	21	1
Briscoe	1920-21	A	30x3½	Cl.	J. 124-1	34	21	1
Buick	1914-15	24-25	32x3½	SS	B.	21	71	6
Buick	1914-15	36-37	34x4	SS	B.	21	72	6
Buick	1914-15	54-55	36x4½	SS	B.	21	72	6
Buick	1916	D-44-45	32-34x4	SS	B. N. S	21	72	6
Buick	1916	D-54-55	36x4½	SS	B. N. S	21	72	6
Buick	1917	D-34-35	30x3½	Cl.	B. 118	21	71	6
Buick	1917	D-44-45	34x4	SS	B. N. S.	21	72	6
Buick	1918	E-44-45	30x3½	Cl.	Perl. 119	19	3-21	1
Buick	1918	E-44-45	34x4	SS	Perl.	19	22	1
Buick	1918	E-46-47	34x4	SS	Perl.	19	22	1
Buick	1918	E-49-50	34x4½	SS	Perl.	19	23	1
Buick	1919	H-44-45	33x4	SS	Stzd.	26	22	1
Buick	1919	H-49-50	34x4½	SS	Stzd.	26	23	1
Buick	1920	44-5-6-7	33x4	SS	Stzd.	26	22	1
Buick	1920	49-50	34x4½	SS	Stzd.	26	23	1
Buick	1921	Lt. Six	33x4	SS	Hay. Buick	26	63	1
Buick	1921	Big Six	34v4½	SS	Hay. Buick	26	123	1
Cadillac	1913	All	36x4½	Cl.	K-B	15	103	
Cadillac	1914-15	All	36x4½	KU	K. U.	15	33	
Cadillac	1916-17	All	36x4½	SS	K. P. S. S.	15	33	
Cadillac	1918-19	All	34x4½	SS	K. P. S. S.	15	33	
Cadillac	1920	All	34x4½	SS	K. P. S. S.	15	33	
Case	1916-17	All	34x4	SS	Gdyr. B	8	42	
Case	1918	All	34x4	SS	Stan. 21	1	12	
Case	1919	U	34x4	SS	Fir. E	7-6	42	3
Case	1920	All	34x4	SS	Fir. E	7-6	42	3
Chalmers	1915	26-B	34x4½	SS	Stan.	1	13	
Chalmers	1915	M Six 29	36x4½	SS	Cont. 3	1	13	
Chalmers	1915	32	34x4	SS	K. 30	13	102	
Chalmers	1916	6-48-26-B	34x4½	SS	Stan. 21	1	13	
Chalmers	1916	6-40-32-B	34x4	SS	K. 30	13	102	
Chalmers	1916	6-30-35-A	32x4	SS	K 30	13	102	
Chalmers	1917	35-5P	32x4	SS	K. 30	13	102	
Chalmers	1917	35-7P	34x4	SS	K. 30	13	102	
Chalmers	1918	6-30-5P	32x4	SS	K. 30	13	102	
Chalmers	1918	6-30-7P	34x4	SS	K. 100	11	112	
Chalmers	1919	All	32x4	SS	K. 110	18	62	
Chalmers	1920-21	All	32x4	SS	K. 110	18	62	
Chandler	1914-15	All	34x4	SS	Fir. E	7	42	3
Chandler	1916-17-18	All	34x4	SS	Fir. E	7	42	3
Chandler	1919	All	33-34x4	SS	Fir. E. Stzd	6 or 30	52 22	3-1
Chandler	1920-21	All	33x4-34x4½	SS	Fir. E. Stzd.	6-7-30	52-22	3-1
Chevrolet	1915	H-2-3-4	32x3½	SS	Det.	24	21	1
Chevrolet	1916	490	30x3½	Cl	Non. Dem.			
Chevrolet	1916	H-2-4	32x3½	SS	Det.	24	21	1
Chevrolet	1917	490	30x3½	Cl.	Non-Dem.			
Chevrolet	1917	F-2-5	32x3½	SS	Det.	24	21	1
Chevrolet	1917	D	34x4	SS	Det.	24	22	1
Chevrolet	1918	490	30x3½	Cl.	J. 124	25	21	1
Chevrolet	1918	F-A-2-5	32x3½	SS	Perl.	26	21	1
Chevrolet	1918	Sedan	32x4	SS	Perl.	26	22	1
Chevrolet	1918	D 4-5	34x4	SS	Perl.	26	22	1
Chevrolet	1919	490	30x3½	Cl	J 124-119	34	21	1
Chevrolet	1919	Baby Grd.	32x3½	SS	Stzd.	26	21	1
Chevrolet	1919	Truck	34x4½	SS	Stzd.	26	23	1
Chevrolet	1920	F-B-2-5	32x3½	SS	Stzd.	26	21	1
Chevrolet	1920	F B Sedan	32x3½	SS	Stzd.	26	21	1
Chevrolet	1920	490	30x3½	Cl	J 124	34	21	1
Chevrolet	1920-21	Truck	30x3½	Cl	J 124-119	34	21	1
Chevrolet	1920	Truck	34x4½	SS	Stzd.	26	23	1
Cleveland	1919-20-21	All	32x4	SS	Fir. E	6-10	42	3
Cole	1915	440-650	34x4	Cl	Fir. A	6-10	42	3
Cole	1915	6-66	36x4½	Cl	Fir. A	6-10	43	3
Cole	1915	8-30	36x4½	Cl	Fir. A	6-10	43	3
Cole	1915	8-60-61	34x4	SS	Gdrh. 9	28	62	5
Cole	1916-17	All	34x4	SS	Fir. E	6-7-10	42	3
Cole	1918	870-1-2	32x4½	SS	Gdrh. 8	33	63	5
Cole	1918	Others	34x4	SS	Gdrh. 9	28	62	5
Cole	1919		32x4½	SS	Kel. 30	13	103	
Cole	1919		32x4½	SS	Gdrh. 8	33	63	5
Cole	1919		32x4½	SS	Perl.	19	23	1

—*Continued on next page.*

—Continued from page 603.

Make	Year	Model	Size	Type	Make of Rim	Wedges Clamps	Bolts	Nuts
Cole	1919		32x4½	SS	Fir. E	6-10	43	3
Cole	1920-21	All	32x4½	SS	Fir. E	6-10	43	3
Crow Elkhart	1916	CE-30	32x3½	SS	Fir. E	6-7	41	3
Crow Elkhart	1916	CE-33	30x3½	Cl	Fir. F	6-7	41	3
Crow Elkhart	1917	CE-35	32x3½	SS	Fir. E	6-7	41	3
Crow Elkhart	1917	CE-33	30x3½	Cl	Fir. F	6-7	41	3
Crow Elkhart	1918	34-36	32x3½	SS	Fir. E	6-7	41	3
Cunningham	1915-16-17	All	36x4½	Cl	Fir. A	6-10	43	3
Cunningham	1918	All	36x4½	Cl	Fir. A	6-10	43	3
Cunningham	1919-20-21	All	34x4½	SS	Fir. C	6-10	43	3
Daniels	1916-17	All	34x4½	Cl	Fir. A	6-10	43	3
Daniels	1918	All	34x4½	Rev.	Fir. B	6-10	43	3
Daniels	1919-20	All	34x4½	SS	Fir. C	6-10	43	3
Davis	1916	6-E	34x4½	Cl	Fir. A	6-10	43	4
Davis	1916	F & G 6-C	34x4	SS	Fir. E	6-7-10	42	3
Davis	1917	6-H-I-K	34x4	SS	Fir. E	6-7-10	42	3
Davis	1917	6J-6I	34x4½	SS	Fir. A	6-10	43	3
Davis	1918	H, I, K, L	34x4	SS	Fir. E	6-10	42	3
Davis	1918	J, M, JI	34x4½	Cl	Fir. A	6-10	43	3
Davis	1919-20-21	51	33x4	SS	Fir. E	6-10	42	3
Detroiter	1913	A	32x3½	Cl	Det.	24	21	1
Detroiter	1914	B	32x3½	Cl	Kel. 20	13	101	
Detroiter	1915	C-5	32x3½	SS	Kel. 30	13	101	
Detroiter	1915	D	32x3½	SS	Kel. 30	13	101	
Detroiter	1916-17	All	32x3½	SS	Kel. 30	13	101	
Dixie Flyer	1916	All	32x3½	SS	Stan. 21	1	11	
Dixie Flyer	1917-18	All	32x3½	SS	Fir. E	6-7	41	
Dixie Flyer	1919	All	32x3½	SS	Stan. 76	5	11	
Dixie Flyer	1920	All	33x4	SS	Stan. 76	5	12	
Dixie Flyer	1921	All	32x3½	SS	Fire. E	6-10	41	1
Dodge Bros.	1915-16	All	32x3½	SS	Stan. 21	1	11	
Dodge Bros.	1917	All	32x3½	SS	Kel. 100	11	111	
Dodge Bros.	1918	All	32x3½	SS	D. B.	1-4	11	
Dodge Bros.	1919	All	32x3½	SS	D. B.	1-4	11	
Dodge Bros.	1920	All	32x3½	SS	D. B.-K-110	4-18	11-61	
Dodge Bros.	1920-21	Truck	32x3½	SS	D. B.-K.110	1-4	11	
Dorris	1916-17-18	JM-JI	36x4½	SS	Fir. C	6-10	43	3
Dorris	1919	6-80-7P	34x4½	SS	Fir. C	6-10	43	3
		6-80-4P	32x4½	SS	Fir. C	6-10	43	3
Dort	1917	All	30x3½	Cl	J 124	25	21	1
Dort	1918	All	30x3½	Cl	J 119-124	25	21	1
Dort	1919	All	30x3½	Cl	J 119-124	25	21	1
Dort	1920	All	30x3½	Cl	Perl. 119	34	21	1
El Car	1916-17-18	All	32x3½	SS	Fir E	7	41	3
El Car	1919-20	All	32x3½	SS	Stan. 21	1	11	
Elgin	1916	All	32x3½	SS	Stan. 21	1	11	
Elgin	1917	All	32x3½	SS	Fir. E	7	41	3
Elgin	1918	All	32x4	SS	Fir. E	6-10	42	3
Elgin	1919	All	32x3½	SS	Fir. E	7	41	3
Elgin	1920	All	33x4	SS	Fir. E	6-10	42	3
Elgin	1921	All	32x4	SS	Fire. E	6-10	42	3
Empire	1916-17-18	All	32x3½	SS	Stan. Fir. E	1-7	11-41	3
Essex	1919-20-21	Sup. 6	32x4	SS	Kel. 110	18	62	
Fiat	1916	All	36x4½	Cl	Fir. A	6-10	43	3
Fiat	1917-18	All	34x4½	Rev	Fir. B	6-10	43	3
Fiat	1919	All	34x4½	Cl	Fir. B	6-10	43	3
Ford	'19-20-21	C & S	30x3½	Cl	Kel. 88-123	16	60	
Ford	'19-20-21	C & S	30x3½	Cl	Hayes 127		60	
Ford	'19-20	Truck	32x4½	Cl	K 115 Hayes	17	63	9
Franklin	'17-8-9	All	32x4		Gdyr. Det.			
Franklin	1920-21	All	32x4		Gdyr. Det.			
Glide	'16-7-8-9	All	34x4	SS	Gdyr. B	8	42	4

Make	Year	Model	Size	Type	Make of Rim	Wedges Clamps	Bolts	Nuts
Grant	'18-19	All	32x3½	SS	Fir. E	6-7	41	3
					Stan.	1	11	
Grant	1920-21	H	32x4	SS	Fir. E	6-10	42	3
Grant	1920	Truck Part	32x4	SS	Gdrh. 8-9	28-33	62	5
Grant	1920	Truck Part	32x4	SS	Fir. E	6-10	42	3
Harroun	'17-8-9	All	30x3½	Cl	J 124	25	21	1
Haynes	1916	All	34x4	SS	Gdyr. B	8	42	4
Haynes	1917	36-37	34x4	SS	Fir. E	6-10	42	3
Haynes	1918	38-39	34x4	SS	Fir. E	6-10	42	3
Haynes	1918	40-41	34x4½	SS	Fir. E	6-10	43	3
Haynes	1918	43-44	34x4	SS	Fir. E	6-10	42	3
Haynes	1919	All	34x4½	SS	Fir. E	6-10	43	3
Haynes	1920-21	All	34x4½	SS	Fir. E	6-10	43	3
Hudson	1914	6-40	34x4	Cl	K 20	13	102	
Hudson	1914	6-40	34x4	Cl	K 30	13	102	
Hudson	1915	54	36x4½	Cl	Stan. 60	31	63	
Hudson	1915	6-54	36x4½	Cl	Fir. A	6-10	43	3
Hudson	1916	6-40	34x4	SS	K 30	13	102	
Hudson	1916	T S Lim	34x4½	SS	K 30	13	103	
Hudson	1917	Sup. 6	34x4	SS	K 30	13	102	
Hudson	1917	Sup. 6	34x4	SS	K 100	11	112	
Hudson	1918	TN	32x4½	SS	K 30	13	103	
Hudson	1918	T & N	32x4½	SS	K 30	13	103	
Hudson	1918	TN Lim.	32x4½	SS	K 30	13	103	
Hudson	1919	Sup. 6	34x4½	SS	K 120	17	63	
Hudson	1920-21	All	34x4½	SS	K 120	17	63	
Hupmobile	1913	All	32x3½	Cl	K 20	13	101	
Hupmobile	1914	H	32x3½	SS	K 30	13	101	
Hupmobile	'15-16	All	34x4	SS	K 30	13	102	
Hupmobile	1917	All	34x4	SS	Fir. E	7-10	42	3
Hupmobile	1918	All	32x4	SS	K 100	11	112	
Hupmobile	'19-20	All	32x4	SS	K 110	11	112	
Hupmobile	1921	All	32x4	SS	Kel 110	18	62	
Jeffery	'14-5	493	34x4	SS	Funk		42	3
Jeffery	1914	693	36x4½	SS	Funk		43	3
Jeffery	1914	6-106	34x4½	SS	Funk		43	3
Jeffery	'16-7-8	4 and 6	34x4	SS	Stan. 21	1	12	
Jordan	1917	4 and 7	34x4	SS	Fir. E	7-10	42	3
Jordan	1918	7 P Sed.	34x4	SS	Fir. E	7-10	42	3
Jordan	1918	4 P Sed.	32x4	SS	Fir. E	7-10	42	3
Jordan	1919	Sport S 7	32x4	SS	Fir. E	7-10	42	3
Jordan	'19-20-21	SII	32x4½	SS	Fir. E	6-10	43	3
King	'13-4-5	ABC	32x3½	SS	Stan. 21	1	11	
King	'16-7-8	All	34x4	SS	Stan. 21	1	12	
King	1919	All	32x4	SS	Stan. 4	1	12	
King	1920	All	32x4	SS	Stan. 76	5	12	
Kissel	1915	4-36–4-42	34x4	SS	Stan. 31	1	12	
Kissel	1915	6-48-60	36x4½	SS	Stan. 21	1	13	
Kissel	1916	4-32	32x3½	SS	Stan. 21	1	11	
Kissel	1916	6-42	34x4	SS	Fir. E	7-10	42	3
Kissel	1917	6-42	34x4	SS	Fir. E	7-10	42	3
Kissel	1917	6-38	32x4	SS	Fir. E	7-10	42	3
Kissel	'18-9	6-38-45	34x4	SS	Fir. E	10	42	3
Kissel	1919-20-21	C. B. 6	32x4½	SS	Fir. E	6-10	43	3
Lexington	1915	All	34x4	SS	Gdyr. B	8	42	4
Lexington	1916	60	32x4	SS	Gdyr. B	8	42	4
Lexington	1916	6-N	34x4	SS	Gdyr. B	8	42	4
Lexington	1917	O	32x4	SS	Gdyr. B	8	42	4
Lexington	1917	P	36x4½	Cl	Fir. A	6	43	3
Lexington	1918	All	34x4	SS	Gdr. 9	28	62	5
Lexington	1919	All	34x4	SS	Gdr. 9	28	62	5
Lexington	1920	All	32x4	SS	Kel 110	18	62	

—Continued on next page.

—Continued from page 604.

Make	Year	Model	Size	Type	Make of Rim	Wedges Clamps	Bolts	Nuts
Lexington	1920	All	34x4	SS	Gdrh. 9	28	62	5
Lexington	1921	All	32x4	SS	Kel. 110	18	62	
Liberty	'16-7	All	32x4	SS	Fir. E	7-10	42	3
Liberty	'18-9-20-21	All	32x4	SS	Fir. E	7-10	42	3
Lincoln	1920-21		32x4½	SS	Kel. 120	15	33	
Locomobile	'13 to 17	All	36x4½	Cl	Fir. A	6	43	3
Locomobile	1918	38-48-2	36x4½	Cl	Fir. A	6	43	3
Locomobile	1918	Rdster	34x4½	Cl	Fir. A	6	43	3
Locomobile	'19-20-21	All	34x4½	SS	Fir. C	6	43	3
Maxwell	'16-7	25	30x3½	Cl	119-120	2-12	11-100	
Maxwell	1918	All	30x3½	Cl	Det. Wheel			
Maxwell	1919	All	30x3½	Cl	119-124 Sp. 77	2-12	11-100	
Maxwell	1920-21	All	30x3½	Cl	K-88-123	16	60	
Mitchell	1915	B-25	34x4	SS	Stan. 21	1	12	
Mitchell	1915	B-45	36x4	SS	Stan. 21	1	12	
Mitchell	1916	D	32x4	SS	Stan. 21	1	12	
					Fir. E	10	42	
Mitchell	1916	Others	34x4	SS	Stan. 21	1	12	
Mitchell	1917	D	32x4	SS	Stan. 21	1	12	
Mitchell	1917	C-42	34x4	SS	Fir. E	7-10	42	3
Mitchell	1918	D	32x4	SS	Stan. 21	1	12	
Mitchell	1918	C	34x4	SS	Stan. 21	1	12	
Mitchell	1919		33x4	SS	Stan. 76	5	12	
Mitchell	1920-21	All	33x4	SS	Stan. 76	5	12	
					Fir. E	10	43	3
Moline Knight	1915	50	36x4½	SS	Fir E	6-10	43	3
Moline Knight	1916	40	34x4	SS	Fir. E	7-10	42	3
Moline Knight	1917	All	34x4	SS	Fir. E	7-10	42	3
Moline Knight	'18-9	All	34x4	SS	Fir. E	7-10	42	3
Moon	1915	All	34x4	SS	Stan. 21	1	12	
Moon	1916	6-40	34x4	SS	Stan. 21	1	12	
Moon	1916	6-30	32x3½	SS	Stan. 21	1	11	
Moon	1917	All	34x4	SS	Fir. E	7-10	42	3
Moon	1918	6-36	32x3½	SS	Fir. E	7-10	41	3
Moon	1918	645-66	34x4	SS	Fir. E	7-10	42	3
Moon	1919	All	32x4	SS	Stan. 76	5	12	
Moon	1920	All	32x4	SS	Fir. E	7-10	42	3
Moon	1921	6-68	32x4½	SS	Fir E	6-10	43	3
Moon	1921	6-48	32x4	SS	Fir. E	6-10	42	3
Nash	1918	All	34x4	SS	Fir. E Stan	10-1	42-12	3
Nash	1918	681-3	34x4	SS	Stan. 21	1	12	
Nash	1918	682-4-5	34x4½	SS	Fir. E Stan.	1-6-10-13-43		3
Nash	1919	All	34x4½	SS	Fir. E Stan	10-1	43-13	3
Nash	1919	681-3	33x4	SS	Fir. E Stan.	6-10-26-43-22-3-1		
Nash	1920	All	34x4½	SS	Stan. 21	1	13	3
Nash	1920	Four	32x3½	SS	Fir. E	6-10	41	
Nash	1920-21	681-6	33x4	SS	Fir. E	6-10	42	3
National	'13-4-5	All	36x4½	Cl	Fir. A	6	43	3
National	1916	6	34x4½	Cl	Fir. A	6	43	3
National	1916	Others	36x4½	Cl	Fir. A	6	43	3
National	'17-8	All	34x4½	Cl	Fir. A	6	43	3
National	1919	All	34x4½	SS	Fir. C	6	43	3
National	1920-21	All	32x4½	SS	Fir. C	6	43	3
Oakland	1916	32-38	32x3½	SS	B	21	71	6
Oakland	1916	50	34x4½	SS	B	21	72	6
Oakland	1917	50	34x4½	SS	B	21	72	6
Oakland	1917	34	32x4	SS	B	21	72	6
Oakland	'18-9	All	32x4	SS	Perl.	19	22	1
Oakland	1920-21	All	32x4	SS	Stzd.	26	22	1
Oldsmobile	'15-6	42-3-4	32x3½	SS	Baker	21	71	6
Oldsmobile	1917	45-5	32x3½	SS	Baker	21	71	6
Oldsmobile	1917	45-7	34x4	SS	Baker	21	72	6
Oldsmobile	1917	37-5	32x4	SS	Baker	21	72	6
Oldsmobile	1918	37 45 Sp.	32x4	SS	Perl.	19	22	1
Oldsmobile	1918	45-A T	34x4	SS	Perl.	19	22	1
Oldsmobile	1919	37	32x4	SS	Stzd.	26	22	1
Oldsmobile	1919	45A-S	32x4	SS	Stzd.	26	82	8
Oldsmobile	1919	45-A T	34x4	SS	Stzd.	26	83	8
Oldsmobile	1920	37-A	32x4	SS	Stzd.	26	22	1
Oldsmobile	1920-21	45-B Port	34x4½	SS	Stzd.	26	83	8
Oldsmobile	1920-21	37-A Port	32x4	SS	Stzd.	26	83	8
Overland	1915	80	34x4	SS	Stan. 21	1	12	
Overland	1915	81	32x3½	SS	Stan. 21	1	11	
Overland	1915	82	34x4	SS	Stan. 21	1	12	
Overland	1916	83	32x3½	SS	Stan. 21	1	11	
Overland	1916	86	34x4	SS	Stan. 21	1	12	
Overland	1916	75	30x3½	Cl	119	3	11	
Overland	'17-8	88	34x4½	SS	Stan. 21	1	13	
Overland	'17-8	84-85	32x4	SS	Stan. 21	1	12	
Overland	'17-8	90	30x3½	Cl	119	3	11	
Overland	1919	90	30x3½	Cl	119	3	11	
Overland	1920	3 P	30x3½	Cl	119	2	11	
Overland	1920-21		33x4	SS	Stan. 76	5	12	
Packard	'13-16	All	36x4½	Cl	Fir. A	6	43	3
Packard	'17-8	All	34x4½	Cl	Fir. A	6	43	3
Packard	'19-20-21	All	34x4½	SS	Fir. C	6	43	3
Packard	1921	Six	32x4	SS	Kel. 110	18	62	
Paige	1915	4-36-4-46	34x4	SS	K 30	13	102	
Paige	1915	6-36	32x4	SS	Fir. E	7-10	42	3
Paige	1916	4-46	34x4	SS	K 30	13	102	
Paige	1916	6-38	32x4	SS	Fir. E	7-10	42	3
Paige	1917	6-51	34x4	SS	K 100	11	112	
Paige	1917	6-30	32x4	SS	K 30	13	102	
Paige	1918	6-55	34x4	SS	K 100	11	112	
Paige	1918	6-40	32x4	SS	Parker	32	92	7
Paige	1919	6-55	32x4	SS	K 110	18	62	
Paige	1920-21	All	32x4	SS	K 110	18	62	
Patterson	'16-7-8	All	32x4	SS	Perl.	19	22	1
Patterson	1919	All	33x4	SS	Stzd.	26	22	1
Peerless	'16-7-8	All	34x4	SS	Fir.E-Stan 21	7-1	42-12	3
Peerless	1919	56	34x4½	SS	Fir. E	6-10	43	3
Peerless	1920-21	56	34x4½	SS	Fir E.	6-10	43	3
Premier	'13 to 16	All	36x4½	Cl	Fir. A	6-10	43	3
Premier	1917	6-B	34x4	SS	Fir. E	7-10	42	3
Premier	'18-19	All	32x4½	SS	Fir. C	6-10	43	3
Premier	1920-21	All	32x4½	SS	Fir. E	6-10	43	3
Reo	1914	All	34x4	SS	Stan. 21	1	12	
Reo	1915	M-N	34x4½	SS	Stan. 21	1	13	
Reo	1915	St & R.	34x4	SS	Stan. 21	1	12	
Reo	'16-17	MN	34x4½	SS	Stan. 21	1	13	
Reo	'16-7	R & S	34x4	SS	Stan. 21	1	12	
Reo	1918	M-N	34x4½	SS	Stan. 21	1	13	
Reo	1918	T. U.	34x4	SS	Fir. E	6-10	42	3
Reo	1919	T. U.	33x4	SS	Fir. E	6-10	42	3
Reo	1920	Truck	34x4½	SS	Fir. E	6-10	43	3
Reo	1920-21		33x4	SS	Fir. E	6-10	42	3
Ross	1916	All	34x4	SS	Det.	24	22	1
Saxon	1915	B-2-S	32x3½	SS	Stan. 21	1	11	
Saxon	1916	6 Cyl	32x3½	SS	Stan. 21	1	11	
Saxon	'17-18	S 4 6	32x3½	SS	Stan. 21	1	11	
Saxon	1919	S 4 6	32x3½	SS	Fir. E	10	41	3
Saxon	1920		30x3½	Cl	Fir. F	10	41	3
Saxon	1921	All	32x4	SS	Fir. E	6-10	42	3
Standard	'16-17	All	34x4	SS	Fir. E	7-10	42	3
Standard	'18-19	All	34x4½	SS	Stan. 21	1	13	
Stanley Steam	1916	725	34x4½	Cl	Fir. A	6-10	43	3

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Make	Year	Model	Size	Type	Make of Rim	Wedges Clamps	Bolts	Nuts
Stanley Steam..	1917	728	34x4½	Cl	Fir. A	6-10	43	3
Stanley Steam..	1917	730-731	34x4	SS	Fir. E	7-10	42	3
Stanley Steam..	'18-19	All	34x4	SS	Fir. E	7-10	42	3
Stanley Steam..	1920	All	34x4½	SS	Fir. C	6-10	43	3
Stearns	'15-16	L-4	34x4	Cl	Stan. 22	3	12	
Stearns	'17-18	Knight	34x4	Cl	Gdrh. 8	33	62	5
Stearns	'17-18	4	32x4	Cl	Gdrh. 8	33	62	5
Stearns	1919	4	32x4	SS	Gdrh. 9	28	62	5
Stearns	1920-21		34x4½	SS	Fir. E	6-10	43	3
Stephens.......	1918	70-75	32x4	SS	K PS. S	15	33	
Stephens..	1919-1920-21		32x4	SS	Stan. 21-76	1	12	
Studebaker.....	1914	Four	32x3½	Cl	K. 20	13	101	
Studebaker.....	1914	Six	34x4	Cl	K. 20	13	102	
Studebaker.....	1915	Four SD	32x3½	Cl	K. 30	13	101	
Studebaker.....	1915	Six-E C	34x4	Cl	K. 30	13	102	
Studebaker.....	1915	Truck	34x4½	Cl	K. 30	13	103	
Studebaker.....	1916-1917	Four	34x4	SS	K. 30	13	102	
Studebaker.....	1916-1917	Six	34x4	SS	K. 30	13	102	
Studebaker.....	1916-1917	Truck	34x4½	SS	K. U.	15	33	
Studebaker.....	1918	Six	34x4	SS	K. 100	11	112	
Studebaker.....	1918	Four	32x4	SS	K. 100	11	112	
Studebaker.....	1918	SH 4	32x3½	SS	K. 100	11	111	
Studebaker.....	1918	Truck,	34x4½	SS	K. S. S.	15	33	
Studebaker.....	1919	Four	32x3½	SS	K. 100	11	111	
Studebaker.....	1919	Six	32x4	SS	K. 100	11	112	
Studebaker.....	1920-21	All	32x4	SS	K. 110	18	62	
Velie...........	1915	650	36x4	SS	Fir. E	7-10	42	3
Velie...........	1915	Builtwell	34x4	SS	Gdyr. B	8	42	4
Velie...........	1916	22-40	34x4	SS	Gdyr.	8	42	4
Velie...........	1916	15-45	34x4	SS	Gdyr. B.	8	42	4
Velie...........	1917	28	32x4	SS	Gdyr. B	8	42	4
Velie...........	1917	27	34x4	SS	Gdyr. B	8	42	4
Velie...........	1918	All	32x4	SS	Gdyr. B	8	42	4
Velie...........	1918	All	32x4	SS	Fir. E	7-10	42	3
Velie...........	1919-1920	All	32x4	SS	Fir. E	7-10	42	3
Westcott.......	1916-17-18	All	34x4	SS	Fir. E	7-10	42	3
Westcott.......	1919-1920-21	A 38	33x4	SS	Fir. E	10	42	3
Westcott.......	1920-21	A 48	32x4½	SS	Fir. E	6-10	43	3
White..........	1915	45-60	36x4½	Cl	Fir. A	6-10	43	3
White..........	1916	GAH	32x4	Cl	Fir. A	6-10	42	3
White..........	1916	GED	36x4½	Cl	Fir. A	6-10	43	3
White..........	1917	GM	36x4½	Cl	Fir. A	6-10	43	3
White..........	1918	All	34x4½	Cl	Fir. A	6-10	43	3
White..........	1919-1920	All	34x4½	SS	Fir. C Tr	6-10	43	3
White..........	1920		36x4½	SS	Fir. Tr	6-10	43	3
White..........	1921	All	34x5	SS	Fir. TT	Ct.	131	11
Willys-Knight ..	1916	84	34x4½	SS	Stan. 21	1	13	
Willys-Knight ..	17-18-19	All	34x4½	SS	Stan. 21	1	13	
Willys Knight...	1920-21	All	33x4	SS	Stan. 76	5	12	
Winton.........	13 to 18.	All	36x4½	Cl	Fir. A	6-10	43	3
Winton.........	1919-1920-21	All	34x4½	SS	Fir. C.	6-10	43	3

Dimensions of Standard Demountable Rims

To illustrate the use of this table, let us assume that a wheel has a 36 x 4 rim (36 x 4 size is not now made) of some old style on it, such as a clincher or old-style quick detachable type, and it is desired that a change be made to take a standard size of tire as listed on page 594. By referring to this page we find that a 33 x 4 or 34 x 4 is the nearest size. The 34 x 4 is not considered a standard size although it is still made; therefore, it would be best to use the 33 x 4.

In order to be able to tell if a 33 x 4 would go on the felloe of the wheel, and to find out if it is necessary to cut the wheel felloe down, or to build it up, refer to the right-hand table. Note that a 36 x 4 measures 26 37/32" outside diameter of the wood felloe, and that, to take a 33 x 4 rim, it must be cut down to 23 27/32" so as to take the 33 x 4 felloe band.

Felloe bands are steel bands placed around the felloe of the wheel, and on which is placed the rim. Felloe bands accompany all complete sets of rims and should be ordered with rims.

This list is for straight-side rims only, except the 30 x 3½ size, which is the clincher demountable.

Size of Tire	A Inside Diam. of Felloe B'nd	B Inside Circum. of Felloe B'nd	C Width Felloe Band	D Outside Circum. of Felloe B'nd	E Distance Between Bolt Holes
30x3½"	21 27/32"	5'-8 5/8 "	1½"	5'-9 51/64"	12 21/64"
32x3½"	23 27/32"	6'-2 29/32"	1½"	6'-4 5/64 "	11 31/64"
34x3½"	25 27/32"	6'-9 3/16 "	1½"	6'-10 3/8 "	12 31/64"
32x4 "	22 27/32"	5'-11 49/64"	1¾"	6'-0 15/16"	10 63/64"
33x4 "	23 27/32"	6'-2 29/32"	1¾"	6'-4 5/64 "	11 31/64"
34x4 "	24 27/32"	6'-6 3/64 "	1¾"	6'-7 15/64"	11 63/64"
36x4 "	26 27/32"	7'-0 21/64"	1¾"	7'-1 33/64"	12 63/64"
32x4½"	21 21/32"	5'-8 1/32 "	2 "	5'-9 7/32 "	10 23/64"
34x4½"	23 21/32"	6'-2 5/16 "	2 "	6'-3½ "	11 23/64"
36x4½"	25 21/32"	6'-8 39/64"	2 "	6'-9 25/32"	9 29/64"
36x6 "	22¼ "	5'-9 29/32"	3¼"	5'-11 5/64"	6 37/64"
38x7 "	22¼ "	5'-9 29/32"	3 29/32"	5'-11 5/64"	6 37/64"
40x8 "	22 "	5'-9 7/64 "	4¼"	5'-10 9/32"	6 33/64"

TOOLS FOR TIRE CHANGING

For tire changing in a repair shop the following tools are necessary:

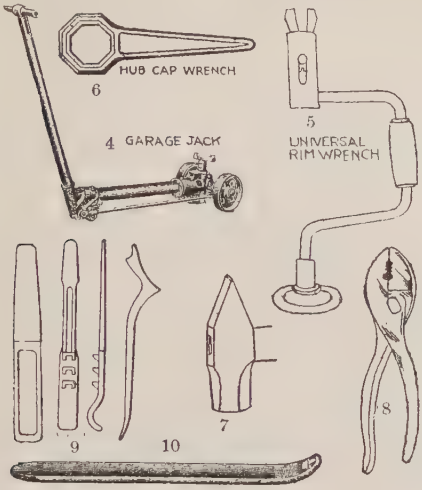

Fig. 61

A garage jack (Fig. 61-4); a universal rim wrench (Fig. 61-5) which is adjustable to 13/16″, suitable for all nuts on all demountable rims; wire-wheel hub-cap wrenches (Fig. 61-6) for Houck and Hays wire wheels; a blacksmith's hammer, about 2 lb. (Fig. 61-7); a large screwdriver; pliers for removing valve and dust caps (Fig. 61-8); tire tools (Fig. 61-9) for clincher one-piece rims, as used on Fords; a tire tool (Fig. 61-10), for removing and replacing casings, made of spring steel, 1″ x 12″; an air compressor. If the shop is not equipped with a power air compressor, see the Jensen pump, page 622, Fig. 60.

For a tire tool for work on all types of rims and tires, there is nothing better than a piece of spring leaf, the longer the better.

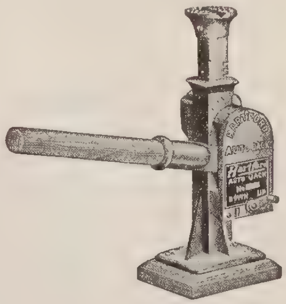

Fig. 62

A good jack is a necessity. With a good jack the heaviest car can be raised with the slightest pressure. This saves time, and will save the car from dropping at a critical time.

A flat block should be placed under a jack when used around a car, to prevent it turning over and sinking in the ground.

Addresses of Some of the Tire Manufacturers

Write for catalogues. You will gain much information from: Amazon Rubber Co., Akron, Ohio; Diamond Rubber Co., Akron, Ohio; Federal Rubber Mfg. Co., Milwaukee, Wis.; Firestone Tire and Rubber Co., Akron, Ohio; Fisk Rubber Co., Chicopee Falls, Mass.; B. F. Goodrich Co., Akron, Ohio; Goodyear Tire and Rubber Co., Akron, Ohio; Hood Tire Co., Watertown, Mass.; Kelly-Springfield Tire Co., 229 W. 57th St., New York, N.Y.; Koochook Rubber Co., Kokomo, Ind.; Lee Tire & Rubber Co., Conshohocken, Pa.; Michelin Tire Co., Milltown, N.J.; Pennsylvania Rubber Co., Jeannette, Pa.; Republic Rubber Co., Youngstown, Ohio; Rutherford Rubber Co. Rutherford, N.J.

INSTRUCTION No. 55

TIRE CONSTRUCTION; CARE AND REPAIR OF TIRES: Vulcanizers; Tools

CONSTRUCTION OF PNEUMATIC TIRES

There are two kinds of pneumatic tire constructions: the "fabric," and the "cord" construction.

In the **fabric construction** the carcass is made of closely woven and **interwoven** cotton fabric.

In the **cord construction,** the carcass is made of loosely woven cords and **not interwoven.**

The fabric carcass type of tire can be constructed by two methods: the "full-molded" method, and the "wrapped" method.

The full-molded method of construction is explained on page 609. It is built up on an iron core or mandrel, and is then placed in a mold (Fig. 2), which in turn is placed in a hydraulic press vulcanizer, the object of the press being to close the halves, (L) and (U) of the molds tightly. With a full-molded type of tire, the entire construction is cured or vulcanized complete at one operation.

With the wrapped-tread method, the fabric carcass, side walls, cushion and breaker-strip are formed or built up in the same manner as a molded tire, but they are semi-cured (half-cured) only in this mold. After this semi-curing operation, the tire is removed from the molds (Fig. 2), and the part where the tread goes is buffed off and cemented with several coats of high-grade vulcanizing cement. A semi-cured tread is then treated with several coats of vulcanizing cement and allowed to dry, after which the tread is applied to the carcass and is rolled down under pressure to remove all air.

An air bag is then placed inside of the tire and the entire tire is **wrapped tightly with canvas cloth strips** about 2″ wide. Then, instead of putting it back in the mold (Fig. 2), where it was semi-cured, it is placed in a horizontal vulcanizer (large kettle), and the final cure (vulcanize) with live steam is given, after which the tire is left standing until cooled. The canvas strips are then removed and tire is laid away for a few weeks to "after-cure."

A wrapped-tread tire can always be distinguished by the slightly roughened surface, which is the impression left from the cloth wrapping.

The advantage of the wrapped-tread construction is the possibility of detecting if there are defects in the tire, as pinches or buckles, which can be determined before the tread is applied, which enables the manufacturer to turn out a perfect tire. This type of tire is more expensive to manufacture.

The rubber used in making the tread and cushion stock of a tire consists of a gummy substance obtained from the milky juice of certain tropical trees, mixed with sulphur to tend to harden it and give it strength. When heated, it changes from a sticky mass resembling chewing gum, to the elastic form in which we see it in a completed tire.

The best rubber is called Para, which comes from the city of Para, near the mouth of the Amazon River. Other good rubber comes from Africa, India, Ceylon, and South America.

The white dust often seen on rubber goods is called "bloom" and comes from the sulphur not chemically combined with the rubber. Old tires in stock a long time accumulate considerable bloom, and get hard.

The strength of the tire lies in this fabric or cord carcass; the cushion and protection for the carcass of the tire is in the rubber. Sea Island cotton, which is very strong, is used for the carcass of the fabric tire, and cords are used for the carcass of the cord tire.

Construction of a Fabric Tire

The carcass, which is the strength of the tire, is built up by placing several layers (4 to 7) of closely woven cotton fabric on a mandrel or core-shaped like the inside of the tire. The carcass is dependent upon the tread, cushion, and breaker for protection (see Fig. 1).

Cotton fabric is used because it is flexible, easily permeated with rubber, and is best adapted to resist heat. If too many layers of fabric were used, it would thicken the carcass, causing it to be stiff, and less flexible, and inside plies would break easily, and heat would be difficult to expel. Heat has a tendency to loosen the "frictioning" between the fabric plies.

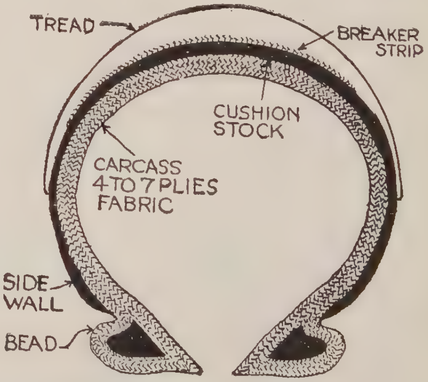

Fig. 1. Construction of a fabric tire.

The tire assembly construction is as follows:

1. **One layer** or ply of fabric is placed over a core on which the tire is to be formed.
2. **A bead** is formed by placing the lower edge of the fabric around the bead form; hard rubber is used to form a bead of a clincher tire, and small wires for straight-side tires.
3. **Other layers** or plies of fabric are placed, one over the other, but before doing so, rubber is infused by pressure into and between, each layer or ply of fabric, which impregnates the fabric thoroughly; this is called **"frictioning."**
4. **A cushion** of 1/8″ soft gum rubber is placed over the fabric carcass.

5. **A breaker-strip** is then placed over the cushion. It is made of coarse loose-woven fabric, and it serves to ward off attacks of sharp objects that may penetrate the tread. When a tire wears through the tread, the "breaker" is exposed.
6. **A chaffing strip,** consisting of a strip of fabric about 2″ wide, is applied to the edge of and above the bead.
7. **Then the side walls,** made of thin tough rubber (made thin to expel heat) are applied.
8. **The tread,** made of thick tough rubber, is applied last.

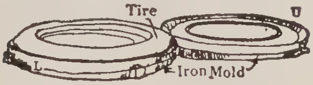

Fig. 2. Iron molds.

9. **The tire on the forming core is then placed in an iron mold** divided into halves (see Fig. 2). The part (**U**) of this mold is placed over the part (**L**), covering the tire, and is fastened down.
10. **The mold with the tire** is then placed in a cylindrical tank, or kettle, or hydraulic press vulcanizer, and "open cured."[1]
11. **Live steam** is turned into this tank at a pressure of 50 to 60 lbs., which corresponds to about 300° F. This tank holds from 25 to 30 tires.
12. **After curing,** the tire is placed in storage to "after cure."

Construction of a Cord Tire

The cord tire differs from the fabric tire previously described in that instead of Sea Island cotton or other closely woven and interwoven fabric being used for the carcass of the tire, cords are used which are loosely woven and not interwoven.

There are two kinds of cord tires, the "cable cord," and the "multiple cord."

The cable-cord tire is known as the Silvertown cord tire, and is a product of the Palmer Tire Co., of England, made in a suburb of London called Silvertown. This tire is made in this country by the B. F. Goodrich Co., and the Carlise and Fiske companies.

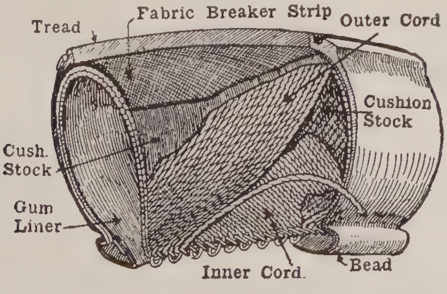

Fig. 3. Construction of the cord tire.

The multiple-cord tire is made by the Firestone, Goodyear, and some of the other tire manufacturers.

The difference between the cable-cord and the multiple-cord tire is in the size of the cords and the number of plies of cords. In the cable-cord tire there are two to four plies of heavy cable cords.

In the **multiple-cord tire** there are six to eight layers or plies of smaller cords or threads.

The cord tire is far stronger than the fabric tire, one principal reason being that the cord tire is not so closely woven or **interwoven** as the fabric carcass tire, and is therefore not broken so easily. The fabric tire is continually sawing itself, as if it were being bent back and forth, and eventually breaks. Another advantage is that a cord tire is not subject to stone bruises, as explained on page 610, as the cords all run one way and are not interwoven as fabric. The result is that they will give without breaking when the tire strikes a stone at high speed. In other words, the carcass will have the same action as the tread—it will stretch under a blow without breaking.

For an example of the construction of the cord tire we will use the "cable-cord" tire as shown in Fig. 3.

The inner lining of a tire is made of a rubber sheet; then the first or **inner layer or ply of cable cord** is laid; then two sheets of pure gum are applied to act as a **cushion** between this and the next ply of cord.

The **second or outer layer** of cord is then applied at right angles, or at an angle of 45°, to the first layer; then two layers of gum cushion stock, then a fabric **breaker-strip,** and then the **tread,** are successively applied.

The body or carcass of the tire, as will be noted, is made of two plies or layers of cords, instead of fabric. These cords are made of cotton fiber, about the size of heavy sewing cotton, twisted into cords about the size of ordinary grocery store twine, but stronger. These cords in turn are woven into cables.

Throughout the process, all units are impregnated, under heavy pressure (hundreds of pounds to the square inch), with a solution of pure, fine rubber. This has much the same effect as waxing shoemaker's thread. The solution permeates every fiber, being literally driven into it.

Treads: There are two types of treads used on cord tires, the "ribbed tread" (Fig. 8, page 592) and the "safety" or "non-skid" tread.

The air pressure carried in the cord tire is given on page 593.

Cord tires are made in sizes which are given on page 594.

Beads of tires are made for tires as noted on page 595.

A heavy truck tire of the cord type is made in sizes given on page 594.

Airplane tires of the cord type are made in 26 x 4 and 32 x 4½ sizes.

The cord tire is a higher-priced tire than the fabric tire, but is the popular tire, as it will outwear the fabric tire and is well worth the difference. This is due to its strong construction. Yet it is resilient and easy riding, and the cords do not break as readily as interwoven fabric.

Cord tires can be made by the "molded" or by the "wrapped tread" method.

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[1] "**Cured**" means vulcanizing; "**open-curing**" is a process where live steam comes in contact with the raw rubber; "dry curing" is where steam is not in direct contact; "uncured" is raw, unvulcanized rubber.

TIRE TROUBLES: CAUSES AND REMEDY

Some of the tire troubles are: stone-bruises, loose treads, sand blisters, worn treads, chafed tires, rim-cuts, punctures, cuts clear through the carcass, blow-outs.

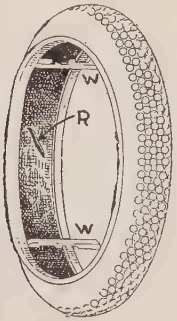


Fig. 4.—**Inside break in fabric** at (R). Note the tire spreaders (W) used to hold the tire apart when examining or repairing it.

Stone bruises are caused by the tire striking a stone at a high rate of speed, resulting in one or all layers of the **fabric breaking,** yet the tread may not even be cut. The inner tube works into this break, and a blow-out (Fig. 6) results.

Tires have been known to blow-out while standing in the garage, as a result of a stone bruise, and it is no doubt often a mystery why it occurred. The reason is simple. The tire struck a stone, or some obstruction when running at a high speed, and the fabric being hard, broke at (R) (Fig. 4) on the inside of the tire, yet the tread showed no effect of the trouble. This is termed a stone-bruise. Examine the tires when off the rim and feel the fabric, inch by inch, for a weak spot. If a break has occurred, you can see it (Fig. 4).

A temporary repair can be made by using "inner" and "outer" shoes (page 611), but it is advisable to repair as shown on page 617, as a blow-out may occur even with this "inner shoe" covering the weak spot.

The cord tire is not as susceptible to stone bruises because the cords are not interwoven, or crosswoven, like a fabric tire, and instead of breaking, they give.

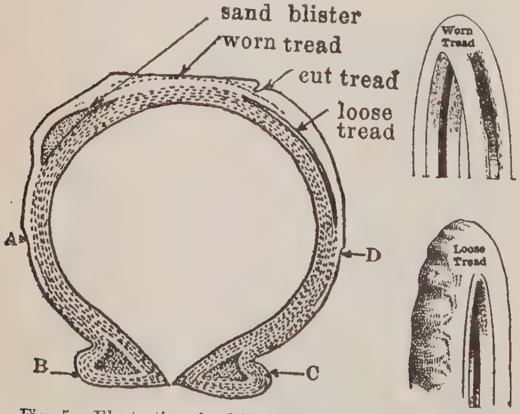


Fig. 5. Illustrating the different troubles that a tire casing is heir to.

Sand blisters are caused by a small hole or cut in the tread through which sand and dirt work under the tire, causing it to pucker up. These will result in a loose tread if not closed up (see Fig. 5). The hole through which the sand worked into and under the tread may be several inches away. Close it up with a plastic substance called "tire dough," or vulcanize it. See page 621: "Sand-blister repair."

Loose treads result from running a tire not properly inflated, or from moisture getting under the tread through a cut in the tread, or from a defect in the tire where the rubber compound is poor and does not adhere, or from setting brakes suddenly.

Loose treads can be repaired, unless the tread is loose about one-third of the way. In this case a new tread must be applied —providing the fabric carcass is not cut (if it is, repair it first)— and providing layers or plies of fabric in the carcass are solid and are not separated.

The molded type of tire is more subject to loose treads than the wrapped-tread construction.

Worn treads in the center, or slightly to the side of the tire, usually are the result of driving in street-car tracks, wheels being out of line (usually on the front) caused by the steering knuckles being bent or the steering apparatus being out of order. See Index under "Alignment of wheels."

Chafed tires, usually worn on the side, result from driving close to curbstones, in street-car tracks, ruts, etc. This permits water to rot the fabric. **Repair** by rebuilding the side walls, and vulcanize.

Rim cuts are the result of running the tire flat after a puncture, or running on the rim which damages the curve in the rim and which in turn cuts the tire at the rim just above the bead. Improper inflation is also a common cause. This permits the edge of the rim to cut the bead when the deflated tire receives a heavy jar. **Rim cuts can be repaired** if cut in only two or three short places, but if cut at sections all around the tire, then it cannot be repaired.

This refers to the old-style clincher rims. Now that most tires are of straight-side construction, rim cutting is not as common a trouble as formerly.

Punctures through tread and carcass, if small, will not cause damage to the carcass, but the tread should be closed by vulcanizing with the small vulcanizer while the tire is inflated on the car, or by some kind of plastic material, such as "tire dough," being stuffed into it to keep water and sand out.

Where tires are cut through the carcass, they can be repaired if the cut does not extend too long and the plies of fabric are not separated. The process of repairing is the same as for a blow-out repair (page 617).

Retreading

Retreading: It is no easy matter to form a correct judgment about any tire with regard to retreading. In some instances a tire case may appear to be sound, and yet may prove to have stone bruises in the carcass on inside examination, or the layers of fabric may be separated from each other. On the other hand, there are undoubtedly covers condemned, because of local damage, which if properly examined, would be worth retreading.

The age of the tire and **condition of the fabric** and cost of the retread **will determine** if it is worth while to retread. The strength of the tire is in the carcass. The rubber tread is merely a protection.

Therefore the condition of the carcass must be determined when deciding as to retreading. There are three questions to determine: (1) is the carcass badly cut in several places—if so, don't retread or repair; (2) are all the layers of fabric of the carcass together and not separated; sometimes these fabric layers separate and pucker up, owing to improper adhesion in manufacture, or to water getting under the tread and into the carcass: (3) is the tire rim cut badly?

Blow-Outs

The greatest tire trouble is blow-outs. A blow-out is simply a hole blown through the carcass or fabric. **There are two classes of blow-outs:** those occurring near the rim, and those in the tread or on the side.

Fig. 6

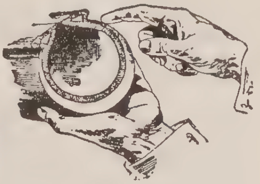


Fig. 7

Fig. 6. When a blow-out occurs it always leaves a weak spot.

Fig. 7. The tire is made thin here for a purpose.

We will designate the first-mentioned as a **"rim blow-out,"** and the latter as a **"tread blow-out."** Wherever a blow-out occurs, that spot always remains weak, because the fabric can never be joined again, but can be repaired (see page 617).

Cause of rim blow-outs: A tire is made thin at the point shown in the illustration (Fig. 7), near the rim, for a purpose. Very nearly all the "bend" and "give" is at this point. If it was made thick and heavy, it would break; therefore, it must be thin and flexible.

If you were to take a wire and bend it quick and often, it would get hot and break. The same is true with this bending point of the tire near the bead—especially if the tire is not properly inflated.

Inside breaks in the fabric are due to stone bruises and to running the tire improperly inflated.

If you were to take a deck of cards and bend them back and forth, it would be noticed that the bottom cards would receive most of the sawing strain. Just so with the several plies of fabric, when the tire is not properly inflated.

Keep the tire inflated, therefore, and many of the tire troubles will be avoided.

A tire may **look** sufficiently inflated and yet have only 40 pounds of air in it, when it should have 70. No amount of kicking, feeling, or looking will tell; the only sure way is to have a reliable air gauge.

Tread blow-outs are the result of cuts on the tread and of stone bruises. Cuts and jabs on the tread of tires permit dampness, oil, or dust to get between the rubber and the fabric, which soon rots and weakens it.

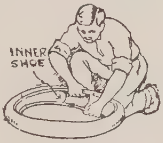
Inasmuch as the fabric must sustain the air pressure, **a weak place in the fabric is enlarged by the pressure,** and a blow-out is the result. Once a blow-out occurs, it can never be repaired so that it will be as strong as it was at first.

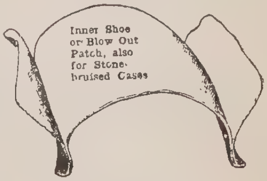
Therefore **repair cuts in the tread and examine tires for internal fabric cuts** caused by stone bruises, when the tire is off the wheel.

External cuts in the tread can be vulcanized while the tire is inflated and on the wheel, and the work can be done with the small vulcanizer shown on pages 615, 617.

A temporary repair of a blow-out or of an internal fabric cut, or of weak places in the carcass, can be effected by inserting an **inner shoe** between the inner tube and the carcass and an **outer shoe** over the tread (Figs. 10, 11, and 12). The defect should be repaired as soon as possible, however, as a cut in the fabric will soon work larger and cause a blow-out from rim to rim.

How to get additional mileage or service out of old tires: Very nearly every motorist has one or more old tires which is of no use. These old tires can be made serviceable again by placing inner shoes inside of the tire, covering the weak spots or holes, and then placing reliners inside of the tire over those reinforced places (see Figs. 8 and 9). Reliners are hard on inner tubes and are not advisable to use in new tires. They should be used only for temporary repair of old tires.





Inner Shoe or Blow Out Patch, also for Stone-bruised Cases

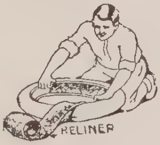


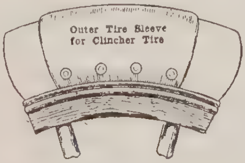
Fig. 8 (upper)
Fig. 9 (lower)

Fig. 10

Fig. 8. Insert an **inner shoe** for small blow-outs or weak places in tires.

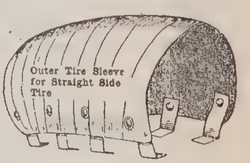
Fig. 9. For bad cuts or large blow-outs, or when using an old or worn-out tire. First insert inner shoes over the holes, then the **reliner** in the inside of the tire, as shown.

Fig. 10. **Inner shoe,** to go on the inside of the tire to protect fabric cuts, breaks, or weak places resulting from small blow-outs or stone bruises or rough spots, and also as a protection to rim cuts. Made of 3-ply fabric with wings, to go under the rim.



Outer Tire Sleeve for Clincher Tire

Fig. 11



Outer Tire Sleeve for Straight Side Tire

Fig. 12

Figs. 11, 12. **Outer shoe,** to be placed temporarily on the outside of the tire when it is cut or damaged, until vulcanized. Note that the lower part fits under the rim for a clincher, and under the tire for a straight side.

CARE OF TIRES AND TUBES[1]

Proper inflation: Keep tires inflated to the pressure recommended by the maker (see page 593). Nothing ruins a tire so quickly as running it so soft that the canvas continually bends. It is almost impossible to over-inflate a tire with a hand pump.

Running a flat tire, even a short distance, is sure **to be costly.** Better run on the rim, very slowly and carefully, if imperatively necessary, and the distance is short.

Keep grease and oil away from your tires and tubes always. They destroy rubber.

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[1] A useful and valuable booklet, *Care and Repair of Tires*, issued by the Firestone Tire Co., Akron, Ohio, will be sent free on request, by writing this firm. A good deal of beneficial information is contained therein. Also write B. F. Goodrich Co., Akron, Ohio.

A book well worth the price of $1.50 on *Tire Repairing and Vulcanizing* can be had of A. L. Dyke, Pub., Granite Bldg., St. Louis, Mo.

Speedy deflation demands instant attention. Carry an extra casing and inner tube.

Equalizing traction: It is important that tires of the same diameter be used on the rear wheels. Furthermore, special treads and chains should be used in pairs. If there is a variation in the diameter of the rear tires or in the traction of the wheels, the differential is caused to work whenever the car is in motion. In this way, considerable power is lost, and the differential parts are unnecessarily worn.

Alignment of wheels: It is very important that the wheels should be in alignment. If they get out of line, the tire treads will wear in a very short while. As usual in this case, the tire manufacturer will not guarantee or rebate on a tire tread ruined by wheels being out of line. See Index for "Alignment of the wheels."

Wheels running over a fraction of an inch out of alignment cause a grinding wear on the rubber. Front wheels suffer most.

Side skidding and rounding corners rapidly will cause rim cutting. Avoid running in car tracks.

Setting brakes suddenly, causing the tire to drag, causes loose treads, and worn treads, and damages the tire. Always set brakes gradually. See Index under "Brakes."

Do not drive in the ruts or bump the side of the tires against the curbing or pavements, and don't start your machine with a jump.

If one of your tires sustains a cut to the extent of exposing the fabric, an emergency band or patch should be applied at once.

Keep an odometer record of the mileage of each tire. You will find that you are getting better mileage than you would otherwise imagine.

Keep rims in good order, straight and true. Rust is destructive. Paint preserves.

The rims, if rusted, should be thoroughly cleaned and sandpapered, and then painted with liquid graphite (common stove polish will answer). Also apply to bead of tire.

Inner tubes: Carry them in the coolest part of the car, away from oil cans and tools. The best protection is a soft bag, well dusted with soapstone, in which the carefully folded tubes are put. See page 613, "How to fold an inner tube."

Unless some pressure is retained however, the tube will have a tendency to crack when again inflated, if left folded for a long time.

Occasionally examine your tires and remove small pieces of glass, etc., that may have become lodged in the rubber. They are likely to work their way through, and cause a puncture.

Spare tires should be kept in a place where they are not subjected to light, heat, or rapid changes in temperature.

Nothing will wear a tire faster than sudden locking of the rear wheels with the brakes, and turning corners at considerable speed. Use your brakes with judgment, and turn corners slowly.

Never allow a tire to wear until the canvas fabric becomes injured, because the wall of the tire is prone to become too thin to prevent the pressure of the inner tube from bursting through the weak portion. Remember that the strength of the tire is in the fabric. The rubber is merely a binder which unites the various layers of fabric and forms a covering over the whole.

To make old tires resilient: Apply an ammonia solution with a rag to the tire or tube. Through application of this solution, the tire or tube will regain all the properties of a new one.

Tire paint[1] for painting the inside and outside of tires is mixed as follows to make 1 gallon: Mix 1 quart of gasoline and 5 lbs. of whitening, stirring until thoroughly mixed. Add 1 quart of No. 1043 Firestone cold-patch cement (or any other cold-patch cement) gradually, and stir until mixed.

The solution is applied with a brush and leaves a white surface which will not crack because of the elasticity of the cement.

Another similar tire paint, for finishing the inside of a tire after repairing, may be made by mixing thoroughly one gallon gasoline, one half-pint C-35 cement, 1½ lbs. soapstone, and ½ lb. whiting. Many successful repairmen are using this formula with the best of results.

Inner Tube Pointers

The cross-sections of inner tubes are made a little smaller than the normal air space inside of the cases. It is not, therefore, advisable to use a 4½″ tube in a 4″ case. This usually wrinkles and creases the rubber with bad results. Do not use a 4″ tube in a 4½″ case for any length of time. When this is done the rubber is required to stretch too much, and the heat and the action resulting from displacement of air in the tire quickly use up the nerve and life of the tube.

Lubrication is most important to the conservation of the tube, but it is a matter that is given least attention. Practically all tire manufacturers treat the inside of cases with a white solution to prevent tubes from sticking to the casing, and to reduce the frictional wear. A good lubricant, however, should also be used.

A gray inner tube is not colored. The best gray tubes use pure Para gum with sulphur, to give it strength. This sulphur causes a "bloom," or white gray dust which gives it the color.

A red inner tube has been dyed to give it color, and instead of sulphur, antimony is used, which will stand a greater amount of heat. Heat causes rubber to harden and crack. Gray tubes stick to cases; red tubes will not stick as freely. Therefore, the advantage of a good red tube lies in these two points.

Some owners neglect dusting soapstone inside of the case when changing a tube; others use the soapstone so sparingly that it does but little, if any, good, or they may use so much that it does more harm than good. If a quantity of it be dumped into the case it will collect at one point, and during the hot weather will heat up to such an extent as to burn the rubber of the tube, making it very thin, brittle, and lifeless; this can be recognized by the honeycombed appearance. **Soapstone** is the lubricant most used for tires, and it is quite satisfactory, but not lasting; therefore a fresh supply should be put into the tires at least two or three times during the season. **Powdered mica** has proved a more durable lubricant than soapstone and quite as effective as graphite, as well as more pleasant to handle. The lubricant should be applied with a soft rag and rubbed into the pores of the tube, and also on the fabric all around the case.

The life of an inner tube—if of good rubber—should be two years. As the tube grows older, the rubber becomes hard and porous, and finally reaches the "past repair" stage, which is noticeable through constant slow leaks. New tubes are then advisable.

How to preserve extra inner tubes: Deflate tube and fold, as shown in Fig. 13; powder the tube with a generous amount of talcum powder, then wrap in a piece of canton flannel or cheesecloth and pack in a small wood box with a sliding top. This will protect the tube indefinitely.

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[1] A liquid tire paint called "Nitrex" protects spare tires, gives a handsome finish to the tire, and protects it from deteriorating. See also page 647.

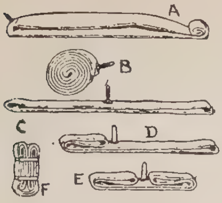

Fig. 13

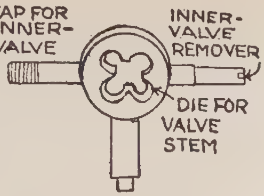

Fig. 14

Fig. 13. **To fold an inner tube:** Remove "inner-valve," then roll slowly as at **(A)** and **(B)** to exclude air. Then lay flat and fold as at **(C)**, **(D)**, **(E)**, and **(F)**. A flannel bag is suitable for carrying extra tubes in.

Fig. 14. **Four-in-one valve tool:** die for recutting threads for valve cap; tap for inner-valve threads; inner valve remover.

Inner Tube Troubles

Slow air leaks from a tube are sometimes traced to the "inner-valve" leaking.

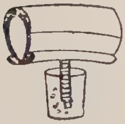

Fig. 15

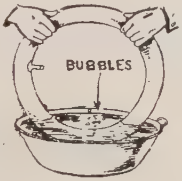

Fig. 16

Fig. 15. **To test an inner valve for a leak:** inflate the tube; place the end of the valve, with valve-cap removed, in a glass of water: if bubbles appear, the inner valve leaks. Put in a new one.

Fig. 16. **To test an inner tube for a leak:** partially inflate the tube and place it in a pan of water; air bubbles will appear at the leak. Mark leaks with indelible pencil.

To test the base of a valve for leak, submerge the valve part of the tube in water, with the tube partially inflated.

To test for an inner-valve leak, inflate the tube and test, as shown in Fig. 15. If leaky, try cleaning the inner valve, and screwing down tight. If this does not remedy the leak, then put in a new inner valve.

A slow leak may also be due to the valve-stem base being loose, or to the inner tube rubber being porous, through age. Old tubes in time harden, become porous, and leak slowly.

To test for valve-stem or slow leak or puncture see Fig. 16.

The average life of a tube is from twelve to eighteen months, perhaps two years; but once it begins to harden, it is advisable to replace it with new tubes.

Punctures may result from a puncture through the tire from outside, or it may result from rough places inside of the case, such as soapstone balls, etc., or from the tube being pinched.

Tube pinching: This is one of the most common causes of damage to inner tubes. Many tubes are pinched beneath the bead of the tire or beneath the staybolts (see page 596, E and F); see also "stone-bruises," page 610.

The valve may leak: It sometimes happens that a tire becomes deflated because of a leaking valve, and the condition may easily be supposed to be due to a puncture. If no visible sign that the tire has been penetrated is discovered, a test of the valve-stem can be made without removing the inner tube, by putting a few drops of water in the valve-stem. Bubbles will indicate a leak, or the valve can be tested as shown in Fig. 15.

If such is found to be the case, the valve parts should be tightened with the notched cap **(B)** of the valve-stem inserted in the valve and used as a wrench, as shown in Fig. 5, page 591.

If this does not remedy the trouble, entire new inner-valve parts **(A)** (page 591) should be put in place. Every repair kit is supplied with them, and they as well as caps **(B)** should be kept in the kit constantly.

METHOD OF REPAIRING INNER TUBE

In a case where the inner tube is punctured, but the casing practically uninjured, as in the case of puncture by a nail or tack: First of all, satisfy yourself that the tack or nail is not sticking in the casing, for if it is, your repaired tube will be punctured again before you have gone 1,000 feet. Having done this, the inner tube may be removed (wholly, or in part, as may be necessary) and either repaired or replaced.

There are two methods of repairing an inner tube: (1) by **cementing a patch** over the puncture, and (2) by **vulcanizing.** The cement patch does not hold, and will leak in time; but the vulcanizing of the tube, as shown on pages 614, 615, will make a permanent repair. The best plan would be to insert a new tube and vulcanize the damaged one later. An inner tube properly vulcanized is as good as new, but it is much easier to make the repair at home.

Do not carry inner tubes in the tool box where they are liable to be bruised or otherwise injured.

The modern method is to have a spare rim with a tire inflated, ready to put in place of the damaged tire, as previously explained. Without this equipment, it will be necessary to repair the tube, or to put in a new one.

Cementing a Patch

If a cement patch is necessary, owing to the absence of a vulcanizer, then proceed as follows:

Select a patch of the right size, that is, large enough to extend three-fourths of an inch or an inch beyond the puncture in each direction. Wipe off every trace of moisture or bloom, and roughen with emery cloth the surfaces to be joined. Apply two coats of cement to the tube surface and to the patch, removing with the fingers all superfluous cement; the less of it there is, the quicker the repair.

Allow the cement to dry until it adheres strongly to the fingers (five minutes at least will be needed), then, and not until then, apply the patch; compress strongly and look carefully to see that the edges of the patch do not loosen.

Before putting back the tire, assure yourself that the cause of the puncture is removed, such as a nail or tack or rough spot inside of the casing, or else the tube will puncture again.

Note. **Never try to join two surfaces while they are still damp,** for rubber cement joints are of no value unless everything is dry. Never apply friction fabric to an inner tube, but always a patch of pure caoutchouc. Friction fabric is not air-tight.

Even though a sound tube has been inserted on the road, the punctured tube should be mended promptly to be ready for another emergency. There is scarcely a limit to the number of repairs a tube will bear, but patches applied with cement cannot safely be considered permanent repairs. It is a paying investment to **make vulcanized repairs** as opportunities present themselves.

When a patch becomes loose: It will sometimes happen that a tire will become partially or even entirely deflated without apparent cause—that is, without any nail or other puncturing instrument being visible. If you have had experience with occurrences of the kind, you will immediately suspect a loosened patch, and proceed to verify your suspicions. Partly inflate the tire, and your ear will tell you whereabouts the leak is. Remove only as much of the casing as will enable you to attack the job conveniently. You will very likely find that, although the air has burrowed a small channel between the patch and the tube in one place, other portions of the patch are holding on tenaciously. Why an inner tube patch does not stick uniformly all over, is something that no one ever could understand.

A drop of gasoline applied with care does wonders in persuading the patch to peel off, and afterward, in cleaning the surface of the tube; but do not apply the solution until you have well roughened the place with sandpaper. Put the old patch away for future use, and apply a fresh patch and two coats of solution; spread on thinly and rub in well, especially the first (you cannot rub the second coat hard, or the lot peels off); squeeze the patch and tube together as hard as possible with finger and thumb, beginning in the center of the patch and working out to the edges. You may hold a block of wood under the tube and beat the patch with a hammer if preferred, but go gently. One motorist belabors his patches unmercifully, and says they never come off. Judicious beating does no harm, and screwing up in the vise between two pieces of wood and leaving all night also works wonders.

Vulcanizing Inner Tubes

Cement patches are only temporary or emergency repairs. The tube should be vulcanized.

A small vulcanizer, as shown in Fig. 19, below, can be used for vulcanizing inner tubes, which is a very simple operation. The tube is cleaned around the puncture and coated with vulcanizing cement. Then a piece of raw rubber, the same as that from which tires are made, is placed over the puncture. The vulcanizer is applied as shown in the illustrations (Figs. 19, 29, page 616), and heat is applied for about fifteen minutes, the actual length of time depending on the kind of vulcanizer that is used, and the thickness of the rubber being vulcanized.

For small cuts, sand blisters, etc., on tires, this vulcanizer will also answer, but for blow-outs and large cuts in tires a larger vulcanizer is necessary.

By giving cuts on casings a little attention now and then, tire mileage can easily be doubled or trebled. Small cuts, neglected, admit dirt and water to rot in the fabric until a blow-out occurs that ruins both tube and casing. The only sure remedy is vulcanization, which, in many instances, can be done while the tire is on the wheel inflated.

What Is Vulcanization?

Vulcanization is the process of cooking or curing raw Para gum. Exactly as in baking a loaf of bread, the best results can be obtained only when the proper amount of heat is used.

The temperature ranges from 250° to 300° F., about 265° being considered best.

It requires 15 to 20 minutes to vulcanize a layer of Para 1/16″ thick at 265° F. temperature, and 5 additional minutes for each additional 1/16″.

It is immaterial whether the vulcanizer be heated by electricity, gas, gasoline or steam. The idea is to keep the vulcanizing surface at a steady and proper degree of heat.

Small Vulcanizing Outfits

There are several standard types of small vulcanizers available. They are designed with a view to supplying machines that are adapted to the most convenient sources of heat. On the road, gasoline is always available; therefore for tube work and small casing repairs a gasoline-heated vulcanizer is handiest. Where there are electric lights, they naturally suggest the cleanest and handiest heat. Motorists who have city lighting current in their garages prefer the electric vulcanizer, on account of its convenience and large capacity. Most of the work is done at home, and an electric vulcanizer, which has its heat controlled automatically and maintained as long as desired (an essential feature), has this advantage that, by leaving it on a tire as long as is necessary, the thickest tread repair can be cured clear through, aside from being able to make a superficial repair. Successive repairs can be made without loss of time, as the vulcanizer can be moved from one tube to another.

The following will clearly explain **the method of tire repairing.** It is the writer's intention to deal with the vulcanizing subject only in an elementary way. To those interested in the tire repair business we suggest writing to C. A. Shaler Co., 22 Jefferson St., Waupun, Wis., for a copy of their very complete books *How to Open a Tire Repair Shop* and *Care and Repair of Tires.* We recommend also writing to Williams Fdry. & Machine Co., Akron, O.; Akron Rubber Mold and Mchy. Co., Akron, Ohio; Lowell Mfg. Co., Lowell, Mass., for additional information.

To Vulcanize an Inner Tube with a Small Gasoline or Alcohol Vulcanizer

Preparation of tube and patch to repair a punctured tube: Clean the spot around the puncture about two inches in diameter with emery paper; then wash off clean with gasoline. Cut sufficient repair rubber to cover the puncture, and dampen with gasoline the surface of the rubber to be applied to the tube, allowing it to dry thoroughly. Then apply the repair rubber to the tube directly over the puncture, as illustrated in Fig. 17.

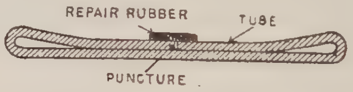

Fig. 17

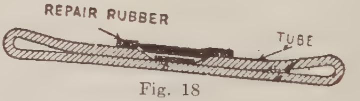

Fig. 18

To repair a rent, pinched, or torn tube: Shear off the damaged part to a beveled edge, and follow the cleaning and washing instructions given above. A piece of repair rubber the exact size and shape of the hole must be placed in position, and another piece of repair rubber larger over all than the hole must be placed on the damaged part, as illustrated in Fig. 18.

Care must be taken that the tube is thoroughly cleaned with emery paper and gasoline, and that the surface of the rubber applied to the tube is washed with gasoline and allowed to dry.

To apply the vulcanizer: Clamp the vulcanizer directly over the prepared tube and fasten securely and uniformly with the thumbscrews, being careful to have the patch centralized beneath the vulcanizer, as illustrated in Fig. 19.

Operation of vulcanizer: After preparing the tube as instructed, attach the vulcanizer as shown. Stand the vulcanizer on the bench, running-board, or floor. Pour the gasoline between the heating flanges, using the measure furnished, and light it. After the flame goes out, which will be in about ten minutes, let the vulcanizer cool a few minutes and the repair is done.

When vulcanizing a casing, clamp the vulcanizer in place with the chain furnished with it (Fig. 22). Heat the vulcanizer with the cylindrical lamp which is furnished. There is no exposed blaze and no chance to spill burning fuel, so that it is perfectly safe to vulcanize a tire while inflated on the wheel.

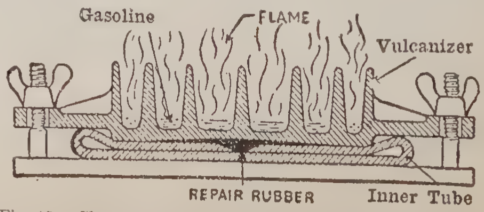

Fig. 19. Showing inner tube being vulcanized, and how the gasoline or alcohol heats the vulcanizer on the Adamson type of gasoline vulcanizer.

To Vulcanize Slight Cuts in a Tire

The small vulcanizer (Fig. 22) can also be used for vulcanizing small cuts, etc., on treads of tires, as explained below.

To prepare casing and patch: Thoroughly cleanse the cut or tear by using sandpaper or a pocket knife, and wash perfectly clean with a rag, using gasoline. Cleanse a layer of repair gum with gasoline, insert it in the cut, and trim it flush with the casing. If the injury is void of material, then build up even with the casing by cleaning each layer of repair gum with gasoline and firmly pressing into place.

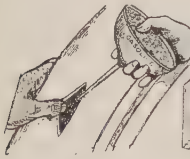

Fig. 20

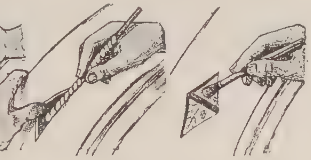

Fig. 21

Fig. 20. Clean with gasoline.

Fig. 21. Get dirt out; then cut the old rubber away, and give another cleaning.

To apply vulcanizer: Firmly clamp the center of the vulcanizer directly over the prepared patch, using care to have the patch centrally located against the face of the vulcanizer as illustrated in Fig. 22. Before applying the vulcanizer, its face may be dusted with soapstone or talcum powder, or a cake of ordinary soap can be rubbed against it to prevent the repair gum from sticking.

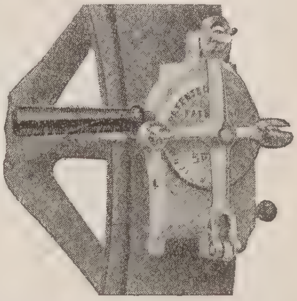

Fig. 22. The Shaler tourist's gasoline or alcohol vulcanizer, vulcanizing a cut on the outer casing.

EXAMPLE OF AN INNER TUBE REPAIR WITH A SHALER PORTABLE ELECTRIC VULCANIZER

Vulcanizing Inner Tube Punctures

Clean the tube thoroughly with gasoline and coarse sandpaper (see page 614). Cement the edges of the hole and apply a thin layer of cement. Let the cement dry.

If the puncture is a small hole, fill even with the surface of the tube with layers of Para rubber cut the size of the hole. Cut a patch of Para ⅛″ larger than the hole or puncture, and apply over it. Then cut another patch ½″ larger than the hole and apply over the first. Cover with waxed paper and apply the vulcanizer.

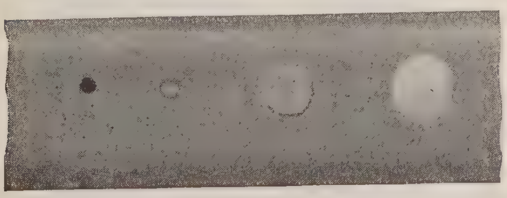

Fig. 23. Repairing a tube puncture.

Edges of punctures or small holes should be beveled with scissors to make a larger uniting surface and to provide room for the new material. Repairs of this sort are to be **vulcanized for fifteen or twenty minutes** at 265°F.

Inner Tube Cuts and Tears

Clean as directed, both inside and outside of tube; coat edges of the cut and inside and outside of the tube with cement, and let dry.

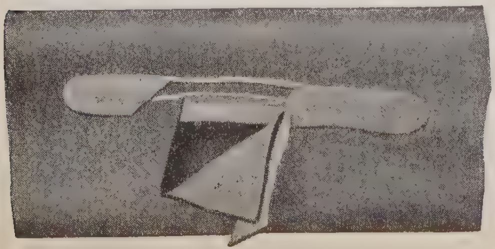

Fig. 24. Repairing a slit in the tube.

Cut a strip of Para rubber as wide as the tube is thick, and stick on the edge of the cut; cut a strip one half-inch wide, place **inside of the tube** under the tear, bring the edges of the tear together, and stick them down to this strip. (The use of semi-cured stock for the inside patch is preferable, as it obviates the use of paper inside the tube.) Apply another strip of Para rubber, one half-inch wide on the **outside of the tear. Vulcanize for twenty-five minutes.** Cover the repair with waxed paper before vulcanizing.

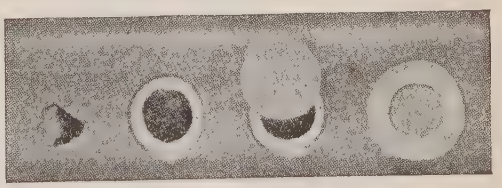

Fig. 25. Repairing a tube blow-out.

Blow-Outs in Tubes

When mending large, irregular bursts or blow-outs in which a piece of rubber has been blown out of the tube, the best method is to trim down to a clean, solid surface, making the hole somewhat regular in shape. The hole may be filled with layers of Para rubber cut to fit.

Inner Tube Splices

It often happens that, when a tube is badly torn, it is easier to cut out a section and replace it with a new piece of tube. In making repairs of this kind, be very careful not to alter the original length of the tube.

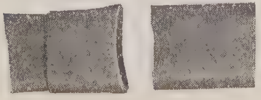

Fig. 26

Fig. 27

Fig. 26. **Splicing** an inner tube; showing tube ready to lap.

Fig. 27. Tube after **lapping.**

Clean the outside of one end of the tube for about four inches. Fold back the other end, turning the tube inside out, and clean for the same distance. Apply at least three coats of cement to each end. (Fig. 26.) A repair of this sort requires a considerable amount of cement if no Para rubber is used, because the adhesiveness of the joint depends upon the cement alone. A narrow strip of Para between the two tubes will add to the strength of the joint. Butt the open end against the folded end, and telescope the latter over it. **Vulcanize in three operations,** the first for twenty minutes, the last two, fifteen minutes each. A block should be used underneath the tube, to prevent pinching the edges of the tube. The vulcanizer is placed on top.

Valve-Stem Seat Repair

Select a good place on the tube, then clean a space about 4″x2½″, and cut a hole about ¼″ in diameter.

Remove the parts from the valve-stem and stretch the hole in the tube over the base of the valve-stem. Push the stem clear through into the tube. It is to be kept inside and away from the repair until after vulcanization.

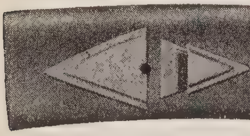

Fig. 28

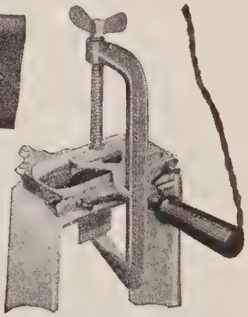

Fig. 29

Fig. 28. Valve-stem seat repair.

Fig. 29. The electric vulcanizer is connected to a lamp socket.

Cement the entire clean surface around the hole in the usual manner.

Cut an oval or diamond-shaped piece of Para about 2″ x 3″, having a hole in the center to correspond with the hole in the tube. Roll it down on the tube so that both holes register. Cover with a layer of blow-out canvas of the same size and shape. Cover all with another layer of Para rubber ¼″ larger all around than the first. **Vulcanize forty minutes.** Shake the valve-stem on the inside of the tube to the vicinity of the hole, and force it through the opening until the base rests against the inside of the tube; then slip the clamp disk **(S-T)** and spreader **(L)** (Fig. 3, page 591) over the valve-stem, and fasten them securely with locknut **(P).**

Pointers When Vulcanizing Inner Tube with Steam Vulcanizer

The time required for vulcanization is determined by the depth of the new material inserted, and not by the size or area of the repair. The following is based upon the maintenance of a uniform steam pressure of 45 pounds.

If the tube is in a very much worn condition, place a piece of rubber tubing larger than the pad under the pad, and vulcanize at a lower steam pressure and more slowly. With a steam pressure of 45 lbs.:

For tubes 1/16″ thick, vulcanize for	7 minutes.
For tubes 1/12″ thick, vulcanize for	8 minutes.
For tubes 1/10″ thick, vulcanize for	10 minutes.
For tubes 1/ 8″ thick, vulcanize for	13 minutes.

How to test a repair: Test the part vulcanized by pressing the thumb nail into it. If it is responsive and elastic to the touch and resembles the rest of the tube in this respect, it is perfectly vulcanized. If, however, it clearly **retains the mark of the nail,** it is under-vulcanized and should again be placed in the vulcanizer and given a longer heat. It is best to add time, **not temperature.**

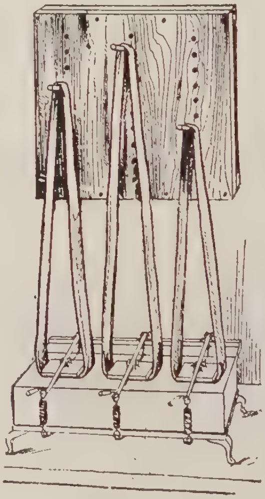

Fig. 30

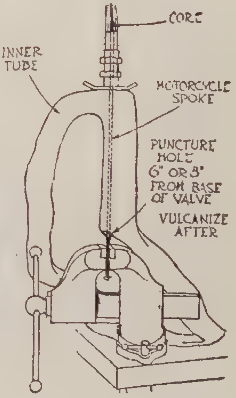

Fig. 31

Fig. 30. A rack for vulcanizing different sized tubes. This device can be used in connection with the small tube vulcanizers. (*Motor World.*)

Fig. 31. Sometimes the inner-valve core becomes immovable from the stem. The diagram explains how to remove. (*Motor Age.*)

TIRE REPAIRING AND VULCANIZING[1]

As previously stated, it is the writer's intention to deal with the vulcanizing subject only in an elementary way. The tire repair business is one in which expert knowledge can be gained only by actual experience. The material following, however, will give one an idea as to the principle, and also of the equipment for small shops and how to make all ordinary repairs.

There are several methods of vulcanizing. It is immaterial whether the vulcanizer be heated by electricity, gas, gasoline, or steam. The idea is to keep the vulcanizing surface at a steady and proper degree of heat. The steam vulcanizer, of course, is used in the larger vulcanizing shops.

Troubles Which Necessitate Tire Repairs

Owing to external causes:

1. **Tread cuts,** which permit dirt to work under the tread and cause "loose treads" and "sand blisters." The moisture also rots the fabric and weakens it.

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[1] The following books are recommended to those who desire more information on tire repairing: *Tire Repairing and Vulcanizing* ($1.50); *Tires and Repairing* ($2.00); *Tire Business Answered* ($2.50); *Better Tiremen* ($2.00) (sold only with the complete set named above); all by Tuford. Address A. L. Dyke, Electrical Dept., Granite Building, St. Louis, Mo.

2. **Cuts clear through tread and carcass:** When a cut is made through tread and carcass it is a perfect cut, but if blown out, the edges are ragged.
3. **Fabric broken and weakened inside,** through striking a stone on the tread of the tire.
4. **Blow-outs** are the result of surface or tread cuts. The admission of moisture causes the fabric to rot, and the pressure of the tube blows through the weakened place with a loud report.

   The blow-out is also frequently attributed to a "stone bruise," as explained on page 610.
5. **Broken back** is a serious and common injury, and is the result of insufficient inflation. The layers of fabric separate. This might be termed a "fabric separation."

Importance of Repairing Slight Cuts on Tires

A set of tires should be gone over at least once every two weeks, and the cuts in the treads of the casings should be sealed up by vulcanizing them. This can be done with the tire inflated and on the wheel. In this way deterioration of the fabric is prevented, and the tires will give a mileage three times as great as that usually given.

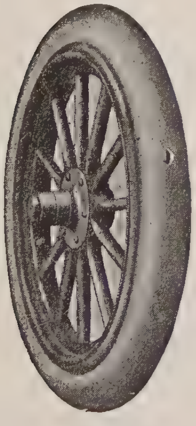
Fig. 32

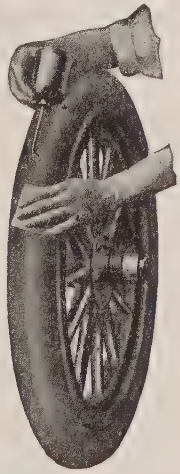
Fig. 33

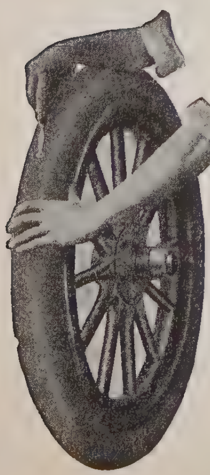
Fig. 34

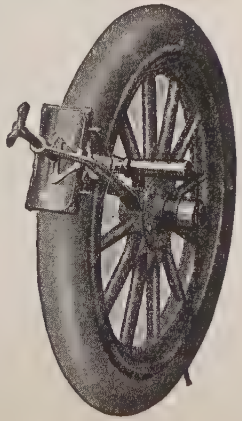
Fig. 35

A tire in which there is **a small cut and a "sand-blister"** or pocket is shown in Fig. 32. If not repaired at once, sand, dirt, and water will be forced into it and rot the fabric until it becomes so weakened that the inner tube will blow out through it and ruin the casing.

The gash being cleaned and filled with new, live Para rubber is shown in Figs. 33, 34.

The Shaler portable electric vulcanizer in place on the tire is shown in Fig. 35. Note that it has not been necessary to remove the tire from the rim. The vulcanizer is left in the position shown for thirty minutes. The portable electric vulcanizer is well adapted for repairs of this kind.

The foregoing instructions cover the **external repairs** of "tread cuts," "sand-blisters," and slight "loose treads."

Internal and External Tire Repairs—Sectional Method

There are two methods for reinforcing and building up tires for internal repairs: (1) the "wrapped-tread" method, and (2) the "sectional" method.

With the **wrapped-tread method,** as explained on page 608, the tire is built up or reinforced from the **inside,** whereas with the **sectional** and **step cutting** method, it is built up from the **inside and outside.**

Step Cutting and Sectional Repair of a Blow-Out

How a blow-out is prepared for reinforcing and building up by the "sectional" method is shown in Figs. 36, 37. Note how each layer of fabric is "stepped off." For example, there may be four layers of friction duck (canvas fabric) in the carcass.

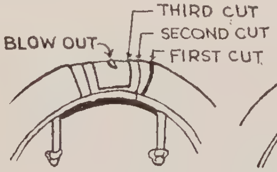

Fig. 36

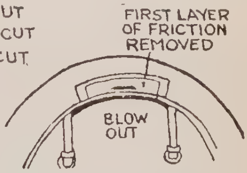

Fig. 37

Fig. 36. Preparing a blow-out for vulcanizing.
Fig. 37. Preparing side-wall blow-out for vulcanizing.

To proceed, the tread stock is cut down with a knife. The first cut made (Fig. 36) goes over each bead, and all fabric within these limits is removed. The second cut does not go over the bead, but falls inside, and borders the first cut by about one inch.

This removes two ply of canvas and the reverse process, or building up, replaces this canvas, "breaking joints" as a mason breaks joints in stone or brick setting, and the final layer of fabric adds one ply to the original strength. The casing is then reinforced with one layer of canvas on the inside, and the total strength, or four ply, has been restored.

A side-wall blow-out in the process of repair is shown in Fig. 37. The same principle of "stepping off" and reinforcing is used. This "stepping off" is one of the most important points to observe in making good tire repairs.

Vulcanizing with Molds

Steam vulcanizers, used in large repair shops, usually employ the **sectional method** of repairing, and use molds for vulcanizing.

Where the blow-outs are on the tread, after repairing, the tire is placed in the sectional or cavity mold (3) (Fig. 47, page 620), to be vulcanized or cured, and is held down by a clamp (C) (Fig. 43). This vulcanizes both inside and outside.

Where the blow-out is on the side-wall, or for a rim-cut repair, it is necessary to insert an "air bag" (Fig. 39). Then the bead mold is placed over the tire, and entire repair is completed at one operation.

Where inside repairs only are cured, or where the tire is to be dried out before vulcanizing, the "inside patch vulcanizer," at (4) (Fig. 47) is suitable.

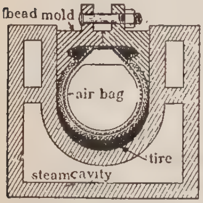

Fig. 39

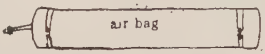

Fig. 38 (upper)

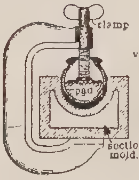

Fig. 40

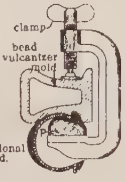

Fig. 41

There are two methods of holding the tire in the mold for tread repairs: (1) by a clamp and pad and mold, as in Fig. 40, and by the use of an air bag (Fig. 38) which expands the tire, used in connection with a cavity mold (Fig. 39).

Where side walls or beads are repaired, the clamp and bead mold and pad (P) (Fig. 41) can be used, or the air bag and bead mold (Fig. 39) can be used.

Shaler Electric Vulcanizer

The Shaler electric vulcanizer, type ACE, is illustrated in Fig. 42, as also the Shaler steam vulcanizer (Fig. 45). Each employs the **wrapped-tread method** of vulcanizing; an example is given on page 620.

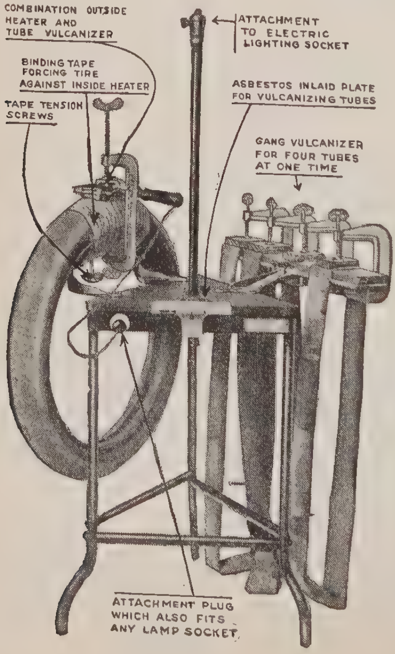
COMBINATION OUTSIDE HEATER AND TUBE VULCANIZER
BINDING TAPE FORCING TIRE AGAINST INSIDE HEATER
TAPE TENSION SCREWS
ATTACHMENT TO ELECTRIC LIGHTING SOCKET
ASBESTOS INLAID PLATE FOR VULCANIZING TUBES
GANG VULCANIZER FOR FOUR TUBES AT ONE TIME
ATTACHMENT PLUG WHICH ALSO FITS ANY LAMP SOCKET

Fig. 42. Shaler electric vulcanizer, type ACE.

Air bags or cavity molds are not used with either of the Shaler vulcanizers. Inside molds or mandrels are inserted for inside repairs, and outside molds or mandrels, or hot plates are used for outside repairs (see page 619, Fig. 45).

The two vulcanizers shown below are of two different types. Fig. 43 illustrates the Akron-Williams model 6F steam vulcanizer, employing the molded method with cavity molds, and Fig. 45 shows the Shaler type NPR steam vulcanizer. This vulcanizer repairs all sizes of casings by the wrapped-tread method and casing forms or heaters are used instead of molds.

An explanation as to the difference between a tire which is repaired by the "wrapped tread method" and one repaired by the "molded method" is given as follows:

Wrapped tread: Refer to Fig. 42 and observe that after the tire has been properly treated, ready for vulcanizing, a piece of waxed paper is placed over the repair and **tape is wrapped** around it. The thumbscrew of the "outside heater" (Fig. 42) is then drawn tight and the electric current is turned on.

Molded method: Refer to Figs. 39 and 43 and observe that the tire is placed in a **mold,** and steam is turned on in the steam cavity (Fig. 39); thus the repair is not wrapped.

The A. K. Sectional Steam Vulcanizer

This vulcanizer is suitable for small repair shops in towns where there is a fairly good number of 4½" and 5" tires. It vulcanizes by the **molded method** with which air bags are used. Steam is generated in boiler (**B**) by gas or gasoline fuel connected at (**G**).

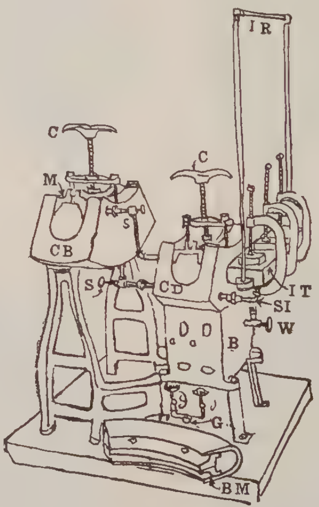

Fig. 43. Akron-Williams type 6F steam vulcanizer.

There are two cavity molds, (**CB**) for 4½" and 5" tires, and (**CD**) for 4" and 3½" tires. Tires of 3" size can be vulcanized by placing the 3" mold (**BM**) in the mold (**CD**). These molds will vulcanize "inside" and "outside" of the tire, as also "side wall" and "bead" repairs. See Fig. 39, and note the bead mold, also (**M**) (Fig. 43).

After the tire is prepared to be vulcanized, an air bag is inserted; it is then placed in mold (CB). The air bag is then inflated to 50 lbs. pressure, clamp (C) applied, and steam turned into the mold at (S).

Where there is considerable repairing, the inside repair mold or patch (4) (Fig. 47), is used. This is also handy for thoroughly drying out tires before vulcanizing.

Inner tubes are vulcanized by placing them over rack (1R) (Fig. 43). The part to be vulcanized is placed on plate (IT) through which steam passes.

Cost of a Small Steam Vulcanizing Plant

The **approximate cost of an outfit,** using the type 6F vulcanizer, together with the material required is given below. Note that the prices are only approximate.

1 model 6F vulcanizer (Fig. 33)	$245.00
5 airbags, 3″ to 5″ x 16″ long	22.70
1 gal. No. 1086 vul. cement	2.40
1 qt. No. 1043 cold patching cement	.67
1 lot inner tube valve patches	1.50
5 lbs. tread stock[1] (cures gray)	5.00
10 lbs. tread stock[1] (cures black)	10.00
5 lbs. inner tube repair stock[1] (red)	7.50
2 lbs. inner tube repair stock[1] (gray)	3.00
2 lbs. inner tube repair stock,[1] cured on one side only, for inside reinforcement	3.00
5 lbs. cushion stock	6.25
5 lbs. breaker-strip fabric	6.25
5 lbs. bead-cover fabric	10.00
10 lbs. carcass fabric	15.00
5 lbs. carcass fabric frictioned, one side only, for last ply next to tube and reinforcements	11.25
1 lot asst'd sizes Schrader valves, inner valves, valve caps, soapstone, waxed paper	7.50
1 lot tire tools as shown in Fig. 46	7.05
Total	$364.07

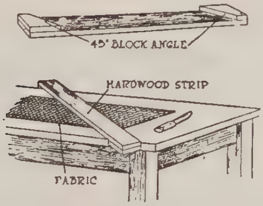

Fig. 44

Fig. 44. **Cutting tire fabric:** A simple but effective device for permitting fabric to be cut on the bias, with a wet knife, instead of shears, is illustrated here. A hardwood strip, forming the straight edge, is placed 45° across the tire repair bench, and each end fitted with hardwood angle blocks in the manner shown. These edges even up against the edge of the bench and secure a perfect 45° cutting angle.

The Shaler Steam Vulcanizer

This steam vulcanizer (Fig. 45) as well as the electric vulcanizer (Fig. 42) are adapted for small-town vulcanizing plants, or for garages where a tire repair department is added. The capacity of each of these vulcanizers is 20 tubes and 1 casing per hour. The vulcanizer (Fig. 45) can be secured with two casing forms or mandrels, which will give double capacity.

All sizes of casings can be repaired with the Shaler vulcanizers by the wrapped-tread method, an example of which is given on page 620.

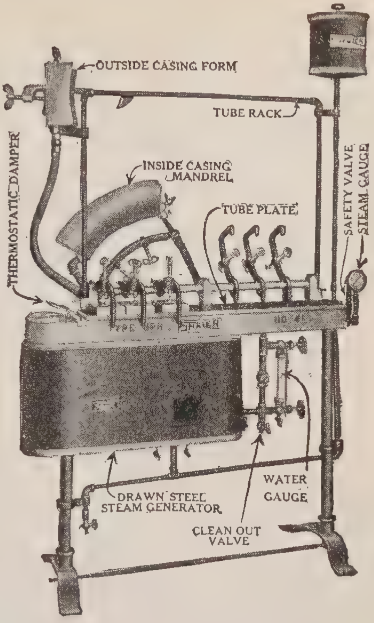

Fig. 45. Shaler steam vulcanizer, type NPR, No. 41.

Shaler Vulcanizing Tools

Some of the tools required for tire repair work are illustrated and listed below.

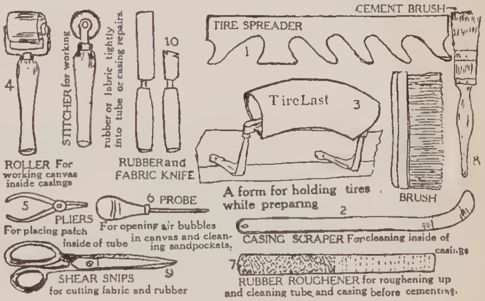
CEMENT BRUSH
TIRE SPREADER
1
4
STITCHER for working rubber or fabric tightly into tube or casing repairs.
10
TireLast
3
8
ROLLER For working canvas inside casings
RUBBER and FABRIC KNIFE
A form for holding tires while preparing
BRUSH
5
PLIERS
For placing patch inside of tube
6 PROBE
For opening air bubbles in canvas and cleaning sandpockets.
2
CASING SCRAPER For cleaning inside of casings
9
SHEAR SNIPS for cutting fabric and rubber
7
RUBBER ROUGHENER for roughening up and cleaning tube and casing before cementing.

Fig. 46. Tire repair tools enumerated as follows:

1. Tire spreaders	$0.50
2. Casing scraper	.45
3. Casing mandrel	2.00
4. Roller for inside canvas work	.50
5. Pliers	.35
6. Probe	.20
7. Rubber roughener	.45
8. Cement brush	.25
9. Shears for cutting fabric	.75
10. Fabric knives, 60c. and 40c.	1.00
11. Stitcher for working rubber and fabric into casing	.60
Total	$7.05

Vulcanizing Rubber, etc.

Para rubber, per sq. ft.	$0.75
Para rubber, 5 lb. roll	6.75
Para Ruber, one side cured, per 5 lb. roll	7.50
Wax paper (sufficient for 1,000 repairs)	.25
Vulcanizing cement, per qt.	.75
Vulcanizing cement, per gal.	2.50
Blow-out canvas, Para-coated, one side, per sq. ft.	.50
Blow-out canvas, Para-coated, both sides, per sq. ft.	.60

Large Steam Vulcanizing Plant

An example of a steam vulcanizing plant of large capacity is given on next page. The vulcanizing plant shown in the illustration (Fig. 47) consists of the following parts:

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[1] Means vulcanizing rubber. Do not use "self-curing gum," or old rubber; it will not vulcanize.

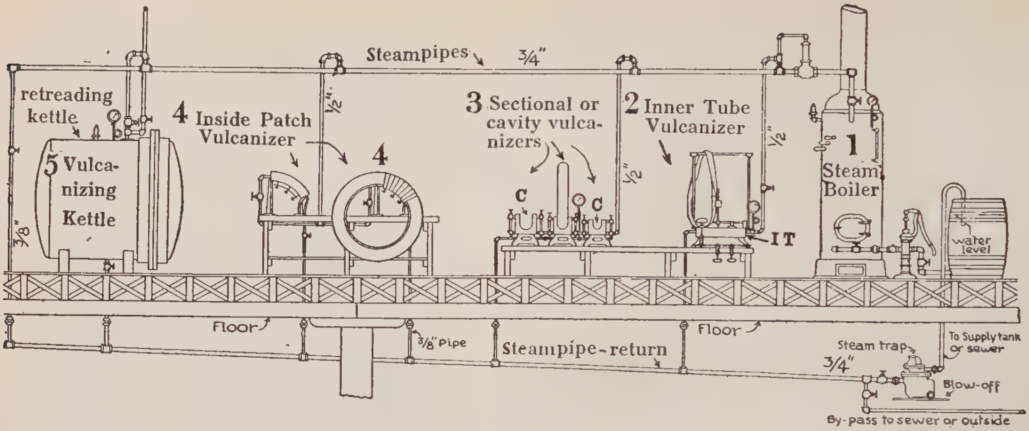

Fig. 47. Example of a large steam vulcanizing plant.

1. **Steam-boiler,** using coal or wood as fuel.
2. **Inner tube vulcanizer.** The steam passes through the iron plate (IT); part of the tube to be vulcanized is placed on this plate and the other part hangs over the rack above it.
3. **Sectional or cavity molds** for repairing tire casings. These are used to vulcanize the inside and outside of the tire in sections. These molds (C) are made to take different sized tires. See Fig. 39, and note that a bead mold is placed over the tire when it is in the cavity mold (C). These bead molds are made for clincher or straight-side beads.

   The air bag, shown in Fig. 38, is placed in the tire and blown up to a pressure of about 50 lbs. to hold it in shape when being vulcanized in the cavity mold (C). Steam passes through the cavity mold, thus giving the necessary heat.
4. **Inside patch vulcanizer,** consisting of an iron core shaped like the inside of a tire, through which the steam passes. The tire is placed over this core when only inside repairs are being made. Also used for drying out tires when repairing. Tires should be free from all moisture when being vulcanized, as moisture turns to steam when heat is applied, and forces the fabric layers apart, making a weak repair.
5. **Vulcanizing kettle,** used in rebuilding or retreading tires. This is used only in very large shops.

REPAIRING A "BLOW-OUT" BY THE "WRAPPED TREAD METHOD" OF VULCANIZING, AND ALSO OTHER REPAIRS

The "sectional" method, where repair is built up or reinforced from the outside, was explained on page 617. With the **wrapped-tread method,** it is built up or reinforced from the inside.

While we speak of **blow-out repairs,** this also covers **repairs for cuts through tread and carcass,** and also **side-wall and rim repairs.**

The following matter is taken from the Instruction Book of the Shailer steam vulcanizer as shown in Fig. 45.

Method of Step Cutting, When Necessary

If the fabric immediately around the hole is rotten and shredded so badly that it is impracticable to work it back into the repair, it will be necessary to remove any loose canvas that may be around the blow-out, "step cutting" it out in two or three steps, similar to the process shown in Fig. 36, page 617, but from the inside. This method, however, will not be required once in twenty repairs.

Cut the steps so that the smallest is at least 2" larger in every direction than the hole through the tire, and make each succeeding step about 1½" larger all around the one below it.

Coat all over with cement, working the cement in between plies of fabric at the ragged edges of the damaged part. After the first coat has dried for an hour or two, put on another coat, and let it stand for several hours—over night if convenient.

Cut layers of blow-out canvas (Para-coated on both sides) to fit the steps from which fabric was removed, and work them thoroughly in place, one at a time. Roll from the center to the edges of the patch, and if air bubbles form under the canvas, prick them with an awl and roll them flat. It is necessary that the canvas be laid smoothly, and that perfect contact be secured between the different layers.

Then put on another patch an inch larger all around than the largest step. Finish with plain friction canvas or canvas Para-coated on one side. This last layer must be long enough to cover the preceding patches entirely and to **reach to the clincher on the outside.** Use from four to six layers of canvas, depending upon the size of the tire and the size of the hole through it.

Reinforcing without Step Cutting

The following method is to be followed where **the fabric is not rotten.** The procedure is as follows:

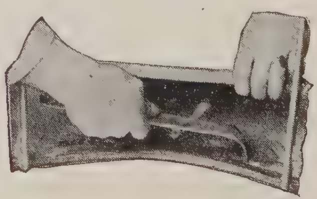

Fig. 48. **Clean the inside of the tire** about 6" on each side of the hole. Use gasoline to soften. Scrape until bare canvas is exposed, but do not cut the fabric.

Note that in these illustrations "tire spreaders" are used to hold the tire apart while being repaired.

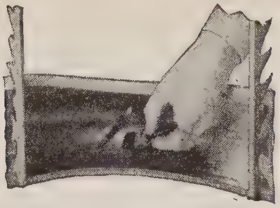

Fig. 49. **Apply two coats of cement over the cleaned surface.** Let the first coat dry one-half hour before applying the second. Cement the hole through the tire thoroughly.

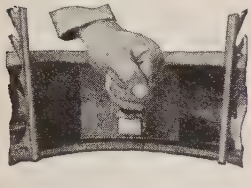

Fig. 50

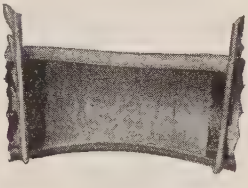

Fig. 51

Fig. 50. **Cut the first layer of the fabric** (Para-coated on both sides), so that it will extend 1″ beyond the hole in every direction. Roll smoothly in place, pricking any air bubbles to let air escape.

Then cut a second layer of fabric (Para-coated on both sides) large enough to cover the first one, and let it extend an inch over it in every direction.

Then cut a third layer (Para-coated on both sides) 1″ larger, and place it over the second layer in the same manner and roll it down.

Then cut a fourth layer (Para-coated on one side) 1″ larger than the third layer, and apply the Para-coated side next to the third layer. In large tires use 5 layers. After the third and fourth layers are applied, the appearance of the patch after all layers have been rolled down will be as shown in Fig. 51.

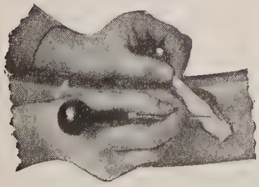

Fig. 52

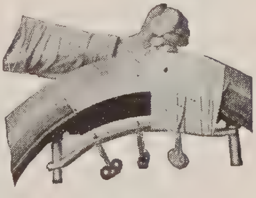

Fig. 53

Fig. 52. **Turn the tire over and fill the gash with tread stock** of narrow strips, and press down carefully. No cement is necessary. Do not fill the hole too full. Sprinkle inside with soapstone.

Fig. 53. **Place the tire over the "inside casing mandrel"** (also termed "form") (see Fig. 45). Lay a piece of waxed paper over the outside repair and place bead strips along the bead as shown; then wrap on tape and tighten the tension of the hand screws, so as to pull the tire down on the mold.

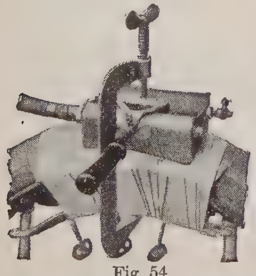

Fig. 54

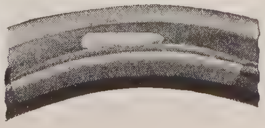

Fig. 55

Fig. 54. **Place the "outside casing form," or mold, over the outside repair,** and apply the steam. Cure for fifteen minutes; then loosen the clamp, and tighten the tape. About 15 minutes in all is required; for larger tires, 1 hour at 40 lbs of steam pressure is desirable.

Fig. 55. **Showing a blow-out repair near the rim.** The same method is used, except that the last layer of fabric is brought clear around the bead and up outside of the tire far enough for the bead strip to get a good grip. Then use the curved side of the "outside casing form," or mold, for rim work. (See also Fig. 45 for location of this on the vulcanizer).

Repairing a Sand Blister

1. Cut half-way around the blister, cutting through the rubber to canvas (**C**), and leave the rubber attached on the side nearest to the tread of the tire. Turn back the flap (**F**) thus formed, and remove all dirt; then clean and cement as directed above for casing cuts.

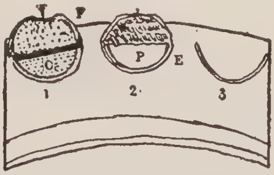

Fig. 57. Repairing a sand blister.

2. Cut a strip of Para rubber as wide as the rubber on the tire is thick, and stick it on the edge of cut (**E**). Then cut a thin sheet of Para the exact size of the canvas, and roll back in place and stick it down tightly (**P**).
3. At (3) is seen the repair after vulcanizing. Be sure to vulcanize the hole where dirt entered and caused the blister. It may be a foot away. Vulcanize according to instructions for small cuts (page 617).

A tire pump is an excellent bellows for blowing dirt out of a cut for a repair to be vulcanized. A sheet of waxed paper should be placed between the vulcanizer and the tire to prevent sticking to the hot iron.

To Repair a Section of a Tire Where Tread Is Loose

Cut through the tread; clean the under side of the tread and canvas thoroughly. Apply two or three coats of cement; when dry replace the tread, wrap with tape, as shown in Fig. 53 (this is the wrapped method of vulcanizing); then cure with inside and outside heaters, as instructed for blow-outs (Figs. 53, 54).

Example of an Anti-Skid Tread Repair

Should a tire have a non-skid pattern on the tread, and a section is to be replaced, the wrapped-tread method as explained in the Shaler instruction book is as follows:

Take a piece of canvas (Para-coated on one side) large enough to cover the repair. Apply to the coated side three layers of ordinary tread stock. Find a good place on the tire, dust it with soapstone, and apply this "pad" (Fig. 58) with the raw rubber side next to the tread. Place the tire on the vulcanizer, wrap tape over the pad and tire, tighten the tape, put on the "outside casing form" heater (Fig. 45, page 619), and cure for half an hour. The pad will then have taken an impression of the tread

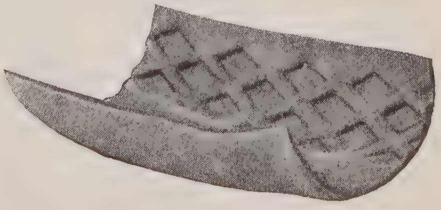

Fig. 58

and will be like Fig. 58. This may be done while you are waiting for the cement to dry on the repair.

When the repair is ready to vulcanize, place the pad over the repair, and wrap binding tape over it. When heated, the original tread pattern will be duplicated. Save the pad for future use, and mark it.

If it is unnecessary to replace a portion of the tread, but it is desired to protect the tread from being flattened by pressure of the tape when curing, simply make a thick paste of soapstone and water, and then fill the depressions in the tread with it before wrapping with the tape. When the repair is cured the dried soapstone is brushed off, and saved for future use.

AN EXAMPLE OF PRICES TO CHARGE FOR TIRE REPAIR WORK

The following are standardized prices adopted by a tire dealers' association in the Northwest, subject, however, to change without notice.

Sectional Repairs on Casing

3 in. sec. 10 in. long	$3.75
3½ in. sec. 10 in. long	4.50
4 in. sec. 10 in. long	5.50
4½ in. sec. 10 in. long	7.00
5 in. sec. 10 in. long	8.50

Retreading Fabric Casings

30 x 3	$10.50	32 x 4½	$22.50
30 x 3½	12.00	33 x 4½	22.50
32 x 3½	14.00	34 x 4½	23.50
31 x 4	16.50	35 x 4½	24.50
32 x 4	17.50	36 x 4½	26.75
33 x 4	18.50	35 x 5	34.25
34 x 4	20.50	37 x 5	36.00

Retreading Palmer Cord Casings

	Min.	Max.
3½ in. sec.	$ 5.50	$ 6.75
4 in. sec.	6.75	7.75
4½ in. sec.	8.50	9.50
5 in. sec.	10.25	12.00
6 in. sec.	25.00 and up.	

Tread Repairs

Tread repairs on 3-in. to 4-in. casings, $1.75 and up.
Tread repairs on 4¼-in. to 5-in. casings, $2.75 and up.

Reinforcing Casings

Inside reinforcement on 3¼-in. and 4-in. casings, $1.75 and up.
Inside reinforcement on 4½-in. and 5-in. casings, $3.00 and up.

Tube Repairs

Valve cores applied	$0.25
Tubes demounted	.50 and up
Tubes mounted	.75 and up
Add'l punctures	.25 each
New valve bases	.50
New valves 3 in.	.75
New valves 3½ in. and up	1.00

Reinforcements, blow-outs, and sectional work extra.

We reserve the right to turn down any tire during any stage of inspection, and we are not liable for so doing.

Where tread bands are used, add 10 per cent to the foregoing prices.

Flaps and Flap Repairs

Old flap repair	$0.50
New flap, 3½ x 4	1.50
New flap, 4½ x 5	2.00

Special repairs, not quoted, are based on cost of material and labor.

AIR COMPRESSORS FOR USE ON THE CAR

Air compressors can be classified under two headings: (1) hand or foot air pumps; (2) power air compressors.

Hand and Foot Air Pumps

This type of air pump is made in the "single" and "**compound**" type.

The single-acting hand air pump (Fig. 59) is made with a single barrel. It is seldom used, because it requires a heavy exertion to pump a tire to the proper pressure, unless the fulcrum is great enough to reduce the effort required to manipulate the pump.

A very satisfactory type of hand air pump for general garage use, employing the fulcrum and lever principle, is shown in Fig. 60. It consists of one welded steel cylinder packed with gum rubber to prevent leakage. The plunger is made of oak leather. Ball valves prevent back pressure. The name of this pump is the Jensen, manufactured by the W. H. Howell Co., Geneva, Ill.

A compound type of hand air pump is shown in Figs. 61 and 62. This type of pump employs two barrels; on some types there are as many as three barrels.

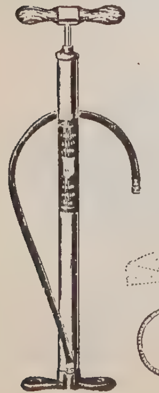

Fig. 59

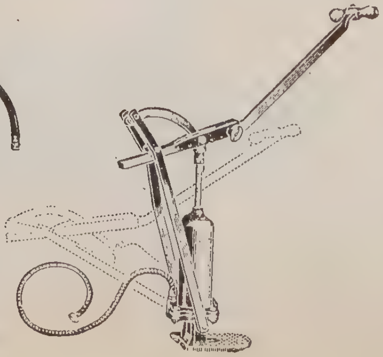

Fig. 60

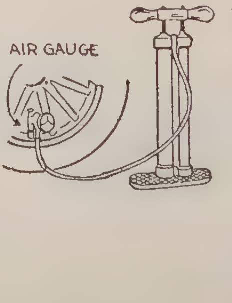

Fig. 61. Showing a compound air pump with an air pressure gauge attached. The gauge shows the amount of air pressure in lbs. per square inch.

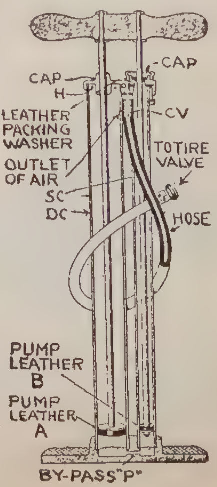

Fig. 62

Principle of operation: The air is drawn in from the atmosphere into the large cylinder and is compressed by the down stroke of the handle; at the same time it is forced into the smaller cylinder through by-pass (P).

The up-stroke of the pump forces the air from the smaller cylinder into the tire through check valve and hose (CV), and the large cylinder sucks in another charge.

While the air admitted into the large cylinder is receiving its first compression, it is forced through passage (P) (connecting the two cylinders) and up past cup leather (B) into the upper portion of the smaller cylinder. The cup leathers (A) and (B) are fitted to their pistons in opposite positions, that is, the leather (A) is put in with its open side downward, and leather (B) has its open side upward. If both leathers are put in the same way, the pump will not work.

A pump of this kind differs from a single-cylinder pump, in that each stroke is a power stroke, while in a single-cylinder pump only the down strokes are power strokes.

Keep the leather packing washer (around the piston rod of the small cylinder) tight, otherwise the air will blow through here instead of going into the tire.

Power Air Compressors for Use on the Car

Under this heading there are two types of pumps: (1) the impulse air pump; (2) the power-driven air compressor.

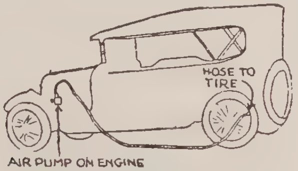

Fig. 63. Illustrating how the connection is made from the air pump (driven from the engine, or transmission shaft) to the tire. The air hose is detachable, and is usually carried under the seat.

The Brown impulse air pump: This pump (Fig. 64) has the appearance of a compound pump, because of the large and small cylinders, but they are built in this form to make it possible to pump the high pressures necessary for large tires, and at the same time not have any too good a compression in the engine cylinder. The lower piston, with its large area, receives its impulse from the compression in the engine cylinder, and transmits it to the upper piston through the medium of the hollow piston rod, to which both pump pistons are attached.

Action: As the engine piston makes its suction stroke, it draws fresh air through valve (1) which opens inwardly, and at the same time, both pump pistons make their downward stroke. You will note that piston rod (6) is hollow. This is the air passage to the upper cylinder through ball check (12). As the engine piston makes its compression stroke, it forces its charge of compressed air into the upper cylinder and against the lower piston of the pump, and causes it to make an upward stroke. This piston being so much larger than the upper piston, the charge is further compressed and sent through outlet valve (21), at the top, thence through the hose to the tires or the tank.

These pumps are very often spoken of as compound pumps, because of the fact that the air pressure is raised in two stages; but don't forget that the first stage is performed in the engine cylinder and not in the pump cylinder. It is a single-stage pump, capable of raising the pressure from 50 or 60 lbs. in the engine cylinder to 100 lbs. or more in the tire or the tank. It is advisable to let the pump make a few strokes before attaching the hose to the tire valve.

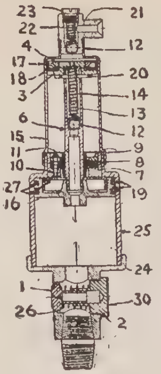

Fig. 64

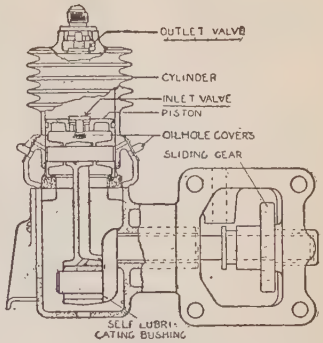

Fig. 65

Fig. 64. The impulse pump, sometimes termed the spark-plug pump, because it is screwed into the spark-plug hole and operates by means of the compression of the engine cylinder. (1) Inlet valve disk; (2) Inlet valve body; (3) Upper piston; (4) Upper piston nut; (6) Piston rod; (7) Stuffing box; (8) Rod packing; (9) Rod packing nut; (12) Ball check valves; (13) Upper piston pin; (14) Check valve spring; (15) Upper cylinder shell; (16) Lower piston; (18) Piston cup leather; (19) Piston rings; (21) Outlet valve; (22) Outlet valve spring; (23) Outlet valve cap; (24) Cylinder base; (25) Lower cylinder shell; (26) Inlet valve seat.

Fig. 65. **A power-driven tire air compressor** explained below.

Power-Driven Tire Air Compressor

The illustration is of the compressor used on a Cadillac car. It is bolted to the left-side transmission case and is driven by a sliding gear which meshes with the reverse idler gear in transmission. The sliding gear is thrown in when needed, and out when not needed, by a lever.

To operate: Stop the engine, wait until the transmission gears are idle, then shift the gear of the compressor in mesh with the reverse idler gear. Then start the engine, being sure that the gear-shift lever is in neutral position.

Run the engine at speed of 900 to 1,100 r.p.m. This is indicated by the ammeter showing 16 or 18 amperes, if the third-brush is properly regulated on the generator. Do not race the engine when inflating tires. Throw the gear out of mesh when through pumping tires. Lubricate the compressor often. By observing the illustration, it will be seen that the inlet of air is taken in through the "inlet valve" in the top of the piston, from the crank case of the pump, when the piston travels down. It is compressed and forced out of the "outlet valve" as the piston travels up.

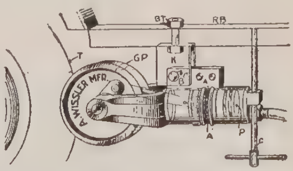

Fig. 66. Wissler friction-drive air pump: (T) tire; (GP) grooved pulley on pump connecting rod; (K) bracket bolting pump to running board; (A) air intake; (P) piston; (C) adjustment of tension of (GP) to (T). The rear wheel is jacked up, with the engine run on low or reverse gear. (Wissler Inst. Co., St. Louis.)

POWER-DRIVEN AIR COMPRESSORS FOR GARAGE USE

There are two types of air compressors for general garage use: (1) the air-cooled compressor; (2) the water-cooled compressor.

Where compressors are used almost continuously, the water-cooled type is recommended, because, for heavy constant duty, the air-cooled compressor would heat. When heating occurs, the air drawn into the hot compressor expands; then when it cools in the tank, it contracts, with the consequence that the pressure drops. The usual pressure is maintained at about 150 lbs., which is sufficient for all ordinary requirements. The pressure in the tank must, of course, be somewhat higher than at the outlets, usually about 15 lbs. higher. This, naturally, is determined by the number of outlets. There is usually a safety valve on the air tank which can be adjusted accordingly.

When purchasing a compressor be sure that it is over-size rather than under-size, as the business may grow; furthermore it is hard on the compressor if it is operated continuously when under-size.

Tank capacity: The following table is taken from the instructions furnished with the air compressors manufactured by the Brunner Mfg. Co., Utica, N.Y.

Size Tank to Use

Tank	Size	200 lbs.	180 lbs.	160 lbs.	140 lbs.
20 gal.	14x30	4 Tires	3 Tires	2 Tires	1½ Tires
32 "	16x36	6 "	5 "	4 "	3 "
40 "	16x48	9 "	8 "	6 "	4 "
50 "	16x60	12 "	10 "	8 "	6 "
65 "	18x60	15 "	13 "	10 "	8 "
80 "	18x72	19 "	17 "	13 "	10 "

Tank sizes, at the pressure given above, will inflate the given number of 35 x 4½ tires to 85 lbs. as shown in the table. For example, a 40-gallon tank at 180 lbs. pressure will inflate eight 35 x 4½ tires to 85 lbs.

After inflating tires of this size, each will have from 89 to 90 lbs. left, with which to inflate several smaller tires.

Drive methods: The air compressor can be driven by a belt from a line shaft, or by an electric motor. When self-contained—all in one unit—it can be driven by a belt, by a silent chain, or by gears.

Pointers on belt-driven compressors: A belt should be used of the width of the compressor pulley. If a smaller belt is employed, it will slip and stretch. Leather belts are best, as it is easier to lace them than fabric belts.

The speed of the compressor should be exactly that which the manufacturers advise. If it is run too fast, the compressor will heat; if run too slow, the capacity will be reduced.

How to Determine Speed and Size of Pulley to Use for Driving Air Compressors

The speed at which air compressors should operate is of importance and is determined by the sizes of pulleys. It should be remembered that the larger the driving pulley, the faster the compressor, having a given size of pulley, will be driven, and vice versa. We give here the method of determining the pulley sizes and speeds under different conditions:

When the compressor is driven direct from an electric motor, a 3″ pulley is generally used in order to keep the pulley on the compressor as small as possible. **To determine the size of the compressor pulley,** multiply the speed of the motor pulley by the diameter of the motor pulley, and divide the result by the number of revolutions of the compressor.

Example: What size of compressor pulley is required to drive an air compressor at 340 r.p.m. direct from an electric motor having a 3″ pulley and running at 1,700 r.p.m.?

1,700 × 3=5,100÷340=15″ pulley on the compressor.

When it is desired to drive a compressor from a motor by means of a countershaft, to ascertain the size of the countershaft pulleys, multiply the speed of the motor by the diameter of its pulley, and divide by the desired speed of the countershaft; this gives the size of the driven pulley on the countershaft. Then multiply the recommended speed of the compressor by the diameter of its pulley, and divide the result by the speed of the countershaft for the size of its driving pulley.

Example: It is desired to drive an air compressor, having a 9″ pulley, at 350 r.p.m. by a motor having a 3″ pulley and a speed of 1,700 r.p.m. The compressor cannot be driven direct from the motor, and a countershaft must be used. What size of pulley must the countershaft have?

1,700 × 3=5,100÷425 (speed of countershaft)=12 in., the size of the driven pulley.

350 × 9=3,150 ÷425 (speed of countershaft)= 7.4 in.

The nearest commercial pulley is 8″. Therefore an 8″ driving pulley is used on the countershaft.

When the countershaft runs at the same speed as the compressor, then the pulley on the compressor and the drive pulley on the countershaft must be of the same diameter, irrespective of what that diameter is (anywhere from 3″ to 3 ft.).

When an air compressor is driven from a line shaft without a countershaft, and the size of the driving pulley is required, multiply the speed of the compressor by the diameter of its pulley, and divide by the speed of the line shaft.

Example: An air compressor having a 9″ pulley is to be driven at 350 r.p.m. from a line of shafting having a speed of 450 r.p.m. What size of pulley must be used on the line shaft?

350 × 9=3,150÷450=7 in., the size of the driving pulley on the line shaft.

See also Index under "Diameter of pulleys; how to find," for further suggestions on the subject of finding the diameter of pulleys.

Installing an Air Compressor

Place the compressor on a firm foundation in a location where the pipes will not have to extend too far. Locate it preferably where short pipes can be used, and where fresh air and not gasoline fumes will be drawn into the compressor. It is best to draw the air from outside the building with a screened air intake.

Locate the tank where it can be easily drained, as vapor in the air condenses and should be drained. It does not matter if the tank is placed in a horizontal or in a vertical position.

Locate the air pipes where they can be used most and will be accessible for the greatest number of purposes, such as for outside free air service, for the vulcanizing department, for the tire-testing tank, for the buffing machine, etc.

Use flexible, woven-fabric-covered hose of very small diameter, as it is better than rubber.

Pipe and pipe joints should be connected by using shellac, asphaltum, or a mixture of litharge and glycerine to insure air-tight joints. The elimination of air leaks is a very important factor. Use the size of pipe recommended by the manufacturer of the compressor. The pipe leading to **the inlet** of compressor should never be smaller than the full diameter of the compressor inlet opening, and also of the outlet pipe. Iron or steel pipe is satisfactory.

Attach the **outlet pipe** from the air tank as high as possible from the tank, to avoid water condensation going to the tires.

A draincock in the pipe should be placed at the lowest point, especially when outside of the building, as the condensation is likely to freeze.

Air-Compressor Outfits

The Brunner air compressors[1] are used here as an example. The illustration (Fig. 67) is the layout for a belt-driven outfit, and in Figs. 68 and 69, electric motor-driven compressors are shown.

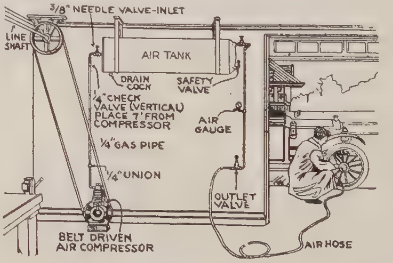

Fig. 67. **Belt-driven garage outfit No. 2,** for garages housing from 15 to 20 cars, and for vulcanizing shops.

1	No. 100 belt-driven compressor, 8″ T. & L. pulleys (1 tight and 1 loose)	$24.00
1	20 gal. 14″ x 30″ galvanized air tank	20.00
1	Model "B" air gauge	3.00
1	No. 75 vertical check valve	1.80
1	No. 72 safety valve for air tank	2.75
1	No. 83—¼″ needle valve	1.80
1	No. 83—⅜″ needle valve	1.80
1	No. 82—⅜″ needle valve with swivel	1.80
1	Tire connection and 25′ hose	6.55
		$63.50

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[1] Manufactured by Brunner Mfg. Co., Utica, N.Y. Write for catalogue. Prices quoted above are not guaranteed, but are subject to market conditions.

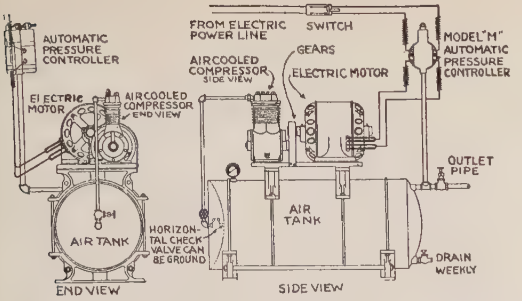
AUTOMATIC PRESSURE CONTROLLER
ELECTRIC MOTOR
AIRCOOLED COMPRESSOR END VIEW
AIR TANK
HORIZONTAL CHECK VALVE CAN BE GROUND
END VIEW
FROM ELECTRIC POWER LINE
SWITCH
GEARS
AIRCOOLED COMPRESSOR SIDE VIEW
ELECTRIC MOTOR
MODEL "M" AUTOMATIC PRESSURE CONTROLLER
OUTLET PIPE
AIR TANK
DRAIN WEEKLY
SIDE VIEW

Fig. 68. **A self-contained air compressor outfit** using Brunner No. 102 air compressor suitable for garages up to 60 to 70 car capacity. This air compressor is air cooled and is driven by an electric motor, ½ h.p.

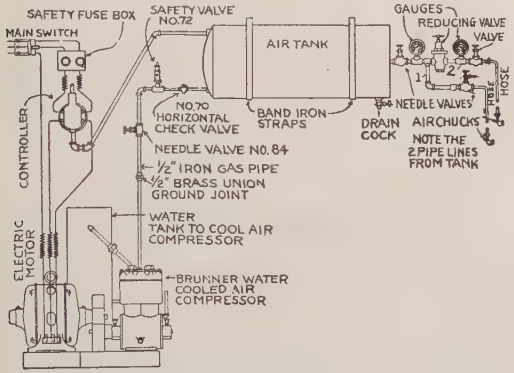

Fig. 69. **A heavy-duty air compressor outfit** using Brunner No. 17 vertical air compressor. This air compressor is water cooled and driven by an electric motor, 2 h.p. Designed for very large garages, for tire air service, and also for operating paint sprayers, small pneumatic tools, general shop work, etc. Note that there are two pipe lines leading from air tanks 1 and 2. No. 1 is at normal pressure of the tank, and No. 2 is at a reduced pressure through the reducing valve.

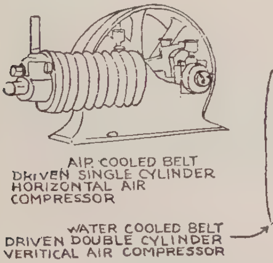
AIR COOLED BELT DRIVEN SINGLE CYLINDER HORIZONTAL AIR COMPRESSOR
WATER COOLED BELT DRIVEN DOUBLE CYLINDER VERITICAL AIR COMPRESSOR

Fig. 70

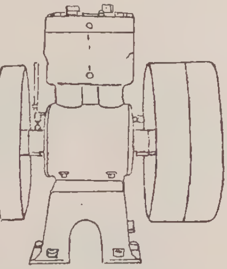

Fig. 71

Fig. 70. Brunner **belt-driven single-cylinder horizontal air compressor,** adapted to small vulcanizing shops: bore 1 13/16″; stroke, 2″; guaranteed pressure up to 175 lbs. at 350 r.p.m., the capacity is 1 cu. ft.; at 400 r.p.m., 1 1/6 cu. ft.; at 450 r.p.m., 1 1/3 cu. ft. free air per minute; uses 1½″ belt for an 8″ loose and tight pulley; power required, ¼ h.p. at 100 lbs. pressure; outlet pipe is ¼″; weighs 23 lbs. and costs $24.00.

A Brunner **belt-driven double-cylinder vertical air compressor** gives about twice the capacity. Price, with 9″ pulley and friction clutch, $53.00. Requires ½ h.p.

Fig. 71. Brunner **belt-driven double-cylinder water-cooled vertical air compressor** for continuous service under high pressure; bore 3″; stroke 3″; capacity at 250 r.p.m., 6 cu. ft.; at 500 r.p.m., 12¼ cu. ft. of air per minute. Pulleys 16×3″: fly wheel. Requires 1½ h.p. at 100 lbs. pressure, 300 r.p.m. Price, $135.00 complete.

Portable Air Compressor

A Brunner portable motor-driven air compressor outfit is shown in Fig. 72. It can be moved to different parts of the garage, and is suitable for inflating tires direct without the aid of a tank and storage system.

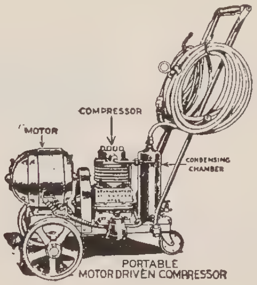

Fig. 72

The attachment plug is screwed into a lamp socket which operates the ¼ h.p. electric motor. This operates the air compressor which stores air in the tank. The advantages are apparent. Manufactured by the Brunner Mfg. Co., Utica, N.Y.

Compressed Air Used for Other Purposes

Compressed air for cleaning the upholstering is used in many up-to-date garages. With special connections and a vacuum tank the work is rendered easy and is done quickly. It is also used for spraying paint, for small pneumatic tools, etc.

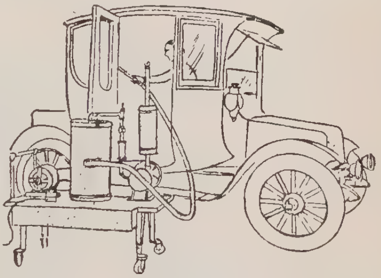

Fig. 73. Cleaning car with a motor-driven vacuum cleaner.

Care of Air Compressors

An air compressor might be compared with a gasoline engine. A piston draws air into the compressor cylinder through an inlet valve on the suction stroke. As the piston returns on its next stroke, the valve closes and the air is compressed and forced through the outlet valve to the air-storage tank.

The valves must seat properly, otherwise the pressure will be reduced. The valves are of the poppet type.

Lubrication of compressors is a subject of importance; that is, it is highly necessary to use the proper grade of oil as recommended by the manufacturer. Too much oil will gum the rings and get into the air tank, and will also necessitate frequent valve grinding. Lack of oil will result in burned-out bearings.

Cylinder-head bolts should be drawn tight, otherwise the compressor will fall below its capacity. Cylinder head gaskets should be used as recommended by the manufacturer. Paper or rubber will not do.

Knocks are often due to loose flywheels, carbon on the piston, or to worn bearings.

Compressed-Air Fittings

Fig. 74

Fig. 75

Fig. 74. **Wire-wrapped air hose for garage work:** inside diameter ¼″ and ⅜″.

Fig. 75. **Copper-wrapped brass-wire-woven flexible hose:** inside diameter ¼″ and ⅜″. For hand or portable pumps. The hose generally used is 3/16″ or ¼″ diameter.

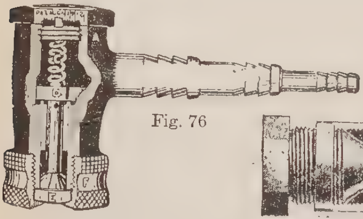
Fig. 76

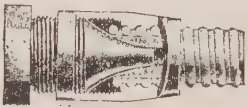
Fig. 77

Fig. 76. Romort style "A" **automatic air valve for use on air hose where it is in constant use.** Bronze; instantaneous in opening and closing; air-tight; step-up stem fits any size tubing from ¼″ to ½″.

Fig. 77. **Air hose couplings:** Takes care of any hose, large or small, metal covered or rubber; the hose is expanded at the end and the threaded nipple is so designed that it always holds firm—the harder the pull the tighter the grip; bushing is furnished to use on hose of small diameter. The type shown is the Romort "Universal," and is shown connected to metal covered hose. It can also be used on plain rubber air hose.

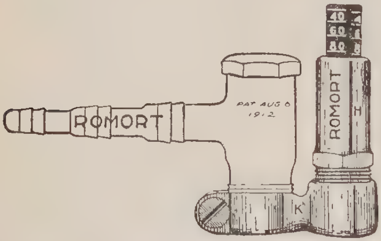

Fig. 78. **Tire tester and air-valve attachment** combined. The Schrader tire air-pressure gauge is shown attached to the Romort automatic air valve.

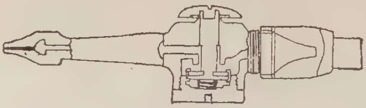
Fig. 79

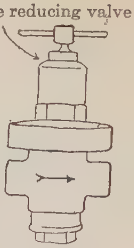

Fig. 83

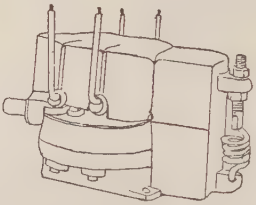
Fig. 80

Fig. 82

Fig. 81

Fig. 79. Romort **blow gun:** bronze metal; can be used wherever there is a lathe or other machine where it is necessary to remove chips, dirt, or other waste matter; entirely automatic; the valve closes when pressure on the trigger is released; connection to the hose is made by the Romort Universal hose connection, which fits all popular sizes of rubber hose and prevents the gun from blowing off the hose; can be used in the garage for cleaning all the dirt from tires to be vulcanized, for cleaning cushions, and for various other purposes.

An automatic blow cock, used in connection with an air-storage system for dusting out cars, cleaning engine and parts, can be had of the Stevens Co., 375 Broadway, New York, N.Y.

Fig. 80. Brunner **automatic electric air-pressure controller** (model M): Especially designed for use in motor-driven air compressors for garages, pneumatic water systems, etc.; automatically maintains air-tank pressure between predetermined limits; compact and substantially built; mechanism carefully made throughout with all moving parts protected from dirt and dust by metal cover; carries sufficient current to operate single, two, or three-phase A. C. motors up to 2 h p. and 440 volts; also suitable to operate D. C. motors up to and including ½ h.p.; regularly adjusted to start motor at 115 lbs. tank pressure, and stop it at 140 lbs.; can be adjusted at factory for other limits, but there must be 25 lbs. difference between maximum and minimum limits.

Fig. 81. Brunner **vertical check valves** for air lines for female connections ¼″ and ⅜″.

Fig. 82. Brunner **safety valves:** Have a ball seat; can be adjusted to blow off at any desired pressure up to 175 lbs.; intended as a tank safeguard by preventing higher tank pressure than that for which the valve is set.

Fig. 83. Brunner **pressure-reducing valve:** Metal construction, designed for work on air tanks carrying up to 150 lbs. initial pressure, and will reduce air-line pressure to a steady flow at any point between 10 and 60 lbs. to the square inch; by turning the adjusting screw in the top, the pressure can be instantly raised or lowered to any point between these limits; for service in reducing pressure on pneumatic tools or any other service where accuracy or great durability is desired.

SOLID TIRES

Solid tires can be divided into two classes: (1) the single, and (2) the dual type. The single solid tire is the type in general use. It has what is termed a hard base pressed on a single solid tire. The rim used is a channel-type non-detachable rim.

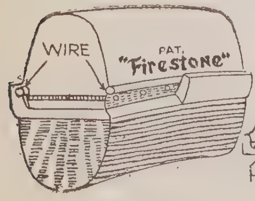

Fig. 84

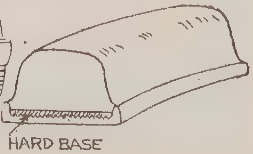

Fig. 85

The original automobile solid tire (Fig. 84)(now obsolete) was held in place by side wires.

The hard-base pressed-on type of solid tire and channel rim is shown in Fig. 85.

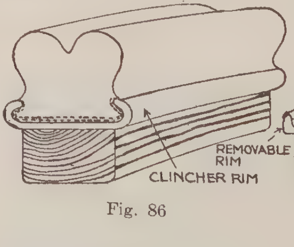

Fig. 86

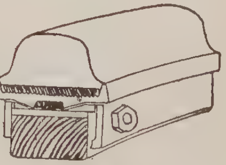
Fig. 87

The cushion tire is used where more resiliency is required. The rubber is softer than that in the regular solid tire. Fig. 86 shows a cushion type of tire on a clincher rim. This rim is now obsolete, and a channel rim, the same as used with other solid tires, is now used. This type of tire is used extensively on fire-department trucks.

The solid tire mounted on a quick detachable, demountable rim is shown in Fig. 87. This rim is now obsolete, the principle involved in the hard-base pressed-on tire being used instead.

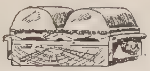

Fig. 88

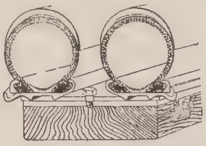

Fig. 89

The dual solid tire (Fig. 88) is now being replaced with single Giant solid tires. The dual construction consisted of sections or blocks, mounted on demountable rims.

The dual pneumatic tires for truck use (Fig. 89), mounted on quick-detachable side-ring type rims is now seldom used; instead, the Giant pneumatic cord tire, or the Giant solid tires are used.

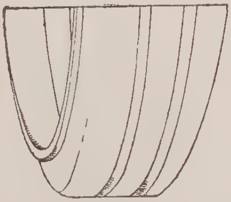

Fig. 90

The Giant single solid tire (Fig. 90) is the type of solid tire in general use for heavy trucks. It has a hard base and is pressed on the rim.

Standard Sizes of Solid Tires and Carrying Capacity

The solid tire in general use is divided into three classes:

1. The "Regular" single solid tire.
2. The "Cushion" solid tire.
3. The "Giant" solid tire.

Carrying Capacities of Firestone "Regular" Solid Tires and also "Cushion" and "Giant" Tires

For tires of 36″ or less:

3 inch, maximum load per wheel, 1,000 lbs.
3½ inch, maximum load per wheel, 1,300 lbs.
4 inch, maximum load per wheel, 1,700 lbs.
5 inch, maximum load per wheel, 2,500 lbs.
6 inch, maximum load per wheel, 3,500 lbs.
7 inch, maximum load per wheel, 4,500 lbs.
8 inch, maximum load per wheel, 5,500 lbs.
10 inch, maximum load per wheel, 7,500 lbs.
12 inch, maximum load per wheel, 9,500 lbs.

Dual solid rubber tire capacities are figured by multiplying the figures given above by 2.

For tires of 38″ and 40″:

5 inch, maximum load per wheel, 3,000 lbs.
6 inch, maximum load per wheel, 4,000 lbs.
7 inch, maximum load per wheel, 5,000 lbs.
8 inch, maximum load per wheel, 6,000 lbs.
10 inch, maximum load per wheel, 8,000 lbs.
12 inch, maximum load per wheel, 10,000 lbs.
14 inch, maximum load per wheel, 12,000 lbs.

Standard Sizes of Firestone Regular Solid Tires

32 x 3
34 x 3
36 x 3
32 x 3½
34 x 3½
36 x 3½
32 x 4
34 x 4
36 x 4
34 x 5
36 x 5
40 x 5
34 x 6
36 x 6
40 x 6

Standard Sizes of Firestone Giant Solid Tires

34 x 7
36 x 7
40 x 7
34 x 8
36 x 8
36 x 10
40 x 10
36 x 12
40 x 12
40 x 14

Cushion solid rubber tires are made in the foregoing sizes, except 32 x 3, 36 x 3, 40 x 5, 34 x 7, 34 x 8, 36 x 12.

Solid Tire Troubles

Solid tire troubles occur mostly as a result of cuts and bruises which soon cause the tire to wear rapidly. These are caused by driving in car tracks, by chains being too tight, wheels being out of alignment, by skidding, by overloading, by speeding on bad roads, etc.

The solid tire cannot be successfully vulcanized. Therefore the only recourse is to run the tire for as long a time as possible.

Chains for Solid Tires

Chains for solid tires are a very important factor, as the solid tire has a tendency to skid—more so than pneumatic tires. They are also essential for gripping the road, snow, ice, etc.

Several methods of applying chains and grips are shown below.

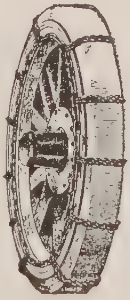

Fig. 91

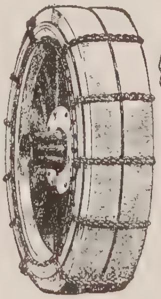

Fig. 92

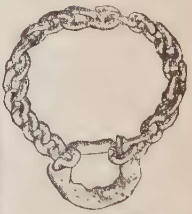

Fig. 93 (upper)

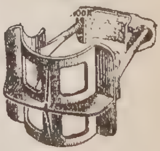

Fig. 94 (lower)

Fig. 91. Weed solid tire chains for single solid tires.

Fig. 92. Weed solid tire chains for dual solid tires.

Fig. 93. Woodworth solid tire chains.

Fig. 94. Mud hooks.

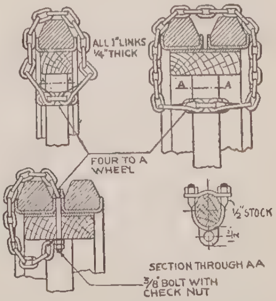

Fig. 95. Either twisted links or straight link chains may be used on solid tires as shown above. Chains should be applied at 4 points on each rear wheel. They should be removed when not required. The illustration at the lower left shows where clearance will not allow a chain on the inside tire of dual construction (Gen'l Vehicle Co.).

Increasing the Tire Repair Business

There are many ways of building up a tire business. Many tire repairmen, instead of depending alone upon obtaining work from the owner, build up a respectable business through the garages and gasoline filling stations. Garage men will not go out of their way for this, and therefore the usual discount allowed is 25 per cent. Tires can be left at the garage man's place and can be called for by the tire repairman.

Another way to increase business is to suggest to owners of trucks to change the solid tire to pneumatics. Of course you would not suggest changing solids to pneumatics on a 5-ton truck hauling sand or coal for short distances, but where a 2, 2½, or 3-ton truck is making daily trips of 75 or 100 miles over fairly good roads, it would pay the owner at least to fit the front wheels of such a truck with penumatics, and this is the business you should look for.

Before soliciting this work, first consider carefully if pneumatics will do the work. Having decided that the change would be an advantage to the owner, the next step is to decide the proper size of tire to use.

This may be done by running the front end of the truck, fully loaded, on a scale. Then when you know the weight which the front tires are carrying, it is a simple matter to refer to the table on page 593, and select a size of cord tire designed to carry that weight.

For a 1-ton capacity truck, a 34 x 5 cord pneumatic tire is the usual size. If only two wheels are to be fitted with pneumatic tires, then fit the **front wheels** with this size.

For 1½-ton capacity trucks, use 36 x 6 cord pneumatics; for 2-ton trucks, 38 x 7 or 40 x 8 Giant cord pneumatics, or 38 x 7 on the front and 40 x 8 on the rear.

The carrying capacities for solid tires and for pneumatic tires are given on pages 627 and 593.

Of course, if a 2-ton capacity truck usually carries light loads of a bulky nature, but not up to capacity, the proper course is to figure the load carried by each wheel and select tires accordingly.

Some of the points to bear in mind relative to fitting a truck with tires are as follows:

Pneumatic tires, of course, will give greater truck protection through the absence of vibration, and will also increase the radius of travel per day. The minimum speed is increased because it is not necessary to slow down for rough spots in the road. In such work as hauling in oil fields it is almost impossible to use solid tires, and only pneumatic tires can be used. In coal mines and on extremely rocky roads and with heavy hauling, the pneumatic tires would be more expensive, and solid tires are better adapted here.

The cushion tire is pressed on to the wheel, just like the regular solid tire. The cushion tire might be classed half-way between the solid tire and the pneumatic tire, in that it is softer than the solid tire and has greater resiliency, but is a solid tire in the true sense of the word. The fire department uses the cushion tire to a great extent, and it is also used on 1, 1½, and 2-ton trucks to a large extent.

For extremely heavy duty, such as 3½, 5, and 7½-ton trucks, where extremely heavy loads are carried and at a very slow speed, **the Giant solid tire is the most economical.**

Very few trucks have the same size tires all around, and we find that sometimes most of the load is carried on the rear. If the same size tires are carried on all four wheels, then the load should be equally distributed.

For example, suppose we had a truck weighing 4,000 lbs. and it carried a load of 2,000 lbs.: this would give us total load carried by the four wheels of 6,000 lbs., providing the load was equally distributed on all four wheels. By dividing the 6,000 lbs. by 4, we have 1,500 lbs. load per wheel. Therefore by referring to our capacity table on page 627, we should use a 4″ tire which carries a wheel load of 1,700 lbs. Always figure over rather than under.

If, however, three-fourths of the load is carried on the rear wheels, or 4,500 lbs., then one-half of this 4,500 lbs. would be carried on each rear wheel, or 2,250 lbs. per wheel. By referring to our capacity table on page 627, we find that we should use a 5″ tire on the rear, and a 3″ tire would be sufficient for the front.

For the best plan for finding the wheel load for any particular size tire: See page 594, which explains how to weigh, and how to find out how much of a load each wheel carries. Then refer to the table giving the carrying capacity of the different sizes of tires.

When fitting truck wheels with pneumatic tires, which are already equipped with solid tires, it will be necessary to have new rims fitted to the wheels. This should be done by a wheelwright who specializes on this work.

The usual cost of such work runs about $15 per wheel plus the cost of the rims, with a discount of 20 per cent to the dealer. The time required for changing two wheels would be about one day.

For example, **the cost of changing two solid-tired wheels to pneumatics** would be estimated, approximately, as follows:

Wheelwright's charge, 2 wheels at $15.00	$ 30.00
2 34 x 5 rims complete with felloe bands, bolts, etc.	40.70
2 34 x 5 cord pneumatic tires at $53.50	107.00
2 34 x 5 high-test red inner tubes at $5.85	11.70
	$189.40

Usually, when the owner of a truck agrees to have the solid tires changed to pneumatic tires, he insists on having his solid tires traded in on the job. This can usually be adjusted with the tire branch, so that an arrangement for taking them on trade can be made.

INSTRUCTION No. 56

OPERATING A CAR: Gear Shifts, Control Levers and Pedals of Some of the Leading Cars; Pointers on Selecting a New Car; Judging and Testing a Second-Hand Car

HOW TO OPERATE A CAR

When learning to operate an automobile, the first step is to become familiar with how to start and stop the engine and how to control the speed. This can be learned best with the engine running.

The simplest way in which this can be done is to jack up the rear wheels so that they are clear of the ground, letting the weight of the car rest on a solid box. The point is to get the driving wheels clear of the ground, and free to revolve without moving car.

The different speeds may then be handled, and the movements of the levers and pedals may be gone through with, without being under the necessity of steering, the steering being the simplest and easiest part to learn. Care should be taken to block the front wheels so that the vibration of the engine cannot shake the car from its support.

Lever Systems

There are three types of side-lever systems: (1) the type which operates the planetary transmission gears; (2) the type which operates the old-style progressive gears, and (3) the type which operates the selective type of gear.

The planetary gear type is used on the Ford car, and is very simple. See the Ford instruction.

The progressive gear type is now seldom used. Its principle and operation is shown on page 25.

The selective type is the type most used, and it is with this type that we shall deal principally. This type is shown on pages 26, 28, 29.

The gear-shift lever used with a selective transmission is constructed in two types: the "gate" type, and the "ball and socket" type (page 27).

The emergency or hand-brake lever is usually placed alongside the gear-shift lever. On early model cars these levers were placed on the side of the car, but are more commonly found in the center (see Fig. 3 page 630). For a further description of the selective lever operation, see pages 26 to 29.

Pedal Systems

The foot brake is a pedal operated by the right foot. **The clutch pedal** is a pedal operated by the left foot.

The accelerator is usually placed to the right of the foot-brake pedal.

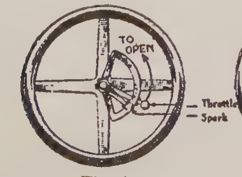

Fig. 1

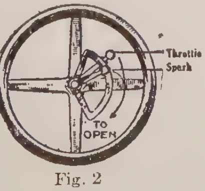

Fig. 2

Fig. 1. On most cars the throttle and spark lever are moved up to open the throttle and advance the spark. Full open throttle and full advanced spark would then be all the way up. Full retard would be all the way down.

Fig. 2. On some few cars the throttle and spark lever are moved down to open and advance.

Note. On some makes of cars the long lever is the spark lever.

The spark and throttle levers are, in most instances, placed on the steering wheel. On a few cars they are placed under the wheel on the steering post. The throttle lever is usually the longest of the two. The movement of the throttle lever, whether up or down, to open the throttle is easily determined by noting the movement of the throttle on the carburetor. The spark lever for advancing can also be determined by noticing the direction in which it moves the timer or interrupter on the magneto. Usually the **throttle and spark lever are pushed up** to open and to advance.

Note that on the Pierce-Arrow "series 32" and the Cadillac "type 61" (pages 638, 635), the spark and throttle levers are now made very short.

Preparing a Car for Service

Before attempting to drive the car, make sure that it is ready for the road. See to the following:

1. That there is gasoline in the tank at the rear.
2. That the radiator is filled to the level of the overflow with clean water, or with an anti-freezing mixture in winter.
3. That the crank case is filled with oil to the level indicated by the oil gauge.
4. That the storage battery is properly connected.
5. That the gasoline shut-off cock between the vacuum tank and the carburetor is fully open.
6. That the car is provided with a driving license.
7. That the fan is working.
8. If the car has been standing idle for several days, it may also be necessary to prime the vacuum tank by removing the pipe plug in the cover and introducing a pint or so of gasoline (see page 115). Be sure to screw the plug in tight when replacing it.
9. See that the tires are properly inflated (see page 593).
10. See that a spare tire is supplied for emergency use.

How to Start the Engine

As an example, the Studebaker "Light Six," model "EJ" will be used.

Gear-shift lever: See that the gear-shift lever stands in **neutral** (upright) position, where it is free to move sideways.

Position of spark lever when starting engine: The automatic advance as well as a hand or manual advance of the spark is used on this car. The spark lever (short lever) is placed in normal driving position, or about two-thirds of the way to the top of quadrant when starting the engine with the starting motor.

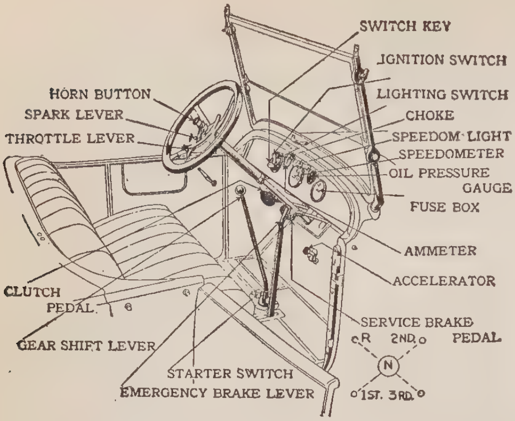

Fig. 3. Studebaker model "EJ" control levers, etc.

If an engine is equipped with a manual or hand control alone, and with no automatic advance of spark, it is best to retard the spark when starting, especially when starting the engine with the hand crank.

Position of throttle lever: Open the butterfly valve in the carburetor slightly by means of the hand-throttle lever on the steering gear sector; turn the ignition switch to the "On" position.

If the engine is cold, it will be necessary to pull out the carburetor "choke" button, located on the instrument board (Fig. 3). It may be found necessary to leave the "choke" button pulled part way out for a short time until the engine is warm. (See carburetor instructions.)

Make sure that the gear-shift lever is in "neutral" position; then press down on the starter switch. The instant the engine starts on its own power, release the starter switch. **This is important.**

After the engine starts, advance the spark lever half-way on the sector. If the engine does not start within a few seconds after you have pressed down on the starter switch, release the switch, as the continued use of the starter will discharge the battery. Investigate and find out where the fault lies, and correct it before attempting to start the engine again. (See "Digest of Troubles," page 454.)

In connection with the releasing of the starting-motor switch pedal, be sure to remove your foot from the starting switch, the moment the engine starts, and be sure that the lever springs back into its original position.

The time required for the operation varies from one half-second under good conditions when the engine is warm, to from five to ten seconds for cold weather starting. If the engine does not start within the period mentioned, release the starting switch, since you will know that something is out of adjustment and that you are throwing an undue strain on the battery. (For a full explanation of this operation and the proper care, see the starting-motor instructions, referring to the type of motor system with which cars are equipped.)

Cranking the engine by hand: If, for any reason, the driver wishes to crank the engine by hand, the adjustment for starting should be the same as for operation of an electric starter except that the spark should be retarded. When cranking by hand, be sure to make the crank engage at the point with the handle nearest the ground. Then it should be pulled up clockwise with a short, snappy pull.

While on this subject, an explanation should be given of the proper method of cranking an engine, as illustrated in Figs. 4, 5, and 6. The reason for the necessity of starting a gasoline engine, either by cranking by an electric motor, or by hand, is explained on page 31.

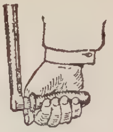

Fig. 4

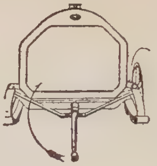

Fig. 5

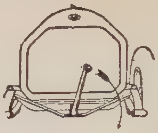

Fig. 6

Fig. 4 shows the proper method of grasping a starting crank.

Fig. 5 shows the direction as indicated by the arrow point, in which to **pull up** on the crank with a quick, snappy pull, in order to spin the engine crank shaft. With the crank grasped as shown in Fig. 4, and the "pull-up" made as in Fig. 5, there is no chance for a back-fire of the engine to cause a kick-back.

In Fig. 6, note that if the starting crank is **pushed down,** and if the engine should back-fire, which often occurs, when the engine is being slowly cranked, if—under these conditions— the spark lever is advanced, the full force of the kick-back is against the arm, and a sprained or broken wrist may result. **Never push down on a starting crank** to start an engine. **Pull up.**

Another point to remember is, do not tire yourself out by continually cranking, if an engine does not start after cranking five or six times. Find the cause of the failure to start.

After the engine is started, close the throttle and place the spark lever about half or two-thirds on sector until the engine runs slowly and evenly. On the Studebaker "EJ," the instructions are to place the spark lever at full manual advance; on the Buick, about half-way, and on the Westcott, at two-thirds advance.

As the engine warms up, the "choke," button should be pushed in; in fact, this should be done as soon as possible.

Never allow the engine to run any length of time with the air regulator turned to "choke," as this gives an excessively rich mixture and uses an abnormal amount of gasoline.

Handling the Spark

Ordinarily, on most engines using an automatic advance of spark, the spark lever should be about half to three-quarters of the way to the top of the quadrant for normal driving conditions. On the Studebaker "EJ," the automatic spark advance for starting and running speeds is full advance; on the Westcott, using an automatic advance, the spark lever is placed about three-quarters of the way to the top of the quadrant or sector; on the Buick about half way. The automatic spark advance, which is incorporated in the ignition system, will control the spark position without further attention on the part of the driver. It is arranged so as automatically to advance or retard the spark to the proper position, depending on the speed of the engine; but as the car slows down, as on ascending a steep hill, or when negotiating a heavy road, it is necessary to retard the spark lever by hand until the engine runs smoothly and without knocking.

With engines not equipped with an automatic advance of spark, it is best to start the engine with the spark lever near full retard, and then, after the engine is started, it should be advanced. The exact location of the lever will depend upon the speed of the engine.

Just how much the spark should be advanced, or, rather, how much spark advance the engine will stand, depends largely on how fast it is running. The faster the engine is running, the more the spark should be advanced. Bear in mind constantly, however, that there is such a thing as overdoing it and advancing the spark lever too far. When this is done, the ignition takes place before the charge has been fully compressed, and consequently the piston is obliged to overcome the pressure of the expanded gases of the exploded charge before it can commence on its power-delivering stroke.

Furthermore, when the spark is advanced too far, a slight pounding noise in the engine is the result. This pounding is sometimes not noticed by the beginner, as it usually is but slight, owing to the substantial construction of the crank shaft, and by the uninitiated it is often accepted as permissible.

Advancing the spark too far is very injurious, because by it the bearings, crank shaft, and connecting rods are required to withstand strains which are greatly in excess of those produced when the ignition occurs at the proper moment.

The engine should never be allowed to run for any length of time with the spark retarded.

With a retarded spark and a late explosion, the combustion or burning of the charge of gas is not complete. This causes a great amount of carbon to be deposited on the walls of the cylinders, combustion chambers, piston heads, spark plugs, etc. It also causes the engine to heat to a much higher temperature, which causes a very severe action on the valves and valve seats. When the charge is ignited at just the right instant, the combustion is practically complete, so that when the valves open a thoroughly burned charge passes out. On the other hand, when the charge is ignited late, the charge is still burning when it passes through the valve opening and tends to heat, burn, and scale, and to cause pits on the valve and valve seats. In time, this creates a condition which prevents the valves from seating properly or fitting tightly, and therefore a loss of compression and a corresponding loss of power is the result.

Starting a Car—Shifting Gears

How to start a car: After the engine has started, be sure that the oil-pressure gauge and ammeter are indicating properly; then release the hand brake. Place the left foot on the clutch (left) pedal (see Fig. 3), and press it forward as far as it will go, thus disengaging the clutch. The engine is now running independently of the transmission, the gear-shift lever is supposed to be in "neutral" position, and the clutch is held "out" by the left foot. The next operation is to place the right hand on the gear-shift lever and to move it to the left, sidewise, and pull it back into "first" gear position.

Next, slowly release the pressure on the clutch pedal, at same time pressing easily on the accelerator pedal with the right foot, to increase the speed of the engine. As the clutch takes hold, the car will commence to move forward.

Shifting from first to second gear: When the car is moving about four to six miles an hour, the gear shift from "first" to "second" gear should be made. This is done by disengaging the clutch, as explained above, and moving the gear-shift lever forward to "neutral" position, then to right and forward again to "second speed" position. Re-engage the clutch and accelerate as before. The gears are now in "second gear" position. (See gear-shift movement of the Studebaker at the lower right-hand corner of Fig. 3, and of the Buick, Fig. 9, page 635.)

Shifting from second to third or high gear: The car should be accelerated to about eight to ten miles an hour, and the gear shift from "second" to "third" gear should be made by pulling the lever straight back, the clutch being disengaged as before. "Third" or "high" gear is used in all ordinary driving, but there are times when it is necessary to shift to second gear: for instance, when climbing hills, or when on rough or heavy roads, or when slowing down for traffic.

To increase the speed of the car under these conditions, the butterfly throttle valve of the carburetor is opened gradually, by means of the accelerator, and the spark lever should also be advanced as the speed increases.

Pointers on Shifting Gears when Starting Car

When shifting from a lower to a higher gear, as **when first starting,** it is important that the speed of the car be accelerated just before making the change, so that the two gears that are to be meshed together will be running at approximately the same speed. The proper handling of the clutch pedal and accelerator so as to make the motor "pick up" its load quickly, and at the same time prevent it from "racing" when the clutch is released, requires considerable practice.

In changing gears, especially when starting the car from a standstill, always let the clutch pedal come back gently, otherwise, a quick release of the foot clutch pedal will let the clutch take hold with a violent jerk.

In shifting gears from one speed to another, the motion should be made firmly and without hesitation. If the gears fail to mesh correctly the first time, release the pressure on the control lever and clutch pedal for a moment and try again. With a little practice, the various changes can be made easily and without noise.

When there is a grinding noise on shifting gears, it is usually the result of the clutch not being "thrown out" sufficiently, and the engine is thus driving the main transmission shaft. By pressing firmly on the foot clutch and quickly shifting the gears, the shift should be made without a particle of noise—providing the clutch pedal is not released until the shift is made.

If there is noise, such as a clashing of gears, with the foot clutch pedal thrown out fully, then the clutch is dragging, or the transmission main shaft bearings are worn.

Most cars use a selective type of transmission, giving three forward speeds and one reverse speed. The Locomobile uses four speeds forward and one reverse speed. The Pierce-Arrow (Fig. 21, page 637) also uses four forward and one reverse. The "series 32" model (Fig. 22, page 638) uses three speeds forward and one reverse.

Stopping Car and Engine

To stop the car, slow down the engine by removing the foot pressure on the accelerator pedal by pressing down on the clutch pedal with the left foot. Then disengage clutch, gradually press down on the foot-brake pedal (right pedal), so as to bring the car to a gradual stop. At the same time move the gear-shift lever to "neutral" position at which time the foot can be removed from the clutch pedal. After the car has stopped, apply the hand brake by pulling the hand-brake lever to the rear. Never leave the car standing with the hand brake released.

If the road surface is wet and slippery, a greater breaking effect may be had by pushing in on the foot-brake pedal intermittently, i.e., hold the brake pedal down for an instant only, then release and apply again. Keep doing this until the car is brought to a stop. If the brake is constantly applied, the rear wheels will be locked and traction will be lost.

To stop the engine, turn the ignition switch off. Before doing so, however, it is good practice to open the throttle with the hand-throttle lever, thus permitting the engine to take in a full charge of gas before coming to rest and leaving it ready for a quick start next time; also move the spark lever to the starting position and set the hand brake before leaving the car.

Lock the ignition switch when leaving the car standing alone. Never leave the car with the engine running, as this is a useless waste of gasoline, and there is always a chance that someone may throw the gears into mesh.

Reversing

To reverse the motion of the car, it is first necessary to stop the car. Never attempt to shift into "reverse" gear when the car is in motion. With clutch disengaged, move the shifting lever to left and forward, and then gradually engage the clutch and accelerate the engine as before. One rule that the driver must always remember is that the clutch must be disengaged whenever gears are shifted.

Starting Car on a Grade

To start a car when on a grade, start the engine as before; then release the hand brake and hold the car with the foot brake while shifting gears. Now accelerate the engine with the hand throttle while gradually releasing pressure on both pedals together. It takes practice in operating the clutch and brake pedals to make the one take hold while releasing the other without "stalling" the engine.

Shifting from a High to a Lower Gear after Car Is Under Way

Shifting down is the term used when a car is running on high gear and it is desirable or necessary to shift to a lower gear.

Shifting from third or high to second: To shift from "third" or "high," to "second" gear, disengage the clutch; accelerate the engine to approximately twice the revolutions at which the engine was turning over previous to shifting gears; then push the lever to "second" gear position and re-engage the clutch.

"Low" or "first" gear is ordinarily used only in starting, but in exceptional cases of very heavy pulls, it will be better to shift back to "first" gear, which is done in a similar manner as the shift from "third" to "second." In coming to a bad piece of road, full of ruts, bumps, or holes, it is best to shift immediately into "second," or "first" if necessary. Thus, you have much better control of the car and can pick up more readily. When using lower speeds you can control the car almost entirely with the accelerator, letting yourself down easily into holes and over bumps without having to slip the clutch.

When passing through traffic, it is sometimes desirable to change to a lower gear on level ground without slowing down the car. To attempt this by de-clutching and putting the lever directly into the lower speed notch—in the same way that this is done while ascending a hill—would be to invite a very noisy clash of the gears.

Instead of this, **the change is made in three progressive steps,** as shown in Fig. 7, and the speed of the car is not reduced to any appreciable degree.

The first movement shown at (A) in the illustration (Fig. 7) is to disengage the clutch and shift the gear-shift lever forward **from high to neutral** (center position as shown in the dotted lines). This leaves the car coasting with the engine running.

The clutch is now let in, and the levers are in the position shown at (B). Now this is the point at which skill is required, and where practice is necessary.

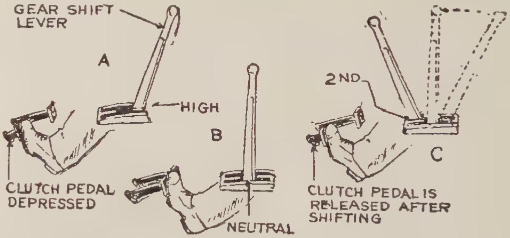

Fig. 7. Example of **shifting from high to second gear while the car is in motion:** (A) clutch out and gear-shift lever brought to neutral; (B), gear-shift lever in neutral position; (C), clutch out and gear-shift lever pushed forward to second; clutch is then released.

The engine is speeded up until it is turning over at the same rate of speed as it would be were the low speed engaged. It will take a little practice to accustom the ear to judge by the sound of the engine whether it is turning over at the correct speed or not.

After the engine is speeded up to the proper degree, the clutch pedal is depressed, and the change gear lever brought into second speed gear as at (C). The same method will apply in going from second to first.

Changing from higher to lower speed on a grade: When the car is facing **upwards,** it is a little more difficult to be able to judge when the speed is sufficiently great to justify a change from first to second speed. The hill may be of such slope that it is an easy matter for the car to take it on high in ordinary running, but may still be so steep that the pause in the gear-shifting act is sufficient to cause the speed to drop considerably. In a case of this kind the driver should be able to judge at just what speed he should throw out his clutch and make the change. The steeper the hill, the greater will be the speed required before the change can safely be made.

Trouble in dropping to lower speed on a hill can be averted if the critical moment at which to make the change is learned. If the driver waits too long, he may "kill the engine," and sometimes place himself in a very serious position.

If he tries to make the change too soon, he will clash gears.

By changing at the critical moment, however, an easy, quick change can be made.

"Running in" a New Car

When setting up and starting any new piece of complicated machinery, you would ordinarily expect to watch it pretty closely, and go a little easy with it until its various bearings, parts, etc., had become thoroughly "worked in." An automobile is no exception to the rule. While every bolt and nut in the automobile is drawn tight, and secured with either cotter pins or lock washers when the car leaves the factory, nevertheless it is advisable to go over a few of the more important points and make sure that everything is in perfect shape.

The following points should receive your special attention during the time that the car is being driven the first few hundred miles:

Between the upper crank case and the oil pan, or between the cylinder heads and the cylinder block, there are usually gaskets. During the first few days of service a gasket may become slightly compressed, thus loosening the crank case to oil-pan bolts. Consequently it will pay to **go over the nuts on the bottom of the oil pan** with a wrench and tighten them up. Drive a few days, and try them again. Continue to do this until the gasket has become fully compressed and the parts have settled into permanent working position. If you will take this precaution, the joint will be absolutely tight and you will never have any trouble, such as loss of oil or water, and dirt being washed into the oil pan and then circulating with the oil through the bearings, causing excessive wear and cutting.

At first, it will be well occasionally to **go over all of the bolts that hold the engine to the frame,** and see that they are kept tight. If you find them perfectly tight after inspecting them two or three times, you need never fear that they will loosen up.

It is advisable to **put a wrench to all nuts on different parts of the car** and make sure that they are perfectly tight after it has been driven a hundred miles or so. When they have once been screwed up as tightly as possible and the car has been thoroughly "run in," there will not be so much danger of loosening up and causing damage.

Spring clips will loosen if the nuts on the clips are not tightened occasionally. **It is very important to tighten these nuts often.**

Fender bolts also demand attention.

The universal joints should be kept well supplied with grease.

Lubrication of a new car. It is needless to remark that lubrication is one of the most important things to look after on a new car. All parts should be thoroughly lubricated and greased as directions provide. Follow the lines there suggested. In the absence of directions from the maker, study the lubrication subject carefully.

Remember one thing: cheap oil will cost ten times more, maybe a hundred times more in the long run, in the way of repairs. The best oil is none too good.

Also remember that oil should be changed in the engine **often,** for reasons stated on page 167. Just how often to change will be determined by the amount of gasoline in the oil, which one should take particular note of, when changing.

"Running in" a New Engine

"Running in" a new engine is a very important factor in the life of a car. More harm can be done during the first few days than one can imagine—if care is not exercised. For an explanation of this, read pages 171, 167, relative to the importance of lubrication and slow running for the first 500 or 1,000 miles, in order to work the pistons properly to a smooth fit to the cylinders, and so as to avoid cutting or scoring the cylinders. See also Index under "Reaming cylinder."

Don't race an engine: Never open the throttle suddenly, or leave it open very far, when the car is standing and the engine is running idle. This is known as racing the engine, and there is nothing more injurious, especially when the engine is cold. More engines have been ruined by racing while idle than have been worn out in actual driving under load.

When the engine stands over night, don't immediately race the engine to warm it up, because the oil has drained from the bearings, the cylinder walls, etc. Consequently it is going to take a few minutes to lubricate these parts properly. Therefore first let it run slowly for a minute or so.

Hill Climbing

Until you have become thoroughly familiar with the operation of the car, and have mastered the things necessary to make a good driver, do not attempt to climb "on high" every hill you see, just because your neighbor possibly has said that his car would do it. **There can be nothing more detrimental to the engine and driving parts than to try climbing everything on "high."**

The first and second-speed gears are placed in the car for a purpose, and if the hill that you are approaching is at all steep, shift into **"second"** a little before you are really on the hill. Do not try to go into "second," however, at any time unless the speed of your car has been reduced to the pace at which the second speed would carry you if it had already been changed. Many accidents, and serious ones, have resulted from a driver attempting to rush a hill "on high," getting half-way up, and having the speed of the engine so reduced that when he came to shift into low it was too late; the engine would not then accelerate sufficiently to carry the car up on low, and possibly the brakes were not working just as they should, the result being that the car would back down the hill faster and faster, until it finally landed in the ditch. Backing down hill with brakes is a task for a skillful and experienced driver, and even he cannot guarantee a good job. It is a most confusing situation and requires the instant exercise of good judgment.

The secret of successful hill climbing is to keep your engine running a little faster at all times than its work requires it to run, i.e., to keep it **"ahead" of its work,** so that it is ready for extra duty without stalling at the critical moment. The foregoing does not mean that many hills cannot be climbed "on high," but it is best not to try until you are sure of yourself and of your ability to get into **second,** or even **first** if necessary, half-way up the hill, and also to determine from the sound of the engine whether it is "working hard." If you must go into a lower gear on a hill, shift with a quick, firm movement, and take care not to let the momentum of your car be reduced any more than is absolutely necessary. Every second that you have the clutch disengaged on a hill for gear shifting, counts, as the car slows down at a very surprising rate.

If, on climbing a hill on "third," the engine has been stalled before reaching the top, it may require considerable skill to start from your standing position on the incline. Immediately upon finding yourself in such a predicament, apply the hand brake with all your strength, and **be sure that the brake ratchet catches;** then throw the gear-shifting lever into neutral. After starting the engine again, push out the clutch (leave the hand brake still on), push the gear lever into first speed, and slightly race the engine (the only condition under which it is permissible, excepting when in a mud hole or the like); then take hold of the hand brake and keep the engine speeded until the brake has been entirely released, the clutch entirely engaged, and a safe start has once more been made up the hill. Experience is the best possible teacher where there is a considerable amount of hill work to do.

Importance of the Clutch

The clutch of an automobile is a device by means of which the power of the engine and the driving mechanism may be connected or disconnected at the will of the driver. This particular part is probably used more than any other part of the car, and a careful study of its purpose and principle is advised. Though the device is simple and its use plain at first glance, the clutch, nevertheless, lends itself to a number of skillful uses in the hands of the experienced driver. **Remember always to "throw out" the clutch before changing gears.**

When the clutch is "let in," or engaged, this should at all times be done smoothly and so gradually that the motion of the engine shaft is transmitted to the drive shaft without jarring.

A suddenly let-in clutch will do one of two things: it will either rack the mechanism of the entire car, or stall the engine. With a little practice the left foot may be schooled to **let the clutch in quickly, yet gently and smoothly.**

When you meet a stretch of road covered with sharp, broken stones, it is an excellent plan to speed your car a little before you reach the stones and then disengage your clutch, permitting your car to coast over the bad spot. By shutting off the driving power you protect your tires against a very destructive action, termed the "traction," which otherwise would be set up between the sharp stones and the tires.

When reversing, remember to bring the rear wheels to a dead stop before letting the clutch in. Complete familiarity with the motions of going from one speed to another and back again should also be acquired before attempting to run on the open road.

Learn to drive by throttling the engine, instead of constantly throwing the clutch out. The average driver uses the clutch about twice as much as he should.

Instructions on Steering a Car

Steering is largely a matter of practice.

The positions to assume in steering or driving a car are shown in Fig. 8 (2), (3), (4), and (10). A very slight movement of the steering wheel or lever is sufficient to turn the car, and too sudden a turn may cause an upset.

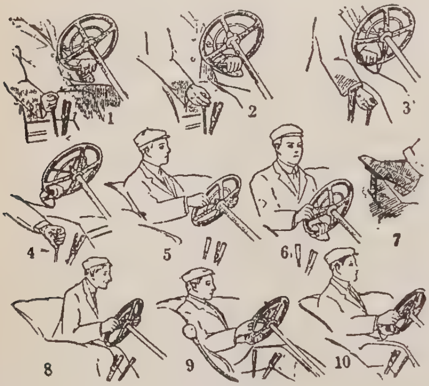

Fig. 8. **Correct and incorrect positions in driving:** (1) fierce grip, a bad method; (2) correct hold for forward movement; (3) finish of forward movement; (4) alternative grip suitable for many gears; (5) awkward hold of wheel; (6) proper and comfortable hold; (7) wrong foot position; (8) nervous, uncomfortable position; (9) careless, lounging position; (10) correct "seat." (*Popular Mechanics.*)

When learning to drive a car, it is a good plan to select a straight road, as wide as possible, and with the engine running slowly, throw in the low speed. The car will move forward slowly, and it will then be necessary to steer. The first inclination will be to grip the wheel as tightly as possible, but after a little running a light grip will be found sufficient. At this stage it is necessary to learn **self-control** first, and not to get "rattled."

If the car begins to run off the road, or into an obstruction, throw out the clutch and apply the foot brake, so that it comes to a standstill. When the excitement has died down, try again, and it will not be long before steering comes easily.

There is no time lost between the turning of the steering wheel and the turning of the car; **when taking a corner do not move the wheel until the car is at the point where turning is necessary.**

How to Use the Brakes

When the brakes are suddenly applied with full force to the wheels of a car speeding along at the rate of, say, thirty miles an hour, the braking action will be so powerful as immediately to stop the rotation of the driving wheels—but the car will not come to an immediate standstill; its momentum will send it forward, and the locked rear wheels will slide over the ground with **most destructive effect on the tires.**

When you consider that in railroad practice the so-called "flat wheel" is produced by too sudden braking, you will be able to appreciate the effect which a similar practice must have on the soft rubber tires of an automobile.

Bear in mind, therefore, that the best method of using the brakes is that which applies pressure on them so gradually that the forward movement of the car and the rotation of the wheels **come to a stop together.**

Nothing is more severe on a car than the spectacular stopping often indulged in by ignorant drivers, in an effort to "show off."

The careful driver shuts his power off before he reaches the stopping point and permits the car to carry him along on its momentum, bringing it, with a gradual application of the brakes, to a halt at the exact spot.

In order to slow down gradually, as when approaching a crossing, close the throttle and apply the foot brake without disengaging the clutch. It is more economical to wear out the brakes than to wear out the clutch. It is of course necessary to disengage the clutch when making a complete stop.

Whenever it becomes necessary to slow down quickly, release the clutch first; that alone will have an immediate slowing-down effect on the movement of the car, because it disconnects the power. If additional checking is needed, apply the foot brake, or, for a quick stop, the foot and hand brakes together. To make it plain, **the clutch pedal goes down first, the brake pedal next.**

If a full stop is not desired, assuming that the emergency has passed, release the brake pedal first, then let the clutch pedal come up. If you did the reverse, the engine would be compelled to pull against the brake, with a consequent rapid wearing down of the brake lining. (See also "Brake adjustments," under the discussion of the repair subject.)

No motorist is qualified to give his car the best care until he has mastered the control of the gears and of the brakes.

Slipping brakes are usually caused by oil working out the rear axle on to the brake lining.

If a grade is long and steep, use the foot and hand brakes alternately. This equalizes the wear on them, and also gives them a chance to cool.

If the Brakes Fail

If the engine stops while descending a hill, the brakes should be thrown on at once to keep the car under control. If poor adjustment of the brakes renders them insufficient for this, then place the gears in low speed. This will tend to check the car. It is then a matter of steering the car to the best advantage.

If, when ascending a hill, the engine stops and the brakes fail, try putting the gears in reverse. This will then turn the engine in the right direction, and ought to start it. It may be possible to steer it—owing to its extremely slow speed—off the road into a bank or other obstruction that will stop the car without much damage to it or to its occupants.

Situations such as this require a cool head and a steady hand, and the more experience in operating that the driver has, the greater are the chances for handling it in the right way.

Stopping a car on an up-grade and starting again requires skill, for the brakes must be withdrawn and the clutch let in at the same instant with one movement.

On a long descent, when you find it necessary to use the brakes constantly, apply the hand and foot brakes alternately, to avoid burning out the brake linings.

On extremely steep hills, when descending, the maximum of resistance and the best control may be obtained by shifting into first gear, switching off the ignition, and applying the brakes at intervals. Just before reaching the bottom of the hill, with the car still moving at a fair pace, close the ignition switch and the engine will start firing again.

Note. There is a disadvantage in opening the ignition circuit. When it is closed at the bottom of a hill, the gas drawn in may have accumulated in the exhaust pipe and muffler. Cases have been known where this gas was ignited and disrupted the muffler. When throwing on the ignition, don't open the throttle too wide.

When the Car Skids

Although the driver feels helpless at first, a little experience will soon give him confidence. Most skids can be corrected by the manipulation of the steering and brakes. An expert driver can keep his car straight under almost any conditions, but it is impossible to explain just how he does it. Usually the rear end skids first, and in the right-hand direction, this being caused by the crown of the road. Under such conditions, the skidding action will be aggravated if the brakes are applied, and the car may be ditched or continue to skid until it hits the curb.

In an emergency of this kind the correct action is to let up on the accelerator pedal to shut off the power, but not entirely so, or it will have the same effect as putting on the brake. If the car seems to right itself, the power may be applied gradually, and it will be advisable to steer for the center of the road again. However, if the car continues to skid sideways, steer for the center of the road, applying the power gently. This will aggravate the skid for the moment, but will leave you with the front wheels in the center of the road and the car pointing at an angle. By so doing, you can mount to the crown of the road again, and the momentum of the car will take the rear wheels out of the ditch on the right-hand side. It is customary to advise turning the front wheels in the direction in which the car is skidding, in order to correct the action, but this can hardly be said to be true in all cases. It holds good where there is unlimited side room, but usually the car hits the curb, or is in the ditch, before you can straighten it out with the steering wheel.

INSTRUMENTS, CONTROL LEVERS, PEDALS, AND GEAR SHIFTS OF SOME OF THE LEADING CARS

The following illustrations show the hand levers, foot pedals, dash or cowl with instruments, and also the gear-shift movements of some of the leading cars.

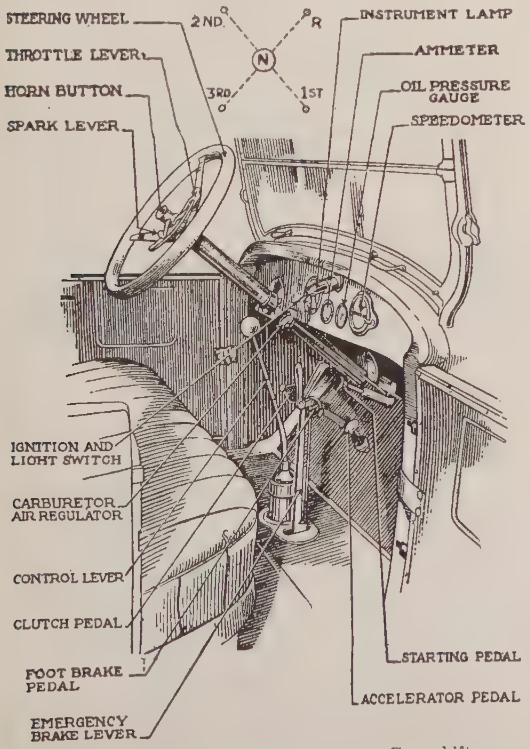

Fig. 9. **Buick, 1921, six-cylinder car.** Gear-shift movement is shown at top of illustration. Firing order of engine is 1, 4, 2, 6, 3, 5.

The purpose of these illustrations is to familiarize the reader with the gear-shift movements and the location and purpose of the control members.

Most cars now use the "ball-and socket type of gear-shift" lever.

The "gear-shift movement," or the direction in which to move the gear-shift lever to obtain various speeds, is shown in each illustration.

Most of the **gear shift movements** are, what is termed the S. A. E. standard gear-shift movement as illustrated in Fig. 19, page 29. Some are different.

The make of electric system used on these cars, as well as on other makes of cars, can be found by referring to the Index for "Specifications of leading cars."

The make of carburetor, steering device, rear axle, engine, etc., can also be found in these specifications.

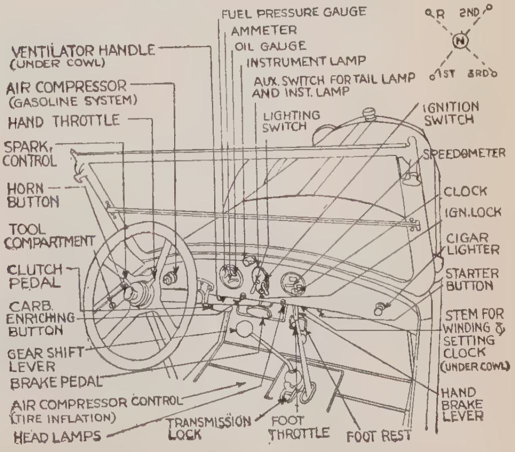

Fig. 10. **Cadillac type "61."** Note the **short spark and throttle levers,** and also that the fuel pressure gauge, the ammeter, and the oil gauge are in one unit on the cowl.

Gear-shift movements shown above. The firing order of the engine is shown on page 84.

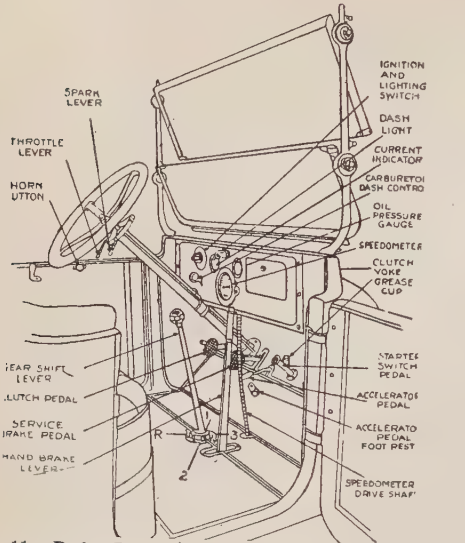

Fig. 11. **Dodge Bros.** Gear-shift movement is shown on floor board. Firing order, 1, 3, 4, 2.

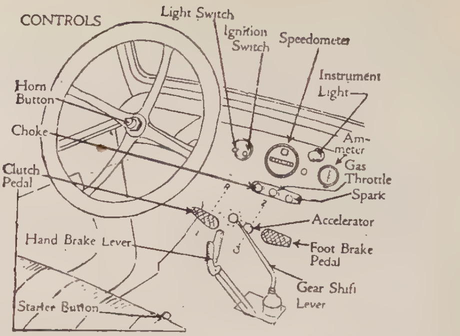

Fig. 14. **Overland "4."** Note that the spark and throttle control is on the cowl board. Firing order, 1, 3, 4, 2. Gear-shift movement is shown.

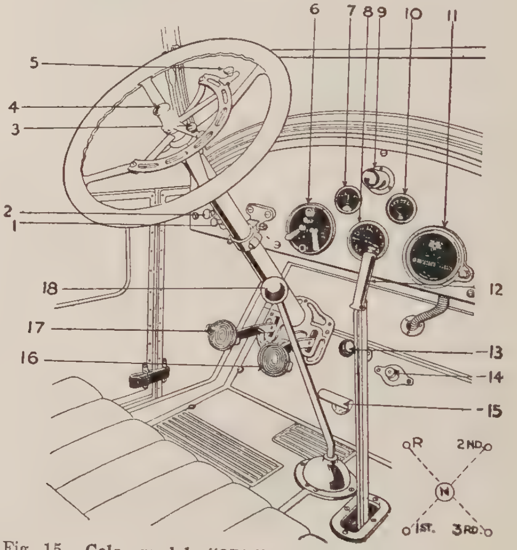

Fig. 15. **Cole model "870."** Gear-shift movement is shown. Firing order is 1-8, 3-6, 4-5, 2-7. Parts: 1, carburetor choke button; 2, carburetor adjusting button; 3, spark lever; 4, horn button; 5, throttle; 6, ignition switch; 7, ammeter; 8, clock; 9, cowl light; 10, oil gauge; 11, speedometer and odometer; 12, hand-brake lever; 13, accelerator; 14, starting-motor switch; 15, accelerator heel rest; 16, foot-brake pedal; 17, clutch pedal; 18, gear-shift lever.

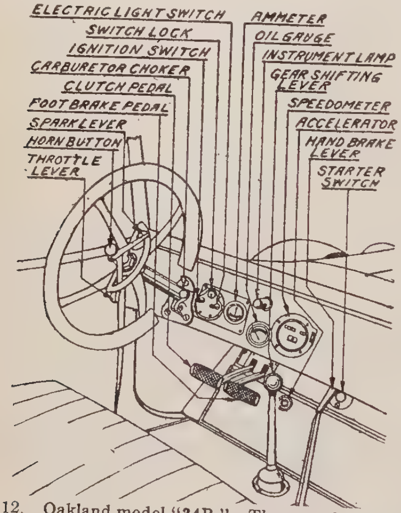

Fig. 12. **Oakland model "34B."** The gear-shift movement is standard S. A. E. three-speed, as shown in Figs. 14 and 15. Firing order, 1, 5, 3, 6, 2, 4.

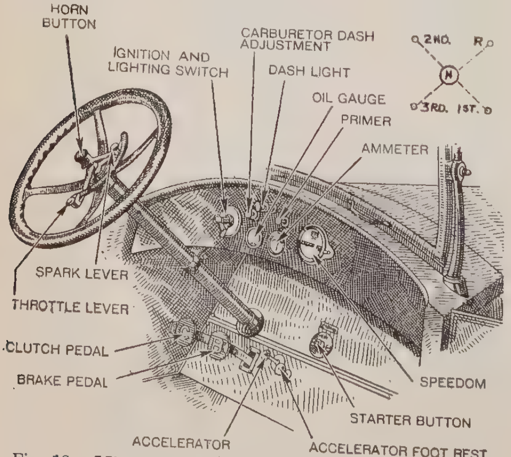

Fig. 13. **Mitchell model "F."** Gear-shift movement is shown at top. Firing order is 1, 5, 3, 6, 2, 4.

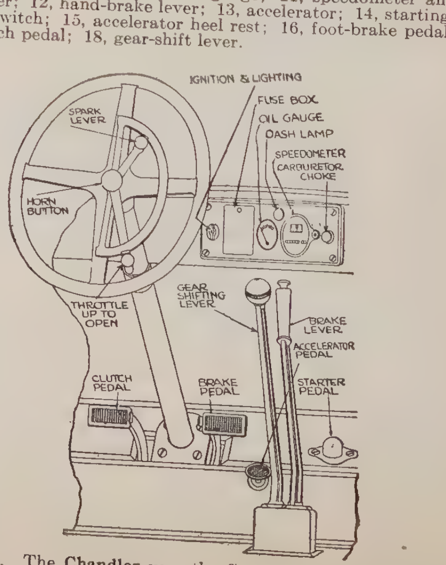

Fig. 16. The **Chandler** uses the S. A. E. standard three-speed gear shift (see pages 27. 29).

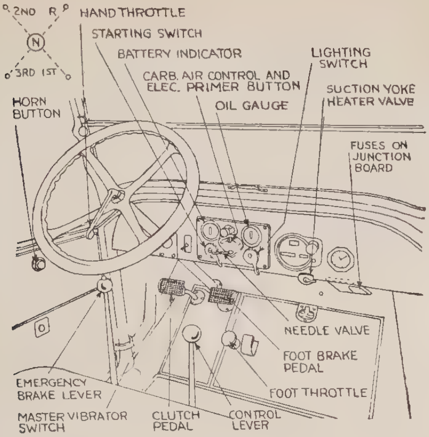

Fig. 17. **Franklin series "9-B."** Gear-shift movement is shown. Firing order is 1, 4, 2, 6, 3, 5.

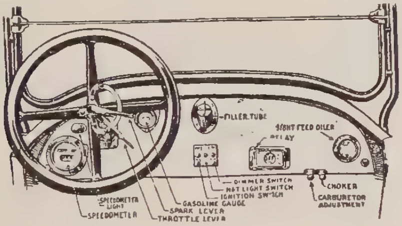

Fig. 18. Briscoe.

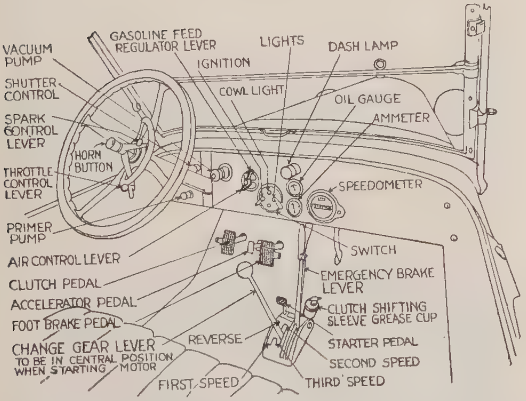

Fig. 19. **Hudson model "O."** To start the Hudson engine: Place the spark lever near the top; open the throttle slightly; place the gasoline feed-regulator lever a little to left of center position; when the engine is cold unlock the primer pump by turning knob until it releases. Give the plunger two slow strokes. Lock again by turning the knob until the pin lines up with the slot. Then press in and give a quarter-turn. Notice that the primer must always be locked when driving; turn on the ignition switch; press the starting pedal and release it when the engine starts.

If the engine does not start immediately, turn the air control lever, or choke to the right for a few revolutions, and then let it go back again. Firing order, 1, 5, 3, 6, 2, 4.

Ammeter: Shows whether the storage battery is discharging or being charged by the generator. It should always show charge when the car is traveling over 10 m.p.h. with the lights out. See page 397 for wiring diagram.

Oil-pressure gauge: Simply an indication as to whether the oil pump is delivering oil or not. It should always show pressure when the engine is running. It does NOT register the quantity of oil being delivered to the motor. That is governed by an adjustment of the pump itself. See page 163.

Carburetor control: The upper lever adjusts the amount of fuel allowed to enter the motor. The lower one is a choke to facilitate starting in cold weather or when the motor has been idle for some time. See pages 136, 137 for Hudson carburetor.

Vacuum pump: Used for filling the vacuum tank (see (14), Fig. 1, page 113) when it has become emptied. Ordinarily the motor supplies the vacuum necessary to deliver the fuel.

Spark lever: Controls the distributor and spark timing. The distributor is controlled by an automatic adjusting mechanism, but to obtain all-around efficiency, the spark must also be controlled manually to a certain extent. If the engine shows a tendency to knock on a heavy pull, gradually retard the spark until the knock ceases. It is a good rule always to carry the spark advanced as far as possible without the engine exhibiting any tendency to knock. See page 397 for electrical wiring diagram.

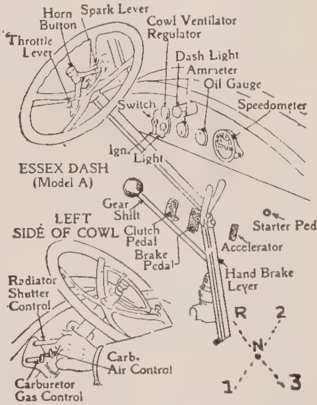

Fig. 20. **Essex model "A."** Firing order, 1, 3, 4, 2.

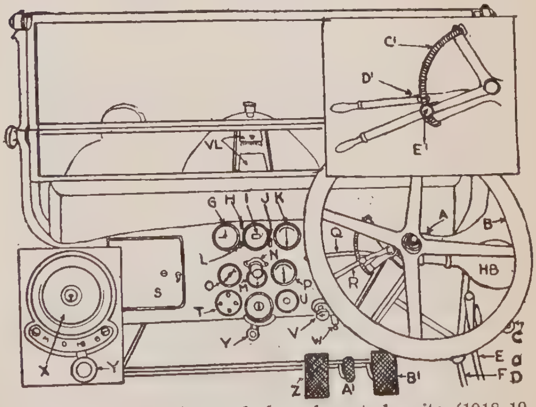

Fig. 21. **Pierce-Arrow dash and control units** (1918–19 model): (A) gasoline regulator on column; (A1) accelerator pedal; (B) steering wheel; (B1) brake pedal; (C) dimmer button; (D) Klaxon horn button; (E) hand-brake lever; (F) gear-shifting lever (see page 27); (G) clock; (H) handle to operate ventilator (VL) on hood; (I) autometer or odometer; (J) knob for setting tenths of a mile; (K) speedometer; (L) knob for setting odometer trip figure back to zero; (M) gasoline gauge; (N) dash lamp; (O) oil gauge; (P) ammeter; (Q) spark lever (see top illustration); (R) throttle lever; (S) left-hand dash cabinet door; (T) lighting switch; (U) starting button; (V) hand-pressure pump handle (arrow pointing to the right for "off" position; arrow pointing to the left for "vent" position); (W) plunger for priming; (X) starting switch (lock above); (Y) starting-switch handle; (Z) clutch pedal.

On some of the Pierce-Arrow models of cars as shown above, the switches (X) and (Y) are two lever switches: ignition and lights, with starting button (U) mounted above the two levers and a Klaxon horn button in the top of the steering column. Note that on this model and on prior models of the Pierce-Arrow car, the throttle and spark levers are placed under the steering wheel. See page 27 for the four-speed gear shift of this model.

Pierce-Arrow 38 and 48 h.p. cars each have four speeds forward, and one reverse; direct on fourth. **The rear-axle gear ratio** on the 38 h.p. is 3.78 to 1, and 3.53 to 1 on the 48 h.p.

		38 h.p.	48 h.p.
1st speed	(trans ratio)	3.88 to 1	4.1 to 1
2d speed	(trans ratio)	2.22 to 1	2.15 to 1
3d speed	(trans ratio)	1.65 to 1	1.65 to 1
4th speed	(trans ratio)	direct	direct
Reverse	(trans ratio)	4.66 to 1	4.93 to 1

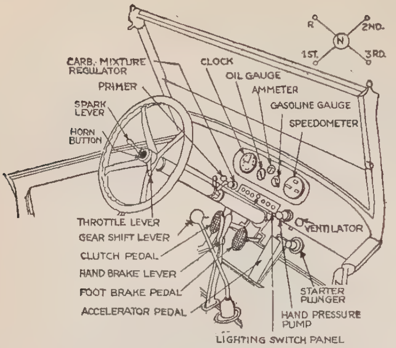

Fig. 22. **Pierce-Arrow "series 32," 1921.** Note the short spark and the throttle levers on the steering wheel. See Index for the rear-axle ratio of Pierce-Arrow "series 32" car. Three forward speeds and one reverse are used on this car. Radiator capacity is 7½ gallons; gasoline tank, 26 gallons; engine oil in crank case, 18 pints. **To start the Pierce-Arrow engine:**

1. Be sure the gear-shift lever is in neutral.
2. Insert the switch key and turn one complete turn to the left. Pull out the ignition button stamped "Double."
3. Advance the throttle (right) lever 1½″.
4. Advance the spark lever about halfway on the quadrant for starting and about two-thirds when driving under normal conditions or up to 50 m.p.h.
5. Prime the engine by pulling out for an instant on the priming button.
6. Press firmly on the starting plunger and release as soon as the engine starts under its own power.
7. Close the throttle until the engine runs slowly.
8. If necessary, move the dash carburetor regulator until the engine runs evenly without missing, by turning to the left.
9. Allow the engine to run a few minutes until it warms up. It will run a great deal smoother and pull better when it starts to move the car.
10. When the engine is thoroughly warmed up, turn the dash carburetor regulator back to normal (center) position. Firing order, 1, 5, 3, 6, 2, 4.

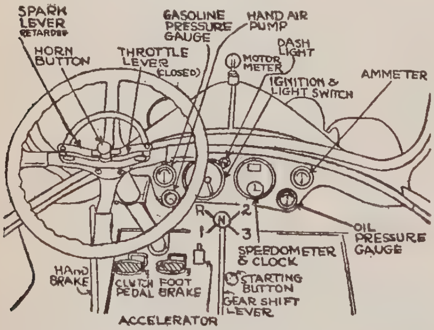

Fig. 23. **Packard Twin-Six,** models "3-25" and "3-35", instrument board and controls and gear changes.

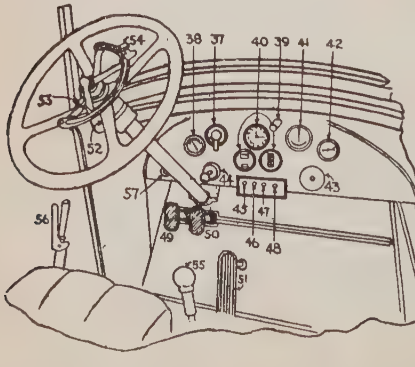

Fig. 24. The **Locomobile** instruments and control members: (37) ignition switch; (38) gasoline pressure gauge; (39) dash light; (40) speedometer and clock; (41) voltmeter; (42) oil gauge; (43) locking switch; (44) hand-pressure pump; (45) starting button; (46) panel-light button; (47) side and tail-light button; (48) head, tail-light button; (49) clutch pedal; (50) brake pedal; (51) accelerator pedal; (52) carburetor adjustment; (53) throttle lever; (54) spark advance lever; (55) gear-shift lever; (56) hand-brake lever; (57) dimming button.

Locomobile 48, series seven, rear-axle ratio is 3.85 to 1. Transmission gear ratio is as follows:

1st speed	15.40 to 1
2d speed	7.39 to 1
3d speed	5.38 to 1
4th speed (direct)	3.85 to 1
Reverse	21.75 to 1

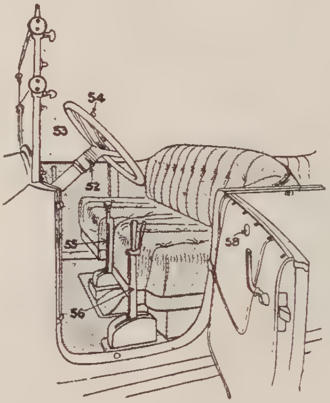

Fig. 25

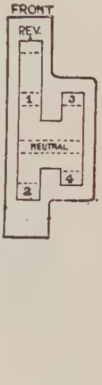

Fig. 26

Fig. 25. **Locomobile** operating levers.

Fig. 26 shows the **four-speed "gate" type of selector,** giving the movements of the lever for 1st, 2d, 3d, 4th, and reverse. See Fig. 17, page 100, for the Locomobile **steering device.** See page 70 for Locomobile **valve timing.** Firing order, 1, 5, 3, 6, 2, 4.

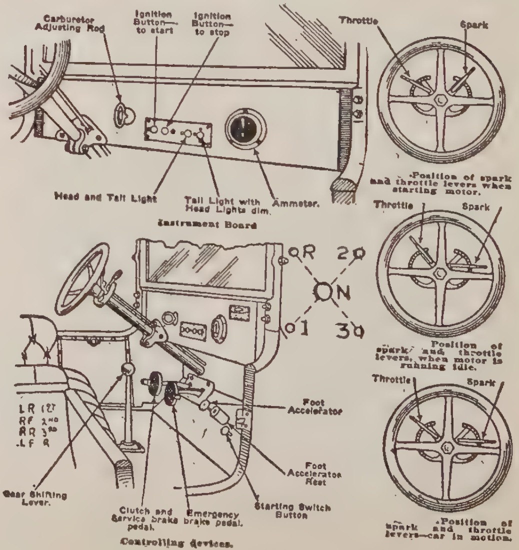

Fig. 27. **Chevrolet "490."** Firing order, 1, 2, 4, 3. The gear shift is shown.

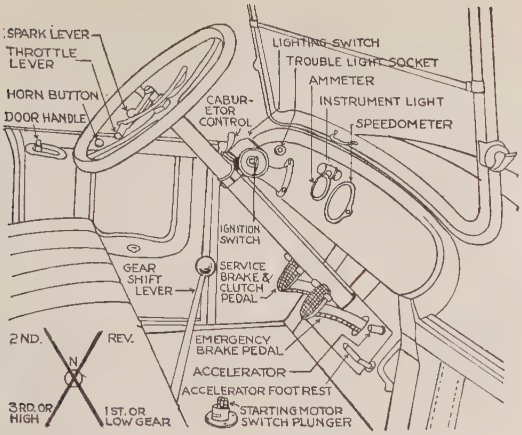

Fig. 28. **Reo models "T6" and "U6."** Note that the combination switch for the ignition, lighting, and carburetor control is mounted under the steering wheel. The carburetor control, when moved towards "Start," enriches the mixture by lifting the nozzle needle of the carburetor. The model "LL3P" Rayfield carburetor is used.

The North East model "L," third-brush regulated generator is used, as also the North East ignition unit. Spark-plug gaps are set at .030″, and the firing order is 1, 4, 2, 6, 3, 5.

The clutch pedal operates the external brakes on the brake drum on the rear wheels, and the emergency (foot brake) pedal (right) operates the internal brakes in the brake drums on the rear wheels.

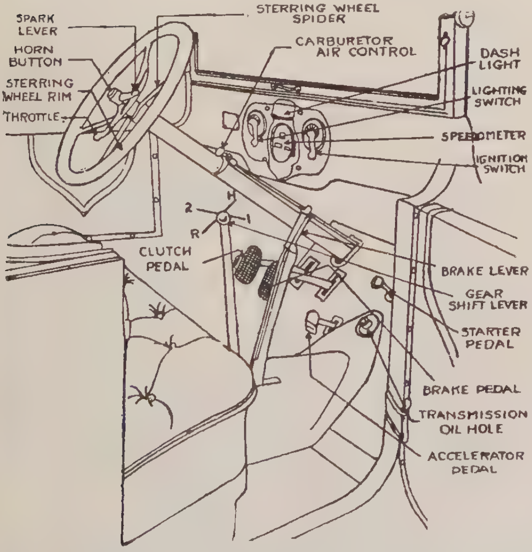

Fig. 29. Hupmobile instrument board and gear shift. Firing order, 1, 2, 4, 3.

As an example of the information concerning a car, which can be obtained from the "Specifications of Leading Cars" (see Index), the data (below) concerning the Hupmobile are taken from same as follows:

Model, R; **wheelbase,** 112″; **engine make,** own; **cylinders,** 4; **bore,** 3¼″; **stroke,** 5½″; **piston displacement,** 182.5; **cylinder shape,** L; **cylinder head,** detachable; **cylinder cast,** in block; **cam-shaft drive,** chain; **cooling,** thermo-syphon; **lubrication,** force through hollow crank shaft; **oil pump,** gear; **carburetor make,** Stromberg; **ignition,** Atwater Kent; **electrical system,** Westinghouse; **rear axle,** own; **rear axle type,** three-quarter floating; **steering-gear make,** Jacox; **hand brake,** internal on rear wheel; **foot brake,** external on rear wheel; **rear-axle bearings,** roller; **front-wheel bearings,** roller.

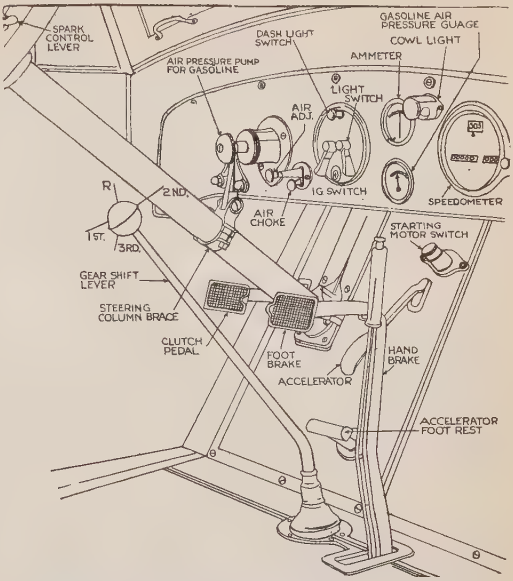

Fig. 30. **H. C. S. series 2 and 3 instrument board and gear shift.** The spark-control lever is the one on the outside of the sector of the steering wheel. Firing order is 1, 3, 4, 2.

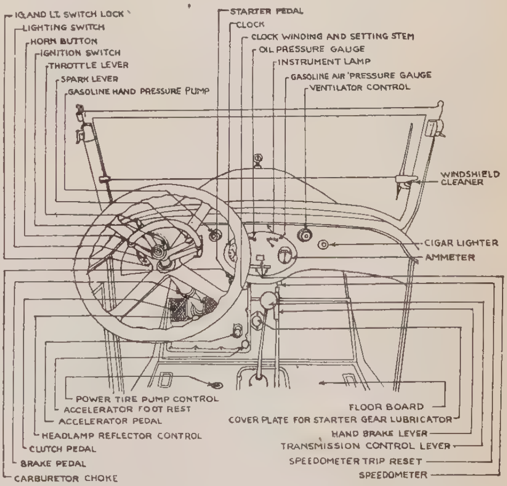

Fig. 31. **Lafayette instrument board and control members.** Gear shifts are as follows: for 1st gear, lever is moved to the left and to the rear; for 2d gear, right side forward; for 3d or high gear, right side, rear; for reverse gear, left side, forward.

The number of teeth in the differential ring gear and the drive pinion is represented by either of the following combinations which would give a **rear-axle ratio** as below:

54—11—4.9 to 1
55—12—4.58 to 1
54—13—4.15 to 1

Note that the 54 is the number of teeth in the master or differential ring gear, and that 11 is the number of teeth in the drive pinion. **To find the rear-axle ratio,** divide 54÷11=4.9. Therefore the drive pinion or propeller shaft would revolve 4.9 times to 1 of the rear wheels or axle shafts.

Engine: Bore, 3¼″; stroke, 5¼″; S.A.E. h.p. rating, 33.8; actual h.p. developed, in excess of 100; valve lift, ⅜″; valve diameter, 1¾″; valve-stem diameter, 5/16″; valve-seat angle, 45°; carburetor, 2″; piston displacement, 348 cubic inches; angle between cylinders, 90°; firing order, 4, 2, 6, 8; 1, 7, 3, 5.

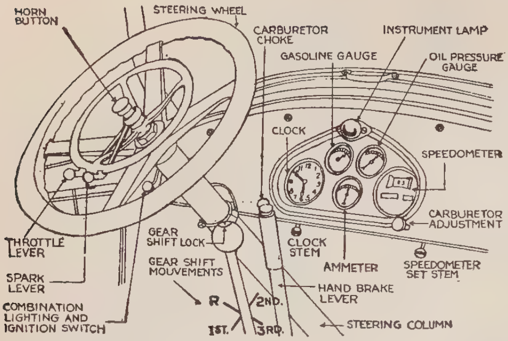

Fig. 32. **Marmon 1922 instruments and controls.** The controls and instruments will be found grouped conveniently about the driver's seat, as shown in the illustration. The clock, speedometer, ammeter, and gasoline and oil pressure gauges are centrally located in the **instrument board, being attached to a die-cast frame which is covered with one piece of glass.** The instruments have no individual glass over their respective dials.

The speedometer trip mileage can readily be set at zero with the adjusting pin. The season mileage can be changed only by returning the instrument to the manufacturer.

The combination switch, on the instrument board just to the left of the steering column, controls the lighting and ignition circuits. The ignition lever has two positions, the "ON" and the "OFF." The lighting lever has three positions. Firing order, 1, 5, 3, 6, 2, 4.

The location of control members not shown in the illustration: The clutch pedal is the left foot pedal; the foot-brake pedal is the right foot pedal; the accelerator pedal is between the two pedals; the starter-switch pedal is just above the toe board.

The **gear-shift movement** is the standard S. A. E. three speed, as shown in the illustration.

The **rear axle** is shown on page 16. The **steering device** and its adjustments are explained under "Adjustment of steering devices" (see Index).

The **engine** is a six-cylinder engine with overhead valves, the principle of which is shown in Fig. 92, page 53. Note in this illustration that the valve push rods are shown on each side of the cylinder, in order to explain the action of both valves in the head, whereas, all of the push rods are on one side of the cylinders.

The **pistons** used in this engine are of a different design from other pistons; see Index under "Marmon pistons."

The **bore and stroke of the engine** are 6¾″x5⅛″, and the piston displacement is 339.7.

POINTERS ON SELECTING A NEW CAR

Power: This is determined by the number of passengers to be carried and the condition of the roads. If the country is a flat district, a low-powered car will do efficiently and infinitely more economically what in a hilly country would necessitate perhaps nearly twice the power to do the work on high gear. For hilly country a car with a low reduction to the rear axle should be selected in order that the engine may take the hills on high gear.

Body: This is not much a matter of choice nowadays, as the cars are all built in large quantities and to a standard type. Putting aside for the moment the case of those who, from consideration of price alone, would confine themselves to a car of power and size suited for a two-seated body only, it is best to have a "touring car" body of 5-passenger type. Though the back seats may be used only once in a while, they are nevertheless too often wanted if not there, and the advantages of being able to give friends a lift and of having plenty of room for luggage and parcels are well worth the slight difference.

Enclosed bodies: The touring-car body is equipped with a very serviceable top, and, in combination with a glass front or wind shield and suitable side curtains, this type of body can be converted into a fairly weatherproof vehicle.

The coupe and cabriolet body (page 5) is a very popular type for business purposes, as it protects one from the dust and weather, and is a very comfortable type of body for winter use.

The sedan type of body is a very popular type for family use, and can be fully enclosed for winter and opened for summer use. This type of body is adapted for those who drive their own car. A suggestion to those who are considering a closed car, yet really prefer an open car, is to purchase an open car and fit the rear with a tonneau wind shield as described on page 649. The difference in cost of an open car and a closed car is quite a sum, and the low cost of the tonneau wind shield will save quite a sum of money, and yet will give the open car a nifty appearance as well as being comfortable. A closed car requires more power and gasoline, and there is usually a greater depreciation in its value. A closed car is generally geared lower than an open car, thus relieving the strain on the engine.

The limousine is a more elaborate type of body and is used where a chauffeur is employed, as the driver's seat is separate from the other seats.

The price with many fixes itself; that is to say, their means enable them to decide in a very short time how far they can go. In any event, to arrive at a maximum figure one must include in the calculation a sum not less than, say, $75.00 to $100.00 for a small car, and so on in proportion to the size, in addition to the purchase price, in acquiring those accessories, spare tires, and tubes, which are necessary.

Service: When purchasing a car don't forget that in time you will need parts and your car will require expert attention. Investigate this feature and find out if the agent carries parts in stock and if he gives his other customers satisfactory service and if he is reasonable in price.

Constant attention is necessary: Whether you intend to employ a chauffeur or to look after the car yourself is a point to consider. There is a limit to the size of car which the owner can (if the car is kept in pretty constant use) attend to himself, unless he be a man of great leisure, and moreover keen enough to put up with the drudgery involved. It is useless to conceal the fact that a car will require constant attention, and while a man may find the time to do justice to a moderate-sized car, a large car might be too much for him.

Cost of running—or up-keep: Here lies the crux of the whole matter. Closely allied with the important question of original outlay is that of the running cost, which must be taken into consideration to a certain extent, when buying. The size of the bill for up-keep bears, of course, a direct proportion to the mileage run. As regards the fuel consumption, this item will not be a large one in any car up to, say, 25 h.p., unless there is some radical defect in the system, or a temporary want of adjustment. In large and heavy cars the gasoline bill quickly mounts up.

Tires are the largest item in the cost of up-keep, and this charge becomes heavier as the speed increases and is again directly proportionate to the mileage run.

There are two kinds of pneumatic tires in general use: the "fabric" tire and the "cord" tire. The "cord" type is the best. The initial cost may be greater, but there is a saving in the long run.

The non-skid tire should be selected for rear wheels. This extra cost is well worth the difference, as the extra wear from the extra amount of rubber, to say nothing of the non-skid feature, is worth a great deal.

Small, light tires spell constant trouble, not to mention short life. Be sure the car is equipped with tires of **ample size** to sustain the weight and speed; also **determine if the size of tire is a standard size,** and if it can be obtained readily. Many of the former sizes have been discontinued (see page 594 for standard sizes).

Also determine if the **rim** is a popular type. The "straight-side," quick-detachable, demountable rim is the rim now used most. One should always carry a tire inflated on a spare rim to replace a damaged tire. It can be mounted on the rim of the wheel by loosening a few bolts and without having to use an air pump at all. There is also an advantage in having the tires the same size on all four wheels.

Which is the best car to buy? This is a question we hear daily. After determining the size of car you want, I will tell you how I would settle the choice, if I were unable to decide otherwise. Go to a used car concern and ascertain which car brings the best price or what make of car sells more readily than others. This may help to answer this question.

Selecting a Commercial Car

There is a distinction between a truck and a delivery wagon. Some of the important points to be decided are:

What type of car is required for your particular needs—gas or electric?

What horsepower?

How many pounds capacity shall it have?

Should several cars be used, or one big one?

Will the use of trailers result in economy?

Shall it be equipped with pneumatic or solid tires?

Can an inexperienced man be given charge of the running and repair work?

Is there any special equipment necessary for greater efficiency?

Should the car always be loaded to capacity?

Should the truck have a long or short wheel base?

Today there are motor trucks and delivery wagons of every conceivable size and design. Therefore, it is the problem of the prospective purchaser to choose carefully the kind of a car best fitted to serve his purpose with the greatest efficiency. It is a very common sight to see a heavy type of delivery wagon make a trip of several blocks and sometimes miles to deliver one or two small packages or baskets of groceries, when one of the smaller types of commercial cars could have done it just as well and with greater efficiency, reducing materially the overhead cost. On the other hand, we have often seen a light delivery or a very heavy type of truck making a trip with an overload. This is just as impractical as an underload, for it will ruin the expensive motor equipment, making the car depreciation very considerable.

A very good rule to stick to closely is to have the car filled nearly to capacity on every trip that is made. A motor truck or delivery wagon should not be chosen with either a maximum or minimum load in mind, but an average load. To get the greatest efficiency out of a commercial vehicle, keep it loaded and moving the largest possible number of hours during the working day.

The manufacturers of large trucks (1½ ton and above) usually sell the chassis only; the body is usually built by some local concern specializing in this work, and is designed to meet the individual requirements of the user. The design of a suitable body is a very important factor; a reliable truck dealer can materially aid the purchaser in making the correct selection.

If electricity is produced in your own plant at a very low cost, and it is possible to secure a man who understands and can care for storage batteries, then it may pay to investigate the electric vehicle.

JUDGING AND TESTING A SECOND-HAND CAR

In order that the purchase of a second-hand car may be attended with some degree of safety, as to its condition, the following tests should be given. It will no doubt be impossible for the purchaser to make all of these tests, but what follows will give a general idea of what should be done to testing or overhauling any car.

General Condition

Ascertain the age, make, and type, and also the horsepower of the engine (see Index under "Horsepower"). If the car is an obsolete model or of antiquated design, it will be a difficult matter to dispose of it later on at any price. Find out if the manufacturer is still in business, in order to know whether parts can be obtained if required. **Do not judge a car by its outside appearance alone.** Paint is ordinarily cheap.

Tires and Rims

Many sizes of tires on some of the older cars have been discontinued (see page 594 for sizes now being made). You may have difficulty in obtaining tires.

Also learn the make of rim. The old-style "one-piece clincher" rim is obsolete, except on the Ford, Chevrolet, Maxwell, and the Overland model "Four." **The modern rim** is the "straight-side," demountable type.

The best tire is the "cord" tire (see page 609). The "fabric" tire is explained on page 608. Examine the condition of the tires after reading page 610, and test for "stone-bruises."

Engine

1. **Test the compression of each cylinder** (see Index under "Testing compression"). Firs learn what compression means (see Index). The compression test will indicate the condition of the rings and cylinder walls and valves. **If the cylinder walls are scored or cut,** then this is an expensive job to repair (see Index under "Cylinders scored"). **If the valves leak,** then this is not so expensive (see Index under "Grinding valves"). **If the rings leak,** this is an item worth noticing (see Index under "Piston rings").

   If there is considerable smoke from the exhaust pipe when running the engine (see page 168), and the smoke is blue or light in color, there is too much oil in the crank case of the engine, or the pistons are pumping oil as explained on page 168, or the rings are loose, or the cylinder walls are scored. If smoke is heavy and black, the carburetor is feeding too much gasoline and should be adjusted. Many new engines have had the cylinders scored by running the engine at too high a speed during the first 1,000 miles and from lack of oil.

2. **Test the bearings.** The best method for doing this is to make a long run, taking at least one or two fairly steep hills, and noting if the engine knocks. By studying the subject (knocks), you can learn to distinguish the cause of different kinds of knocks (see Index under "Knocks").

   When testing for knocks, make allowances if the engine is a four-cylinder, especially of small size, and when taking hills slowly. Many four-cylinder engines must get the engine up to a fairly good speed to take a steep hill, as the power depends upon the momentum of the fly wheel, whereas the six, eight, or twelve-cylinder engine should take a hill with less speed, without pounding or knocking, if the spark is retarded properly.

3. **Test the cooling system.** After making the run suggested above, note if steam comes from the radiator at the vent or overflow tube or filler cap. If so, the engine runs hot, and the trouble is attributable to one of the causes explained on page 152 under "Engine overheats." Understand that an engine runs best at about 170° temperature, but should not steam. Also observe if there are leaks. Usually the leaks are at the hose connections and can be tightened, but if the hose is worn, replace it.

The Clutch

1. **See if the clutch slips** when taking a hill.
2. **See if the clutch drags when released.**
3. **See if the clutch "grabs" or is "fierce"** (see Index under "Clutch grabs").
4. **Ascertain the type of clutch used** in the car by referring to the Index for "Specifications of leading cars." Then turn to Index under the appropriate titles, and note the construction and troubles and remedies.

Transmission

1. **Test the gear shift while the engine is running,** by shifting from reverse, 1st, 2d, 3d speed, to see if the gears can be changed without a clashing noise. If not, then the trouble may be due to the clutch pedal not being thrown far enough "out," or the clutch "drags" or "spins," or the transmission or clutch shaft are out of alignment, owing to worn bearings, or the teeth of the gears are burred.
2. **Test for worn or broken gear teeth:** With the engine running slowly, place the gears in 1st speed; place the finger on the gear lever—if there is a worn place at one point or all round the gear, it can be felt by the vibration. Try this on all speeds and on reverse.
3. **If the transmission is noisy,** and there is plenty of oil in the transmission case, the trouble is probably due to a broken ball or roller bearing or a worn bearing.

If oil leaks out of the transmission bearings, see Index under "Transmission-oil leaks."

Drive Shaft and Universal Joint

1. **Test for looseness** (see Index under "End play in universal joint"): If this is excessive, the looseness is in either worn gears or bearings in the transmission, or there are loose universal joints or loose adjustment of the drive pinion to the differential driven gear (see Index under "Differential gear adjustments").

Rear Axle

1. **Test adjustment of drive pinion** (see Index under "Noisy rear axle"). On some cars, Ford for instance, there is no adjustment, therefore a new drive pinion must be fitted.
2. **Examine the differential by removing the cover,** if a "full-floating" type (see Index), or remove the axle housing, if a "semi" or "three-quarter floating" type (see Index), in order to ascertain if any of the nuts are loose or small differential pinions are worn.
3. **Test wheels for alignment** (see Index).
4. **Test for wobbly wheels** (see Index).
5. **See if axle shaft is bent**—usually at the hub, which would be indicated by the wheel wobbling.
6. **See if oil is working out of the rear hub** into the brake lining.
7. **Test brakes** (see Index).

Steering Device

1. **Test for play,** and for loose bolts and nuts (see Index under "Steering devices, testing of").

Miscellaneous Tests

1. **See if engine will idle** without missing.
2. **Test the battery:** if a coil and battery ignition system (see Index).
3. **Test the magneto:** if a magneto system of ignition, by idling and speeding up the engine to see if there is a missing of explosion.
4. **Examine the wiring** and see if it is oil soaked and ragged.
5. **Test the carburetor** by idling and speeding up the engine to see if explosions are even and if the engine picks up readily under load. Also note if the carburetor air intake and the carburetor mixture are heated.
6. **Examine the spark plugs,** to see that the gap distance is correct at the points (about .025"), and that the porcelains are not cracked.
7. **Run the car and test the mileage gained per gallon of gasoline.** This will require at least a 20 or 25-mile run. Many 6, 8, and 12-cylinder engines will not average over 9 to 14 miles per gallon—depending upon the condition of the rings, or whether there is leakage of gasoline into the crank case, as well as on the size of the cylinders and whether the roads are hilly or level.
8. **Examine all bolts and nuts** on the engine, springs, etc.
9. **See that the engine is properly oiled** and that all parts of the car are greased.
10. **If parts have been replaced,** such as the steering knuckles and spindles in the front wheels, etc., see that they are not made of castings instead of forgings.
11. **The storage battery** is another part which should be examined. Have it tested at a battery station. You can tell if the battery has been repaired by looking at the connectors. Figures are usually stamped at the factory at each end of the connector where they are burned to the post. If there is a bright spot with no figures, it indicates that the battery has been repaired since leaving the factory. The battery should be tested by testing each cell, as explained under "High-amperage tests" and "Cadmium tests of storage batteries."

INSTRUCTION No. 57

CARE OF CAR: Pointers on Driving; Washing, Polishing, and Cleaning Car; Home-Made and Other Polishes; Painting a Car at Home; Pointers on Shipping a Car

GENERAL POINTERS ON DRIVING THE CAR

The driver must keep his eyes and ears open, watching the other occupants of the road as well as the running of the car. See Index relative to "Traffic ordinances," "Rules of the road," etc.

The ear is the best judge of the running of the engine, as it shows any defect by a change in its steady throb. With practice, it becomes easy to recognize a new noise, and the cause should be located and remedied at once. A squeak or rattle that comes at regular intervals may be located in one of the revolving parts; if not regular, it comes from something that is not revolving—the springs, brakes, or a similar part.

Irregular running of the engine may not be serious, but rather the result of a rough road or loose ignition connections. **Knocks or pounds should be located at once,** for they may lead to a serious breakdown.

Know Your Car

Remember that in the care and operation of a motor car, **much must be left to the judgment of the operator,** who should study the construction of his car and thoroughly acquaint himself with its mechanism, the functions of its various parts, and the "why" of everything connected with it.

Learn the speed at which the car will take a turn on mud or wet asphalt, without skidding or side-slipping, and never exceed it. Learn the grade of a hill that the car will climb easily; on steeper grades do not wait for the engine to labor before changing the speed.

Learn the turn that the car will make for every position of the steering wheel, and always make the broadest turns that the width of the road will permit. A sharp turn is more likely to strain and injure the tires, running gear, and steering mechanism, than a broad turn, and, if the car is speeding, is more likely to cause an upset.

Learn the distance that the car will travel before it becomes necessary to refill the tanks—not from the catalogue, but from your own experience, so that a hold-up on the road for supplies may be prevented.

Learn the rapidity with which the car will pick up speed after a slow-down, as it will help when running through traffic, or when it is necessary to dodge another vehicle.

It is important to learn the shortest distance in which the car can be stopped for its different speeds, and the exact extent to which it slows down for each application of the brakes. Learn to use the brakes so that the motion becomes automatic, and can be done without wasting time thinking about it. Learn to judge distance, and the speeds at which the car travels; ability to estimate speeds may prevent arrest.

Learn to recognize the noises of the engine when it is running smoothly: the click of the valves, the hum of the timing, pump, and magneto gears, the puff of the exhaust, so that unusual noises may be easily recognized.

Learn the feel of the compression, by cranking the engine, so that leaks may be detected. Learn the effort required to push the car on a smooth floor by hand, or how freely it will coast down a hill, so that a binding brake or a tight bearing may be felt. In short, get in tune with your car—be part of it—make it part of you; that is, if you want to get good service from it, and save on the repair bills.

Important Points to Remember

The flashy driver, who makes quick turns and sudden stops, attracts attention, but ruins the car. The more smoothly a car is operated, the longer it will last, and the less often it will get out of order. Driving is not a thing to worry about, but to be taken easily.

Easy turns, gentle stops, the running of the engine as slowly as possible for the speed desired, proper adjustments, and constant care, mean long life to the car and freedom from trouble.

When the engine is not acting right, do not rush in and readjust the ignition or the carburetor without first being sure that the trouble has been correctly located. Throwing the carburetor out of adjustment on a guess makes it all the harder to get going again, for its readjustment must be added to the trouble already present. An automobile is not difficult to handle, but neither is it so simple that brain work is not necessary. Get all of the facts possible before doing anything to the mechanism—the noise that the engine made in stopping, the way it stopped, the reasons for the unnatural noises, and the bolts from which nuts may have dropped off. An automobile is constantly in a state of severe vibration, and almost any part is liable to work loose when least expected.

Some accessories are convenient, and others are nuisances. Do not load the dash up with devices that are not of practical use, for they only add to the parts that must be watched and taken care of. Provide the car with a good horn, and use it well when necessary, but never needlessly.

The lubrication is important and must be watched carefully; it takes only a little running without oil to cut the cylinder walls and piston rings. Excessive oil in the crank case means fouled spark points, and should never be permitted; however, it is better to have too much than not enough.

When running, keep to the right, and in meeting another vehicle turn farther to the right, so that it will have room to pass. In passing a vehicle going in the same direction, pass so that it is on your right, and do not swing back to the right side of the road too close in front of it. The other vehicle may speed up as you pass, and be closer than you realize.

Get thoroughly familiar with the different speeds so that there will always be time to stop when necessary. Keep your eye on the people alongside of the road, for they may start to cross without warning. Children are liable to run out of a gate or to cross the road when they are least expected. Cross-roads and cross-streets must be watched, for vehicles or people may come along them.

It is dangerous to run over a dog. It is far safer to slow down when one is barking in front of the car than to try to push it out of the way.

Blow the horn when approaching a turn in the road, for another car may be coming. Do not run on the low speeds if it is possible to run on the high.

Don'ts for Drivers

Don't drive a car until you are old enough to have good ordinary "horse" sense. Don't look around when your hat blows off. Don't try to kiss the lady in the seat beside you. Don't go to sleep while driving. Don't trust one hand to do the guiding. Don't try to make up lost time by speeding down hill. Don't run at night without lamps. Don't delay putting on the chains when the roads get greasy. Don't forget to "STOP, LOOK and LISTEN" before crossing a railway track—Safety First, Last, and All the Time.

Rattling Noise

A disagreeable rattle can often be traced to the hood where it rests on its seat. Strips of rawhide or other anti-friction material should be installed to prevent any squeaks or rattle.

Right Side of an Automobile

Q.: Which side of an automobile is referred to as the right side?

Ans.: The side to the right of the driver when seated in the car.

Why the Engine Runs Smoother at Night

Q.: I have always noticed that my engine runs smoother or better at night. Why is this?

Ans.: Experiments with stationary internal combustion engines have shown that water vapor—steam—injected into the combustion chamber gives an advantage, but the reason is not clear. On the same principle an engine runs better at night when there is more moisture in the air. It may be that the additional oxygen supplied by the small amount of water aids in the combustion of the fuel.

Meaning of 25-35; Engine Rating

Q.: What does 25-35 horsepower mean? I note many manufacturers rate their engines with two ratings.

Ans.: The "25" means the horsepower according to the Society of Automobile Engineers' formula at 1,000 r.p.m. The "35" means the actual block test the engine is capable of developing at full speed. It is taken for granted that the engine will develop 25 horsepower continuously, and will stand an overload of 35 horsepower for short periods. Most electric generators will stand a considerable overload for a short period but will heat if run overloaded continuously. The same applies to the automobile engine.

Save the Tires

If a tire blows out, do not jam on the brakes—cut off the power and let the car coast to a stop. Jamming on the brakes might cause a skid, and that would fatally ruin the tire.

In crossing loose or broken stone, as on a new road, do not drive the car over, but get up speed, and as the car strikes the stones throw out the clutch so that it will coast. If the car has not enough momentum to cross, let it go as far as possible before again throwing in the clutch. Driving across sharp stones forces the wheels to grind against them, while if the car moves without being driven, the tires roll over the stones, and are not so liable to injury.

Jamming on the brakes grinds the tires, and wears them as nothing else does. Letting in the clutch quickly, so that the wheels spin before taking hold of the road, has the same effect.

Tires that are not sufficiently inflated will rim cut, and are more liable to puncture than if blown up hard. Oil rots rubber; therefore, keep the tires clear from it. If they get oily, wipe them with a cloth soaked with gasoline.

If the car is to be idle for a week or more, jack up the wheels to take the weight from the tires—it will be better for them.

Rusty rims cause rim cuts; therefore keep them smooth. When the rims rust, scrape them or rub with emery cloth and give them a coat of shellac or lead paint to prevent them from rusting again.

In applying new tires, put them on the rear wheels, moving the half-worn, one to the front wheels. This will give them a longer life. In applying a single new tire, put it on the right-hand rear wheel, as this is the one that has the hardest work, and needs to be stronger than the others.

Skidding ordinarily occurs only on slippery surfaces and in rounding turns at high speed. In skidding, the wheels of the car slip on the ground, especially on wet asphalt, although the car will occasionally slide on dry surfaces, like loose gravel, etc. See Index for "Skidding."

A Few Words about Gasoline and Fire

Gasoline must be handled with care and common sense. It is dangerous if handled carelessly, but need not be so if the operator uses judgment. Gasoline vaporizes easily, and as the vapor is heavier than air, it sinks to the ground.

When filling the tank, be sure that there are no open lights near, or a fire. If the tank is to be filled at night, don't use a lamp; use a pocket electric flash lamp instead. Have a funnel for gasoline and do not use it for anything else. See Index under "Gasoline" and "Fire, how to extinguish."

In case of fire, do not try to put it out with water, for the burning gasoline will float and spread the fire. Always keep a pail or two of sand handy, and smother the flames with it. In case of fire, the first thing to do, if it is possible, is to turn off the supply cock from the tank to the carburetor, and then push the car away from the blazing gasoline on the ground. Do not let a pool of gasoline drip from the carburetor when priming it, as a chance short circuit may give a spark that will set it on fire. See also Index under "Gasoline fire; how to extinguish."

Fires are usually caused by gasoline dripping from the carburetor and a stray ignition spark. Be careful to see that the carburetor does not drip.

WASHING THE CAR

First, dust off the car and top. Do not wipe it off; this simply rubs the grit into the varnish and makes scratches on the body, fenders, hood, etc.

When washing the car, use only clear water. Warm water is best, but only lukewarm water should be used, otherwise it will soften the varnish. If soap is used, get a good carriage soap that has **no alkali in it.** If it contains alkali, it will take off the varnish.

Mud should not be rubbed off, for the varnish would be scratched. Let the water run gently out of the hose (using no nozzle) and flow over the mud, so that it washes away slowly.

The full force of the water may be used to remove **mud from the under side of fenders, but not from any varnished part.** If a hose cannot be used, pour the water on so that the mud is carried away. Dry mud is more difficult to remove, but if the varnish is to be kept bright, use only the method described, and take time to it.

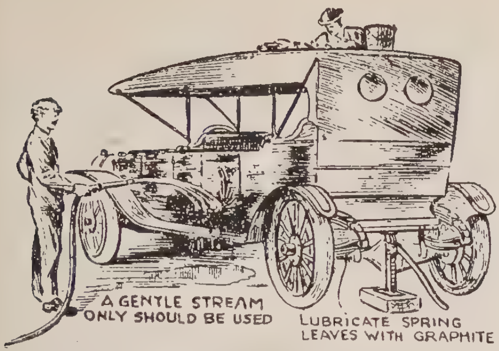

Fig. 1. Washing a car and cleaning the top.

When the body is clean, go over it with a soft sponge, using plenty of water, and dry it with soft, clean chamois skin or wash leather. It is advisable to have a sponge and chamois skin for running gear, a separate sponge and chamois skin for the body.

After the body has been washed, it should be gently dried with a piece of clean chamois skin. Wash out and wring out the water from the chamois as the car is wiped with it.

For removing grease, a sponge with castile soap and tepid water should be used and then body polish applied.

A car ought to be washed and chamoised off immediately if rained upon, otherwise spots will remain if rain is left to dry.

Fig. 2. A flexible wash-hose nozzle.

Wash-rack hose is usually a 4-ply hose of ¾″ inside diameter. A **flexible wash-hose nozzle** (Fig. 2) is best to use for washing cars, instead of a metal nozzle. The nozzle shown is known as the Conqueror brand.

Home-Made Washers

Supply houses can supply complete equipment for washing cars. Below are shown home-made devices.

Supplies for cleaning the car: Two good, clean, soft "wool" sponges, two ten-quart pails, several clean soft chamois, a quantity of canton flannel, a quantity of ivory or pure castile soap, clear running water, a soft wool duster, gasoline for use in extreme cases.

The two sets of pails, sponges and chamois are recommended, so that the pail and sponge used for the first washing may be kept separate from those used in the final washing. See Index under "Sponges"; for the kind of sponges and chamois to use.

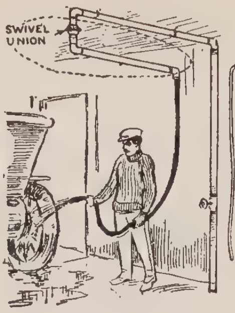

Fig. 3

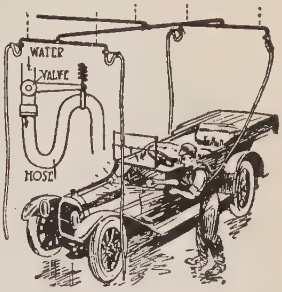

Fig. 4

Fig. 3. **Portable hose swing-rack for washing cars.** This rack is made of standard ¾″ galvanized iron seamless pipe and fittings. The illustration gives an idea of its construction. Large garages usually have means for heating the water..

A washstand is usually made about 12 or 14 ft. wide and about 15 or 18 feet long. It is made of granitoid, so arranged that the water flows to a trap in the center for draining.

Fig. 4. **A washer with several hose outlets,** which meets all requirements and is not likely to get out of order is made out of four lengths of hose suspended from pipe connections at the four corners of the wash rack. Each hose is connected to a plug valve which is spring-closed and opened by a slight pull on the hose. The advantage of the four-hose construction is that it is simple, not likely to get out of order and allows more than one man to work on a car.

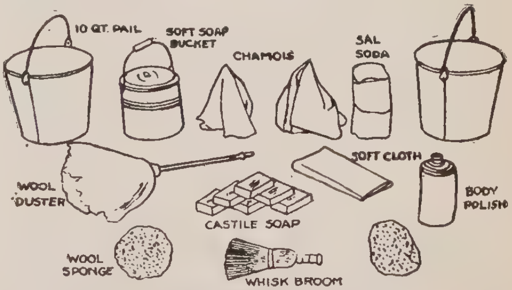

Fig. 5. Supplies necessary for cleaning a car.

Washing Radiator

When it is necessary to clear the radiator spaces of accumulated mud, you should flush the radiator from the rear, not from the front. In that way you avoid getting water into the magneto or ignition system, which is often short-circuited when moisture enters it.

Sponge Off Your Hood

Particular attention should be given to the hood after the car has been run in a heavy rain, inasmuch as after a long run it becomes fairly hot. If raindrops are left to dry upon it in this condition, they will stain it much more than the body. The car should be washed down at once, or if this is not possible, the hood should be sponged off and wiped dry immediately.

A good body polish will remove grease and rain spots from a hood or body.

BODY, METAL, AND GLASS POLISHES

Cleaning and polishing dull varnish: In most cases, dull varnish is not "dead," but is simply coated with a deposit of dirt. When this deposit is removed, the original luster of the varnish can be restored. The following method will give excellent results. The necessary materials are a clean sponge, automobile soap, chamois skin, soft waste, cheesecloth, rotten stone, linseed oil, and Percival automobile polish.

Cleaning: Wash the car thoroughly with automobile soap. Wash small sections of the body at a time, and do not permit the soap to dry on the varnish. Dry the car with chamois skin.

If the finish is very dull after washing, saturate a small pad of selected soft waste (there must be no grit or thread cards in this pad) with water, and dip lightly into fine rotten stone. Do not make a mistake and use pumice stone, for it will completely destroy the finish. Rub with the pad and rotten stone until the surface shows a bright luster. Continue over a complete panel. Be sure to keep the pad saturated with water while rubbing.

Rotten stone has relatively no abrasive effect on gum varnish, but does rapidly abrase the imbedded deposit if the varnish is free from oil and grease. As fast as this deposit is cut away the varnish acts as a lubricant, as the easy sliding of the rotten stone pad will indicate. Remove all rotten stone with damp cheesecloth.

If the finish is only slightly dull or gray, rub with a mixture of 1 oz. rotten stone and 3 oz. linseed oil instead of rotten stone and water. Shake the mixture while using.

Polish: After cleaning as above, polish with Percival automobile polish. The formula follows:

24 oz. wood alcohol....... (By weight)
48 oz. raw linseed oil...... (By weight)
40 oz. white vinegar...... (By weight)
3 oz. aqua ammonia..... (By weight)
3 oz. spirits camphor..... (By weight)
6 oz. butter antimony.... (By weight)

It is imperatively important that these ingredients be **mixed together in the order given,** and that they be shaken thoroughly.

To the formula given above add a mixture of 2 oz. grated beeswax and 3 oz. turpentine, which have been mixed and allowed to dissolve thoroughly for 48 hours. When added, the whole mixture must be shaken. Always shake before drawing from the main supply and while using.

To use the polish: Saturate a pad of fine cheesecloth with the polish and rub the varnish briskly until a full luster appears. The luster can be determined by wiping the parts occasionally with a clean cloth or with the palm of the hand, and looking at the surface as into a mirror. A perfect reflection should be obtained. If dullness appears after the car is used, it will indicate that the deposit was not entirely removed with the rotten stone, or that the polishing was not thoroughly done. Hard, consistent rubbing will invariably bring the desired results.

After thoroughly polishing, wipe off all polish carefully with cheesecloth that has been washed and dried. Then dampen a piece of cheesecloth with alcohol (wood alcohol will be satisfactory), and shake the cloth until no free alcohol is left on its surface. The cloth will then feel cool to the face, but not damp. Wipe over the complete job, occasionally dampening the cloth as described above. This operation removes all traces of oil and polish and leaves the original varnish clean and brilliant. Be careful not to spill alcohol on the finish, and do not use a moist cloth, as the alcohol will dissolve and soften the varnish.

After polishing, the car should be treated as if it were newly painted, with the added advantage that there will be no danger of spots appearing as with a newly painted job.

As it is absolutely necessary that the polish be neutral in its action upon the varnish, use the Percival formula and nothing else.

This process will not be satisfactory on varnish which has been oiled or waxed repeatedly, or on which ordinary furniture polishes have been used.

Another polish for the body for removing rain spots and grease: A much-recommended polish is made by mixing the following ingredients: turpentine, 1 gallon; paraffine oil, 1 pint; oil of citronella, 3½ oz.; oil of cedar, 1½ oz. This should be applied after the car is washed and dried. Apply this with soft, clean cotton waste and rub dry with a clean flannel cloth. If it is not rubbed dry the dust will collect. This preparation in most cases will remove rain spots and grease.

Another method is to use a mixture of boiled linseed oil and turpentine, applying it sparingly and rubbing absolutely dry. The use of these polishes will restore even an old car to a degree of brightness that will surprise you.

Another body polish that is highly recommended is made by using 1 gallon of soft water, 4 oz. ordinary soap, 1 lb. white wax in shavings. Boil well and add 2 oz. of pearlash. This may be diluted with water and laid on with a paint brush, and then rubbed off with a cloth. Another formula often used is 3 oz. shellac, ½ oz. gum mastic, and 1 pint methylated spirits of wine, dissolved. In our opinion, however, better results will be obtained by using some one of the varnish polishes that are on the market and that can be found at almost any hardware or paint store.

A good cleanser for enameled parts of the car, when parts are greasy and very dull, may be made of the following: 1 lb. washing soda crystals to one pail, or 2½ gallons of water. This should be very briskly applied with a soft rag. Then polish with canton flannel.

The solution, before being applied, should be carefully inspected to see that all crystals have been dissolved, as any remaining will scratch the surface.

This solution should be used only on enameled parts of the car, as it will ruin varnish or paint. The enameled parts of the car are the radiator, radiator splashers, bonnet, front and rear fenders, gasoline tank, tire carriers, steering column, shifter lever, black engine parts, and the enameled part of lamps.

Brass

Any good brass polish will work satisfactorily. All these preparations contain some fine abrasive, for which reason care must be taken not to let the polish come in contact with the varnish body surfaces.

Nickel-Plated Parts

All nickel-plated parts may be cleaned with regular silver cleaner paste. Use only the softest flannel rag or chamois to rub with.

Do not clean lamp reflectors except when absolutely necessary, and then use Putz pomade, applied with a very soft clean chamois skin. Reflectors are often silver plated and are very easily spoiled by frequent polishing.

Nickel trimmings should be rubbed over with an oily rag; this will keep them bright without polishing. Before going out for a run in damp or rainy weather, it saves labor to give the brass work a light coat of vaseline to protect it from tarnishing, and put rubber bags over the lamps. When there is little time to give to cleaning the brass work, paint it with black or colored enamel, which looks better than uncleaned brass.

Metal and Glass Polish

Mix one part wheat flour, five parts of dry powdered fire or potter's clay, and use with a damp woolen cloth. This will be found the finest polish ever used, and is cheap. It cannot be beaten for cleaning fly specks, grease, paint, and other stains from glass or metal.

To Clean Glass and Reflectors

For cleaning glass—windows, windshields, lamp lenses, mirror lenses, etc.—there is nothing better than a mixture of half alcohol and half water, which will readily clean off dirt and leave a bright polish. With a soft cloth, or a piece of tissue paper, the work can be done expeditiously. See Index for "Cleaning and polishing reflectors." Putz pomade applied with a very soft, clean chamois skin is also excellent for cleaning reflectors.

To prevent rain or snow from sticking to glass: A trade magazine gives the following mixture to use: 2 oz. glycerine and 1 oz. water with 1 dram salt. Apply to the windshield with cheesecloth—wiping up and down, or in a vertical direction.

CLEANING TOPS, UPHOLSTERING, ETC.

To clean top—outside: A top that has been in use for some time can be cleaned by using the following mixture: ½ pint raw linseed oil; 4 cups water; ½ cup turpentine. Apply with clean rag and rub dry.

A dressing for leather tops: A very good recipe for the purpose is: One part liquid asphaltum to two parts castor oil, to which add ½ oz. ivory black to each pint of the mixture. Apply with a soft brush. This dressing is excellent for a rubber top.

Mohair tops should be frequently dusted and brushed off.

If the top is mohair, a pail of tepid water and a bar of castile soap should be used. Place the soap in the pail and work with the hands until a good lather is obtained. A large clean sponge is dipped into the water and the top is then thoroughly washed.

Pantasote tops and curtains are best cleaned with a soft brush dipped in water in which a little ammonia has been added. Afterwards rub dry. Never attempt to clean top and curtains with gasoline or kerosene.

Do not fold the top until it has become thoroughly dry, because any moisture remaining in the folds is prone to cause mildew, besides making the top leaky and unsightly with spots. When the car is not used for some time, it is best to open the top, which keeps it well stretched and smooth.

If the top is dirty, use a broom first. After it has been cleaned with soap, go over it with clear water so that no alkali spots will appear.

Cleaning Leather Upholstering

Do not use gasoline for cleaning leather upholstery. Plain water with a little ammonia will remove the dirt, and a brisk rubbing with a clean woolen or flannel cloth will do the rest. For still more careful treatment, use a regular leather dressing on all leather.

Recipe for a dressing for leather upholstery: Raw linseed oil and turpentine, mixed in proportions of two of the former to one of the latter, is a time-honored formula.

For cleaning cloth upholstery use clear water and a mixture of ¾ oz. common salt and 2 oz. of either grain or wood alcohol, simply rubbing the cloth with a sponge dampened in the mixture.

To remove ordinary dust from cloth upholstery, beat the cushions and backs lightly with a stick or carpet beater; then remove the dust with a whisk broom or brush. (The vacuum plan is best.)

Grease or oil may be removed by the application of a solution of lukewarm water and ivory soap, applied with a woolen cloth. Any of the approved methods for cleaning woolen cloth may be used with success on this upholstery. Gasoline and benzine have a tendency to spread instead of to remove the dirt. We do not, therefore, recommend their use, although they work no injury to the fabric.

A certain repair shop made a reputation by having **their mechanics wear clean dusters** when working on the interior of a car, thus protecting the upholstering from grease.

PAINTING RADIATOR, ENGINE, CYLINDERS, MANIFOLD, ETC.

To paint the radiator, mix 3 oz. boiled linseed oil, 4 oz. lamp black, 1 oz. turpentine, and thin down with turpentine to the proper consistency. In applying, the radiator must either be dipped into the solution (in this case a great deal more must be mixed), or sprayed (see also, Index under "Painting radiator"), or the radiator can be placed on boxes, face up, and the thin mixture can be applied plentifully so that it will run through the cellular parts of radiator. A camel's hair brush can be used to reach places not covered.

To paint cylinders: Mix 8 oz. white lead in oil, 6 oz. boiled linseed oil, 2 oz. turpentine, and ½ oz. lamp black. If too heavy, thin down with turpentine. This will make a gray paint sufficient for six cylinders.

Aluminum mixed with bronzing liquid can also be used.

To paint the intake manifold: Use regular aluminum, which can be secured at any drug store.

To paint the exhaust manifold: Use aluminum. No paint has as yet been found which will remain on hot exhaust pipes; here is a recipe suggested:

Heat-proof paint: Use 2 parts of black oxide of manganese, 3 parts of graphite, and 9 parts of Fuller's earth, thoroughly mixed, to which add a compound of 10 parts of sodium silicate, 1 part glucose, and 4 parts of water, until it is of such consistency that it may be applied with a brush.

Tire paint: Liquid rubber is a preservative and beautifier of tires. It gives the tire a white coating. It is made of pure unvulcanized rubber in solution. It can be applied with a brush, and if used at regular intervals, it will, it is claimed, prolong the life of the tire because it penetrates and runs into any small cuts or holes and seals them over, thus in a measure preventing moisture from reaching the fabric. It is also suitable for golf balls, rubber mats, and is a highly satisfactory rust preventive for rims. Secured at supply houses.

A very satisfactory tire paint for finishing the inside of a tire after repairing may be made by mixing thoroughly 1 gal. gasoline, ½ pint Firestone rubber C-35 cement, 1½ lbs. soapstone and ½ lb. whiting. Many successful repairmen are using this formula with the best of results. See also page 612.

SUGGESTIONS FOR REPAINTING A CAR AT HOME

In some cases the car owner may feel disposed to do some of the work himself, and then pass it on for the professional painter to put on the finishing coats.

He may, for example, give the car as thorough and complete a washing up as the painter will do. Then by getting the car up on stout wooden horses, so that he can work under it conveniently, the grease and dirt may be removed from the chassis. This is a somewhat smeary job, but anyone who is not afraid of work can save some money by doing it. Saturate the greasy parts with one-third turpentine and two-thirds kerosene or crude oil, and let the applied mixture stand for several hours to soften up the hardened oil and dirt.

Then take a ½″ putty knife and a couple of mowing machine knives and some pieces of coarse burlap, and proceed to cut and scrape the accumulations off, and wipe the parts up. It may take two or three applications of the oil and turpentine mixture, and a lot of rubbing with the burlap, to get the surface clean, but it is all necessary work.

If the surface is worn and the paint beaten off, and the bare metal or wood is disclosed, these pieces will need touching up with a paint mixture containing at least one part raw linseed oil and two parts turpentine. Mix thoroughly some ground white lead and lamp black and add a little at a time to the oil and turpentine. Apply with a small round brush.

Next get some dry white lead and a small quantity of finely ground whiting, using one part of the whiting to two parts dry white lead. Knead it to a good working body in equal parts of coach japan and rubbing varnish. Then, with your putty knife, putty up all the holes and surface fractures, filling them smooth and level with the surrounding surface. While this class of work is somewhat difficult to do well, with care and some practice it may be taken care of.

If the surface is in a condition suitable to sandpaper, apply the color without any further surfacing. The professional painter may then, if desired, be called in to sand this putty and the surface down smooth and apply a coat of color to the car. If any striping is to be applied, the lines may be run on this coat of color, after which apply one or two coats of varnish, according to the class of finish desired.

In case the car needs simply a coat of varnish, with perhaps a few worn or bruised spots touched up with a bit of color, it should first receive a thorough washing and cleaning. The body surface will need going over with water and pulverized pumice stone to lay down the gloss and fit it for the varnish. Then touch up with the color where necessary, and apply a coat of body-finishing varnish. Likewise, give the chassis a stout coat of varnish.

In this connection, it may be stated that the amount and kind of work to be applied to the car depends altogether upon the condition of the surface at the time the work is to be done, and naturally, also, upon the sum of money that the owner wishes to expend upon the work. Generally speaking, if the car is kept well varnished, it will not need heavy painting repairs except at long intervals.

Pointers on Cleaning a Car and Removing Old Paint[1]

Having stripped the car, run it on to the washstand and hose off the mud.

Clean the upholstery and the inside of the car with a good stiff brush, or a vacuum cleaner; if an open car style of top, brush it out well on the inside and outside; and if the outside is very dirty, hose it off and scrub with a stiff brush.

Then clean off the chassis with gasoline (kerosene may be used for cleaning a job that is to be burned off, but is too greasy where only repainting is intended), using a gasoline brush or an old worn-down paint brush for the purpose—scraping off any hardened grease or dirt with a putty knife. Next make up a suds of soap and water and sponge off all of the dirt that has become loosened by the gasoline. Then hose off.

Hot water may be used where the job is to be burned off afterwards—as hot as desirable; but where repainting only is intended, it should not be so hot as to soften any of the paint coats; and where revarnishing only is intended, the water should not be more than lukewarm. After washing a job that is to be repainted or revarnished, hose off thoroughly with plenty of water, and make sure that all soap has been removed from the surfaces. The stripped parts can be similarly cleaned, where necessary. Sponges and chamois used in washing should not be used elsewhere, and it is best to have one set for use on the chassis, which is always the greasiest, and another set for use on the body parts.

Cleaning preparatory to burning off need not be so thorough as when done before repainting, etc. If there is any body polish on the surfaces, wash it off with gasoline preparatory to the washing with soap and water, whenever the job is to be handled without burning off.

Cleaning with no washstand available: In this case clean out the inside and top as described, and then scrape off the caked mud and grease with a putty knife. If the job is to be burned off, the paint remover can be depended upon for removing any remaining grease or dirt.

If burning off is not intended, the surfaces should be further cleaned with gasoline on the chassis, etc., and if necessary with a warm water suds on the body—doing the work from a pail—and then sponging off with clean water. The sanding that the surfaces will receive must free them of any remaining dirt. Wash off all body polish with gasoline.

Cleaning the chassis with a spray: A very quick and effective method of cleaning is that where a spray is used. Such a device cannot be used without compressed air, but where this is to be had, a simple spray nozzle can be rigged up with a few pieces of brass pipe, patterned like that of a garden or orchard spray, and the cleaning solution can be sprayed on the car from it.

A mixture of hot water, soap, and kerosene can be used in cleaning a chassis for burning off; while for repainting, warm water, gasoline, and soap would be used first, and clean water afterwards. There are many cleaning solutions to be had on the market that can be advantageously used in cleaning a car preparatory to burning off, but most of them are too strong for use otherwise.

Materials for use in automobile painting can be had from: Valentine & Co., Chicago; Murphy Varnish Co., Chicago; Chicago College of Auto Painting, Chicago. Brushes can be obtained of Mishawaka Auto Specialty Co., Mishawaka, Ind.

For undercoating a good primer should be used, that is suited for use on both wood and metal, with roughstuff, sanding surfacer, and stiff putty. Colors and color varnishes can be stocked in the most popular shades, and the odd ones can be made as desired with the color and rubbing varnish. A free working and flowing finishing varnish will be best suited for general purposes, especially for body work, but for chassis work use one that is a little heavier bodied. Spar varnish can also be used on the wheels or other small surfaces where there is no danger of laps or runs showing.

The subject of application would require a volume in which to discuss it properly.

Selection of brushes: Brushes are often cheapened in such a way that it does not show. Good hair is placed on the outside and the poor grade is placed at the center. In the best grades, the hair will be found uniform from the center to the outside. The "filled" brushes are not bad ones to work with, but the "pure" ones will outwear them, and as brushes improve with use, it is not desirable to have one start wearing out just at the time when it should be getting good.

It takes some little time before the badger-hair finishing varnish brush can be brought to its maximum efficiency; and, properly cared for, it should last for years. So it would be nothing but false economy to buy anything but the "pure" badger-hair brush for such a use. Brushes that are used for finishing must be absolutely clean, and as this is a condition that can be acquired and maintained only by use and care, these brushes improve in value and usefulness in direct proportion to the care and use given them. Nearly all automobile painters, who make a specialty of finishing, that is, applying the finishing varnish, own their own brushes, and they accord them the very best care and attention.

The following table will show the types and sizes of brushes used in automobile painting:

Brushes for Car Painting

Primer: 2½″ ox-hair or soft bristle for large surface; 1″ ox-hair or soft bristle for small surfaces.

Filler: 2″ flat bristle; 1½″ oval bristle.

Color: Body, 1″ camel's hair for small places; 3″ camel's hair for large panels; chassis, 1½″ camel's hair.

For the automobile colors that are applied in thicker coats, like the whites, creams, and grays, a 1½″ ox-hair brush can be used.

Touch-up: ½″ camel's hair for bolt heals, lugs, etc.

Color rubbing varnish[1]**:** Body, badger-hair, double thick, 1″ for small places; badger-hair, double thick, 2½″ for large panels. Chassis, badger-hair, double thick, 1½″.

Finishing varnish: A set of three, the same as for color-rubbing varnish. For touching up the finished job with an air-drying enamel, irons, running gear, etc., a small brush known as a sign painter's brush is a handy tool. It is a ½″ ox-hair, with the hair about ⅝″ long, and has a long handle. A 1½″ bristle or ox-hair brush will also be required for enameling rims.

Striping, monograming, lettering: Sword stripes, sizes No. 2, No. 3 (stripe up to ⅛″); broad stripes (stripe ⅛″ to ⅝″); monograming and lettering pencils, assortment.

Brushes for Truck Painting

Truck work is harder on brushes, and a high-class finish is not so essential. The surfaces are rougher and do not call for so high-grade a tool.

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[1] From *Motor Age*.

Primer: Body, 2″ bristle for any kind of primer; chassis, 1½″ bristle for any kind of primer.

Filler: 2½″ bristle body.

Color: Body, 2½″ ox-hair; chassis, 1½″ ox-hair.

Varnish:[1] Body, 2½″ bristle (one set for color rubbing varnish); Chassis, 1½″ bristle (one set for finishing varnish). A bristle brush is required for this work because larger surfaces require a longer working or brushing of the varnish, and the longer it is worked the stiffer it gets. Also the heavier bodied varnishes are used on trucks, where so fine a finish is not required. Larger brushes would be required for moving vans, or a number of men could work on a panel at the same time.

POINTERS ON SHIPPING AN AUTOMOBILE

An automobile will be received for transport by freight only when either crated or set up. The usual method in shipping by freight is to ship it complete, and run it right into the car. See that the railroad company blocks the wheels so that the auto will not pitch forward or backward. It is also well to see that the machine is braced from the side.

Get a clear bill of lading from the railroad company, so that you have something on which to base a claim for damages in case of the car being smashed. It is well to box the cushions and all loose parts separately. The charge for conveyance must be ascertained from the railway company.

Place the vehicle in the car parallel with the sides, and see that the front wheels are in line with the back wheels. Wrap the lower third of the tires with burlap to prevent chafing; and set the brakes.

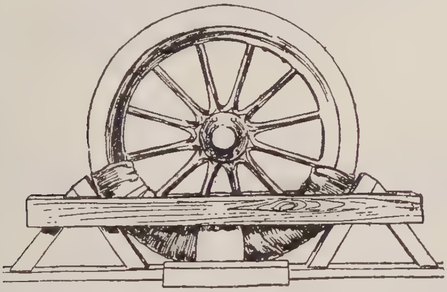

Fig. 6

To block the wheels, fasten each wheel to the floor with a strong band of canvas or several layers of burlap of the width between two spokes. Secure the band to the floor on each side of the wheel with blocks 2″ by 4″ by 12″. Place these blocks parallel with the wheel, using plenty of nails or spikes.

Use blocking in front and behind each tire one-third as high as the diameter of the wheel, and at least one inch wider than the tire. Fasten this securely to the floor, and tie together with one or two-inch lumber from block to block. Have the blocking of sufficient width so that the boards used to tie the blocks together will clear the tire at least a half-inch on each side.

In packing the auto, empty the gasoline and water tanks and disconnect the batteries. In the case of electric cars, remove the batteries.

The tires should be tightly inflated; and the edges of the boards and blocks next to the tire should be rounded or beveled, so that if they should become deflated or in any way come in contact with the boards or blocking, they will not be so liable to chafe. Place the covering over the vehicle to keep off dust. Also remove the lamps to prevent damage to them.

Freight cars should be carefully inspected to see that they are fit for loading. If there are nails or other projections in the floor or sides of the car, they should be removed. If the roof appears to be leaky, or its fastenings for the doors, both end and side, are not complete or ample, the car should be refused, and a car suitable for loading demanded. Failure on the part of the shipper to do this renders him liable for the damages resulting from having loaded the vehicle in a car manifestly unfit.

USEFUL ACCESSORIES

The J. H. tonneau windshield shown in the illustration (Fig. 7) will give to the open car the comforts of the closed car. In the summer it permits of driving in comfort with the top down or up, and in the winter it will close the rear of a car up as comfortably as a limousine or closed. car.

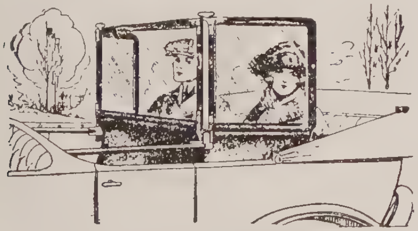

Fig. 7

To those who are debating the question of whether to purchase an **open** or a **closed car,** this device will no doubt prove of advantage in assisting in reaching a decision. The expense of a closed car is considerably more than that of a touring car and less power and wear can be had from it. With this device a considerable sum can be saved. The tonneau windshield is handsomely constructed, and will add greatly to the appearance of a car. Manufactured by the J. H. Tonneau Windshield Co., 1777 Broadway, New York, N.Y.

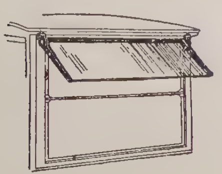

Fig. 8

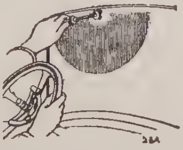

Fig. 9

The Gemco visor for Dodge sedans and coupes is shown in Fig. 8. It is made of heavy plate glass 11″ wide, ¼″ thick; nickel plated trimmings, black enameled frame; the brackets are screwed to the extension of the car; and it is provided with a ratchet for quick adjustment to any angle. With this attachment sleet, rain, and snow cannot obscure the driver's vision. Made by the Gemco Co., Milwaukee, Wis.

Windshield cleaners are made in a number of different forms. Fig. 9 shows a half-circle cleaner which is fitted to the windshield by drilling the glass. It will instantly remove rain or snow in this half circle.

An "automatic" windshield cleaner is another type used. This consists of a small metal cylinder, about six inches long, mounted on the top frame of the windshield. The metal cylinder contains a small piston attached to a scraper arm fitted with a rubber strip. A piece of special rubber tubing is connected to the inlet manifold of the engine, and the scraper is thus operated by the suction from the inlet manifold. When once turned on, the cleaner swings constantly, and removes the rain or snow until stopped.

Fig. 10

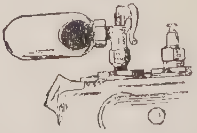

Fig. 11

A mirrorscope for placing on the fender (Fig. 10) will enable one to see the cars in the rear.

A compression whistle is shown in Fig. 11. This device is screwed into the cylinder in place of a relief or priming cock, and is operated from the seat. To those who have difficulty in keeping the battery charged this device will serve instead of the electric horn and thus save electric current.

A good clock is a very necessary cowl-board equipment. Not all clocks on automobiles are good ones. A clock for automobile use should be of the best in order to withstand the vibration. As cars are driven in all seasons of the year, the clock should have a compensating balance so that it will not be affected by extremes in temperature.

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[1] The Columbus Varnish Co., Columbus, Ohio, and the Boyer Chemical Co., 940 N. Clark St., Chicago, supply varnish and paints with instructions as to their use for repainting and touching up cars.

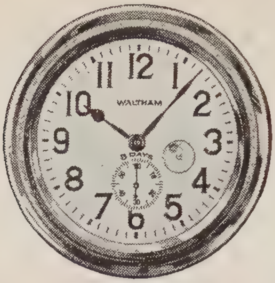


Fig. 12

Fig. 12. Automobile clocks are made in many designs by Waltham Watch Co., Waltham, Mass. The one shown is the model "F." Note the "O" on dial. A red signal will appear three days in advance of the time when winding is necessary.

Experienced automobile drivers advise a clock to do away with the inconvenience of referring to their watch when clothed for cold or stormy weather, as even the few seconds required for this might result in an accident to the machine or passengers.

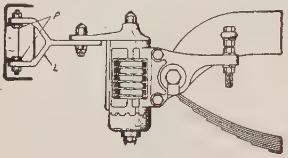


Fig. 13

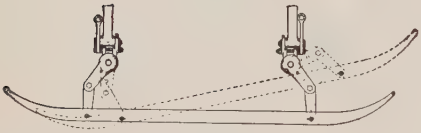


Fig. 14

Fig. 13. The Ramspring bumper, shown above is based on a principle that is different from other principles and constructions. One side may be deflected without materially deflecting the other side. The action of the coiled spring may be varied by changing its tension, which is done by loosening the nut on the bottom and winding up the bottom cap. It will be noted that the bottom cap which holds the spring tension is serrated with heavy square teeth.

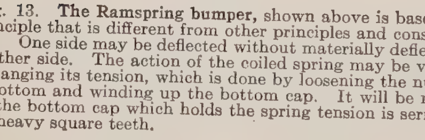


Fig. 15

Action: Heavy coil springs cushion the impact and absorb the shock. Fig. 14 shows the bumper taking a blow from the side; solid lines indicate normal position of the bar; Fig. 15 shows the bumper taking a heavy blow head on. Manufacturers are the Ramspring Bumper Co., 624 W. Adams St., Chicago, Ill.

A bumper for the rear as well as the front of the car will often save the lamps, fenders, body, and radiator. Insurance rates are reduced in most policies where cars are equipped with front and rear bumpers.

Fig. 16. **A gasoline gauge which can be placed on the dash** and which will indicate the amount of gasoline in the tank in the rear of the car is a very handy and serviceable device. A gauge known as the Petrometer, sold by the Porter Carburetor Co., Knickerbocker Bldg., Forty-second Street and Broadway, New York, N.Y., is shown in the illustration.

The glass tube in the gauge of the Petrometer contains a special red fluid which indicates by different levels and the markings beside it the quantity of gasoline in the tank. It is applicable to all motor vehicles or other fuel or liquid tanks which are open to the air—all automobile fuel tanks using gravity or vacuum systems.

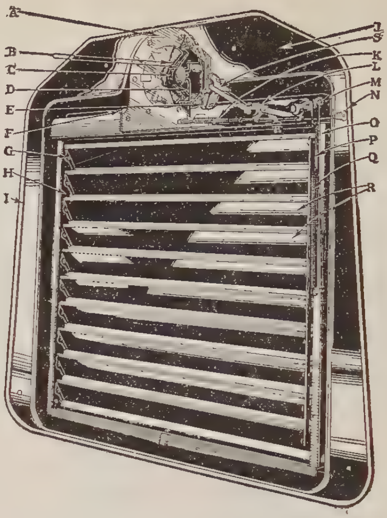


Fig. 17. **The Winterfront radiator shutter** could be classified as a very necessary device for regulating the temperature of the cooling system, thus conserving the heat of the engine, making starting easier, and enabling the engine to warm quickly, as explained with another principle on page 149. The device (Fig. 17) is one which can be secured for any make of car, and fits over the outside flat surface of the radiator core.

Operation: The shutters (R) are ribbed and turn in brass trunnions (G). All shutters operate in unison and are connected with a thermostat.

The **thermostat** consists of a pair of thermo-wafer cells (B) with a spacer (C) and an aluminum heat-conducting flange or plate (A). The thermo-wafer cells are filled with a liquid mixture which forms gas proportioned to make the cells expand or contract at the desired temperatures. For ordinary requirements they are filled to begin expansion at 130° F., and fully expand at 175° to 180°. The heat is derived from the radiator core, through the aluminum heat-conducting flange (A) which rests against the core of the radiator, and as it warms up the heat is carried to the thermo-wafer cells (B), causing them to expand. As the cells (B) expand, they turn the double bell crank (D) which is connected with the shutters (R), opening them gradually as the heat of the radiator rises above 130°, and fully at 175° to 180°. When the temperature drops below 130° the thermo-wafer cells (B) contract and automatically close the shutters (R).

If desirable to close shutters when stopping the car, the exposed closing button (N) can be pressed, which instantly locks them shut. The automatic release (L) restores the shutters to operating position when the engine is started.

Adjustment of the releasing attachment can be changed with a small wrench enclosed with the attaching bolts, etc. It fits the brass bolt projecting through the upper tie bar. This brass bolt can be reached through the space above the top shutter, when the shutters are open. Turning the wrench to the right will make the adjustment more sensitive, and to the left less sensitive.

If shutters should fail to open fully when the engine is heated up, the thermostat disks (B) may have become porous, or the soldering leaks. The disks are replaceable.

Names of parts: **A,** aluminum heat-conducting flange; **B,** thermo-wafer cells; **C,** cell spacer; **D,** double bell crank; **E,** thermostat insulator; **F,** frame insulator; **G,** brass trunnions; **H,** composition bearings; **I,** cushion cord; **J,** shell; **K,** safety spring; **L,** automatic release; **M,** shutter lever; **N,** closing button; **O,** shutter rod; **P,** shutter operating bar; **Q,** closing spring; **R,** shutters. (Manufactured by Pines Mfg. Co., 408 N. Sacremento Blvd., Chicago, Ill.)

To Prevent Steam and Water Collecting on Windshield

A solution suggested by a trade magazine to prevent steam and water collecting on the windshield is as follows: 1 ounce water; 2 ounces glycerine; ½ spoonful of salt. This can be applied by wiping up and down with a cloth saturated in the solution.

INSTRUCTION No. 58

TRAFFIC REGULATIONS: Rules of the Road; Pointers on Driving

STREET, TRAFFIC AND PARKING REGULATIONS

The driver of a car should be careful to observe the rules of the road, for damages are not so likely to be collected, if he can prove that he was where he should have been.

Throughout the United States, **the invariable rule is to keep to the right;** in England it is just the opposite.

The following is a fair example of traffic rules which may vary slightly, but practically represent the ordinances in different large cities.

St. Louis traffic laws and regulations are **cited as an example of ordinances which are substantially similar in all large cities.** Compiled by Mr. J. F. O'Donnell, Atty., under direction of Mr. C. M. Talbert, Director of Streets, St. Louis, Mo.

Definitions

"Vehicle" includes animals that are led, ridden, or driven, and every horse-drawn or motor-driven conveyance except a street car. (Sec. 1294, Rev. Code, 1914.)

"Driver" includes the rider and driver of a horse, the rider of bicycles and motorcycles, and the operator of any other vehicle. (Sec. 1294, R. C. 1914.)

"Congested district" consists of the following described streets, to-wit: (Sec. 1333, R. C. 1914).

"Street" designates every highway and place used by or laid out for the use of vehicles. (Sec. 1294, R. C. 1914.)

"To park" means to stand or store any vehicle on a public highway when it is not being loaded or unloaded. (Sec. 1294, R. C. 1914.)

Authority

Drivers shall at all times promptly obey all reasonable directions of a police officer engaged in directing traffic as to stopping, starting, approaching or departing from any place; the manner of taking up or setting down passengers, and loading or unloading goods in any place. (Sec. 1288, R. C. 1914 amended by Ord. 30174.)

License

State license plates shall be conspicuously displayed and firmly fixed on the front and back of every motor vehicle, except motorcycles and motor tricycles, which shall display a State License Plate permanently fastened to the back only. (State Law, 1917.)

License plates to be kept reasonably clean. (State Law, 1917.)

Lights

Motor vehicles, while on the public highways, whether in operation or otherwise, from a half-hour after sunset to a half-hour before sunrise, and when fog or other atmospheric conditions render the operation of vehicles dangerous to traffic, shall carry at the front at least two lighted lamps, not exceeding 36 candlepower each (except that motorcycles shall carry one lighted lamp), showing white lights visible at least 500 feet ahead and revealing objects 150 feet ahead, adjusted and directed so that on level ground the main shaft of light shall be projected straight forward, no portion of it being above the level of the lamp nor more than 42 inches above the ground. Electric headlights shall, in addition, have their door glasses etched, ground, or so formed that the lighted filament shall appear blurred. (State Law, 1917, and Sec. 1314 R. C. 1914.)

Red light on rear. At all times when lights are required there shall be carried at the rear a lighted lamp exhibiting one red light, plainly visible for 500 feet toward the rear. (State Law, 1917; and Sec. 1315*a*, R. C. 1914.)

Sidelights, or substitutes therefor, may be used with electric bulbs not stronger than 10 candlepower each, provided the condensed light is projected forward and if possible downward below the level of the lamp, and provided the glass openings emitting light are etched or ground as required of headlights. (State Law, 1917; and Sec. 1314*a*, R. C. 1914.) Ground-glass bulbs may be used instead of having glass opening etched, ground, etc.

Spotlights shall not be used on the public streets except in emergencies or when headlights are inadequate owing to rain or fog, and then only providing the shaft of light is directed well downward and at no time into the eyes of other persons. Outside of the city, they may be used if directed well downward and not into the eyes of other persons. (State Law, 1917; and Sec. 1315, R. C. 1914.)

Horsedrawn vehicles from one half-hour after sunset to one half-hour before sunrise during the months from October to March, inclusive, and from one hour after sunset to one hour before sunrise during the months from April to September, inclusive, shall carry at least one light showing white from the front and red from the rear, visible for a distance of at least 300 feet. (Sec. 1308, R. C. 1914.)

Lights and warnings upon extensions shall be placed when any part of the load projects more than five feet beyond the rear of the vehicle. Such extra light or warning must be placed at the extremity of the projection and be visible from both sides and from the rear. (Sec. 1311, R. C. 1914 and penalty; See 1312, R. C. 1914.)

A vehicle being towed shall have separately displayed thereon the lights required on vehicles of the class to which it belongs. (Sec. 1310 and 1312, R. C. 1914.)

Bicycles while on public highways, whether in operation or otherwise, at the times and under the conditions specified for **motor vehicles** shall carry one lighted lamp showing a white light, visible at least 200 feet to the front, and also one red light or one red reflex mirror plainly visible from the rear. (State Law, 1917; and Sec. 1308, R. C. 1914.)

Color of lights: No vehicle shall show any other than a white light to the front and a red light to the rear. (State Law, 1917; and Sec. 1308, R. C. 1914.)

Rules of the Road for Vehicles

How to drive: All vehicles shall be driven in a careful manner, with due regard for the safety of other vehicles and persons (Sec. 1301, R. C. 1914.)

Rights of vehicles: Two vehicles, which are passing each other in opposite directions, shall have the right of way, and no other vehicle to the rear of either of such two vehicles shall pass or attempt to pass such two vehicles. (State Law, 1917.)

Overtaking, meeting and passing: If overtaking another vehicle (except a street car), pass it on its left. (Sec. 1267, R. C. 1914.) In meeting another vehicle, pass it to the right. Keep to the right side of the street. (Secs. 1300 and 1266 R. C. 1914.)

Vehicles to pass other vehicles—how—except street cars: A vehicle overtaking another shall, in passing, keep to the left, and shall not pull over to the right until entirely clear of it, nor shall it leave the line on the right unless there is a clear way of at least one hundred feet in advance on the left. (Sec. 1267, R. C. 1914.)

Right of way: Vehicles in the service of the Police and Fire Departments and United States Mail, underwriters' salvage corps, emergency repair vehicles of public utility companies, and ambulances, when in the course of their regular duty, shall have right-of-way over other vehicles. (Sec. 1278, R. C. 1914.) East and west-bound vehicles shall have right-of-way over north and south-bound vehicles. (Sec. 1280, R. C. 1914.) Excepting where controlled by traffic regulations of a city, the driver of a vehicle approaching an intersection of highways shall yield the right-of-way to a vehicle approaching on his right. (State Law, 1917.)

Stop back of street cars: The driver of every vehicle shall stop at the rear of any street car which has stopped to take on or let off passengers, and shall remain at a standstill until such street car has resumed motion; provided that on streets in the congested district vehicles may pass street cars so stopping if they clear the running board, or lower step by six feet. (Sec. 1283, R. C. 1914.)

Stop back of building line: When so signalled by traffic officer, vehicles shall stop back of the building line, leaving the crossing clear for pedestrians. (Ord. No. 30174.)

Vehicle likely to delay traffic: No one shall drive any vehicle in such condition or so loaded as to be likely to delay traffic, or cause an accident. (Sec. 1285, R. C. 1914.)

Width of vehicle and load: No person shall drive through the streets a vehicle the width of which, with its load, shall exceed ten feet, except on permit from the Director of Streets and Sewers. (Sec. 1287, R. C. 1914.)

Left side to curb not permitted: No vehicle shall stop with its left side to the curb. (Sec. 1289, R. C. 1914.) See special rules for One-Way Streets and Alleys for exception.

Stopping alongside another vehicle not permitted: No vehicle shall stop abreast aonther vehicle lengthwise of a public street except in an emergency. (Sec. 1290, R. C. 1914.)

Slow up on approaching a pedestrian: A driver of a motor vehicle shall slow up on approaching a pedestrian who is on the traveled part of the roadway and signal audibly. (State Law, 1917, see Secs. 1276 and 1277 R. C., 1914.)

Slow up on approaching intersecting highway, curve or corner: The driver of a motor vehicle, on approaching an intersecting highway, curve, or corner, where his view is obstructed, shall slow up so as to stop readily. (State Law, 1917 and see Secs. 1276, 1277, and 1301, R. C. 1914.)

Safety zones: No vehicles shall cross or enter safety zones as designated by the signs. (See Secs. 787 to 789, R. C. 1914.)

Turning: A vehicle wishing to cross from one side of the street to the other in a business district, except in the congested district, shall go to the next intersecting street before making the turn. (See Secs. 1271 and 1272, R. C. 1914, and Sec. 1334 Cong. Dist.)

Vehicles turning into another street to the right shall keep as near the right-hand curb as possible. (Sec. 1269, R. C. 1914.) See special rules for One-Way Streets and Alleys for exception.

Vehicles turning into another street to the left shall turn around the intersection of the center lines of the two streets. (Sec. 1270 R. C. 1914.) See special rules for One-Way Streets and Alleys for exception.

Signals on leaving curb, slowing up, stopping, or turning: The driver shall give an advance signal to those behind by holding out the hand or by some approved signaling device, so as to indicate intention to slow up, stop, or turn. In approaching an intersecting street where other vehicles are approaching, or where a traffic officer is located, the drivers of vehicles shall designate the direction in which they wish to proceed by signals or words. (Secs. 1273 and 1274, R. C. 1914.)

Backing: The driver shall give ample warning to those behind by hand or by some approved signaling device before backing, and constant care shall be exercised to avoid a collision while doing so. (Sec. 1275, R. C. 1914.)

Stop on approach of fire apparatus: The driver of a vehicle, on approach of a fire engine or fire apparatus, shall immediately draw up said vehicle as near as practicable to the right-hand curb, parallel thereto, and bring it to a standstill. Street cars shall immediately stop between intersecting streets and keep stationary on the approach of a fire engine or other fire apparatus. (Secs. 1281 and 1282, R. C. 1914.)

Vehicles to keep near right-hand curb—exceptions: All vehicles shall keep to the right and as near the curb as possible, except when passing vehicles ahead. (Sec. 1266, R. C. 1914.)

Taxicabs and other vehicles regulated by permits shall comply strictly with the provisions set forth in their respective permits. (See Secs. 525 to 554, R. C. 1914.)

No one under 16 years old to drive: No one under sixteen years old shall drive any public, numbered, licensed, or business vehicle on a public highway. (Sec. 1286, R. C. 1914.)

No chauffeur under 18 years old: No certificate of registration of a chauffeur shall be issued to any person under eighteen years old. (State Law, 1917.)

Keep to right drive on divided parkway: On a street divided longitudinally by a parkway, vehicles shall keep to the right of such subdivision. (Sec. 1268 R. C. 1914.)

Vehicles to stop near curb: No vehicle, unless in an emergency, or to allow another vehicle or pedestrian to cross its path, shall stop in any public street or highway, except near the right-hand curb, and so as not to obstruct a crossing, and shall not stop or stand within the intersection of any streets. (Sec. 1292 R. C. 1914.) See Reg. of one-way streets.

Accidents: In case of an accident due to the operation of any vehicle, the driver thereof shall stop and render such assistance as he can, give his name and address to the person injured, or to any other persons who question him, and report the same immediately to the Police. (State Law, 1917.)

Intoxication: No person while under the influence of intoxicating liquor shall drive any kind of vehicle on the public highways. (State Law, 1917.)

Processions: No vehicle shall be driven through a funeral procession except Police, Fire Department, Salvage Corps, emergency repair vehicles of public utility companies, United States mail, and ambulances when on duty. (Sec. 1199, R. C. 1914.)

Obstruction by vehicles and interference with street cars. No vehicle shall so stand on any street as to interrupt or interfere with the passage of street cars or other vehicles. (Sec. 1325, R. C. 1914; see Sec. 1292, R. C. 1914.) This applies particularly to vehicles standing near the corner so as to interfere with street cars rounding curves.

No automobile shall be left unattended with machinery in motion: No automobile shall be left upon any street unattended while any portion of its machinery is in motion. (Sec. 1291, R. C. 1914.)

Vehicles not to obstruct mail boxes: No vehicle shall stand opposite a United States mail box so that convenient access thereto is obstructed. (Sec. 1326, R. C. 1914.)

Length of tow lines: Any vehicle being towed shall be so connected as not to leave more than 12 feet between vehicles.

Glass on street, alley, or driveway: No person, firm, or corporation shall throw or place any glass upon any public street, alley, or driveway. Penalty up to $100 for each offense. (Secs. 1208 and 1209, R. C. 1914.)

Rules of the Road for Pedestrians

Observation of the rules: Pedestrians by observing the rules will facilitate the movement of traffic and minimized danger to themselves. While they have the right to cross the roadway in safety, it is intended, primarily, for vehicular traffic.

Look before stepping from the curb: Look first to the left and then to the right for vehicles.

Use the regular crossing, and cross at right angles and not in the middle of the block or diagonally at intersections.

Stand on sidewalk when waiting for street car until the car approaches.

Obey traffic officer's signals and commands.

Do not cross behind street cars: When alighting from street cars, be sure the way is clear before crossing behind the car.

Congested District

Between the hours of 7 A.M. and 7 P.M. the following regulations shall be enforced in the "Congested District." (Sec. 1330, R. C. 1914 and Sec. 1333.)

Not to park longer than one hour: No vehicle shall remain continuously at the same place in the congested district for a longer period than one hour. Disabled vehicles and vehicles for public hire, operating under proper permit are exempt. (Ord. No. 30405.)

Vehicles for advertising not to stop: Vehicles for display advertising or public inspection shall not stop within the congested district, except on direction of a traffic officer or on approach of fire apparatus, and shall move at not less than three miles per hour. (Sec. 1330, R. C. 1914.)

"No parking" spaces: The Director of Streets and Sewers is authorized to designate spaces on either side of any street where no vehicle shall stand for a longer period than is necessary for the discharge or receipt of passengers or freight, and not longer than fifteen minutes while so engaged. These spaces shall be designated by official signs. It shall be unlawful for any person to place any sign designating any portion of a street as a place at which vehicles shall not be parked except the signs authorized as above. (Sec. 1335, R. C. 1914.)

Entrance to public buildings: No vehicle shall park before any entrance to a building for a longer period than thirty minutes. (Sec. 1331, R. C. 1914.)

Complete turn at intersection prohibited: No vehicle shall make a complete turn so as to face in the opposite direction on any street in the congested district, but such vehicle, in order to turn around, shall be driven around the block. (Sec. 1334, R. C. 1914.) The owner or driver may be a misdemeanant, under this section.

Fire hydrant reservation: No vehicle unattended shall be left standing at any time within 6 feet of a fire hydrant. (Sec. 1330(c) R. C. 1914.)

Speed

Vehicles on the public highways shall be driven in a careful manner and at such speed as not to endanger the safety or injure the property of anyone. (State Law, 1917; Sec. 1301, R. C. 1914.)

Ten feet between vehicles at crossing when pedestrian about to cross: No person in charge of a vehicle shall allow it to come within ten feet of any vehicle in front of him when approaching and passing over a crossing when a pedestrian is about to pass. (Sec. 1276 R. C. 1914.)

Special Rules for One-Way Streets and Alleys

One-way streets have been designated to facilitate the movement of traffic. Vehicles move in the same direction as street cars and on the dead side. Parked vehicles stand on the live side of street cars, leaving space for safety zones. Thus vehicle traffic is not interrupted by stopping while street cars take on and discharge passengers, and the latter are not endangered by moving vehicles. In parking at an angle, autos are required to back in. Thus the top, when down, overhangs the walk, while if headed in, the tops of the larger machines would not clear the street cars.

Sixth Street and Eighth Street between Washington and Market, southbound: Vehicular traffic shall move south on the east side of the street. Waiting vehicles shall stand on the west side, facing south, at an angle of 30 degrees with the curb.

Seventh Street, between Washington and Market and Ninth Street between Washington and Pine, northbound: Vehicular traffic shall move north on the west side of the street. Waiting vehicles shall stand on the east side, facing north at an angle of 30 degrees with the curb.

Vehicles stop with the left to the curb: Since traffic is moving ahead on the left side of the street, vehicles may stop with left side to the left curb, long enough to load or unload, but if intending to park, must take up a position on the right-hand side of the street.

Turning: In turning to the right into a one-way street, the center line of the latter must be passed before making the turn. In turning to the left into a one-way street, the center line of the latter must not be passed before making a turn.

Alleys in business district: In all east-and-west alleys, vehicular traffic shall move west; and in all north-and-south alleys it shall move south.

Signs

"Safety Zones": (Secs. 787 to 789, R. C. 1914.) These signs are placed to designate the space reserved for pedestrians waiting for street cars and through which vehicles must not be driven.

"Congested District" signs are placed at all street corners within the congested district.

"No Parking" signs are furnished and placed by the Department of Streets and Sewers on the curb to designate the ends of the space within which vehicles must not be parked, in accordance with the congested district regulations. (Sec. 1335, R. C. 1914.)

"One-way Traffic Street." These signs are placed at each street corner on a one-way traffic street, designating the direction in which traffic must move.

"In" or "Out" signs are placed at the entrance to one-way alleys in the downtown district, to designate the direction of traffic through the same.

"School Zone" signs are placed on either side of and 100 ft. from school buildings as a warning to drivers to use exceeding care for the protection of children crossing the street.

"Zones of Quiet" signs are placed in the neighborhood of hospitals and similar institutions, where particular care is to be exercised in preventing unnecessary noise. (Secs. 1196–1198, R. C. 1914.)

Pedestrian lines: At certain street crossings in the downtown district, white lines are marked on the roadway pavement, within which pedestrians are expected to stay when crossing the street.

Equipment of Motor Vehicles

Brakes: Adequate brakes must be provided and kept in good working order at all times. (State Law, 1917.)

Warning signals: Every motor vehicle operated on the public highway shall be equipped with a warning device capable of emitting a sound adequate in volume to give warning of the approach of said vehicle. Every person operating a motor vehicle shall sound the warning device whenever necessary, but not at other times. (State Law, 1917; see Secs. 1323 and 1324 R. C. 1914.)

Mufflers shall be attached to the engines of all motor vehicles and shall be of such capacity as to quiet the maximum possible exhaust noise as completely as practicable. (State Law, 1917; and Secs. 1317 to 19, R. C. 1914.)

The muffler cut-out shall be completely closed and disconnected from its operating lever so that it cannot be opened while said vehicle is in motion. No vehicle shall be driven in such a manner as to produce unnecessary noise. (State Law, 1917; and Secs. 1317 to 19, R. C. 1914.)

Locks: Motor vehicles should be provided with good and sufficient locks, installed in a manner that will allow the moving of the car, when necessary, by the Police and Fire Department.

Copies of traffic ordinances similar to these are provided free to motorists in every large city. When touring, one should secure a copy for each large city he enters.

One-way streets are usually those in which street cars run in one direction only. Alleys in business districts are also one-way.

Sec. 1335, under **"Congested District"** above, has been amended. For instance, "No Parking" space, would apply to other than congested districts, if in the judgment of the Director of Streets such spaces are necessary, for the interests of a business firm in loading and unloading freight, etc.

RULES OF THE ROAD AND POINTERS ON DRIVING

The following illustrations show how to make turns, pass other vehicles and street cars, etc.

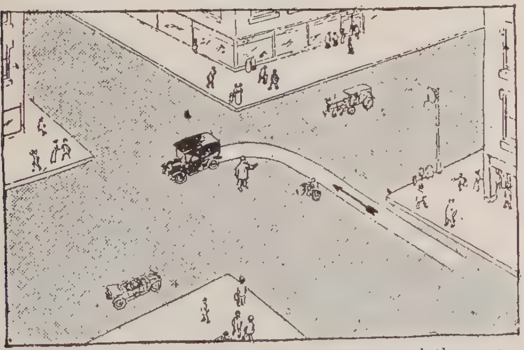


Fig. 1. **When turning to the left,** pass around the center of the intersection of two streets.

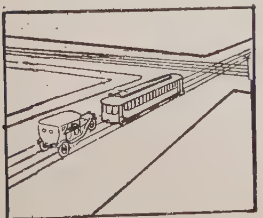


Fig. 2. **Passing a street car on the left** is a violation of the law.

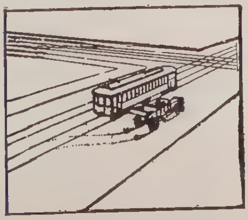


Fig. 3. **The right way to pass a street car is on the right,** and if passengers are getting on or off, stop.

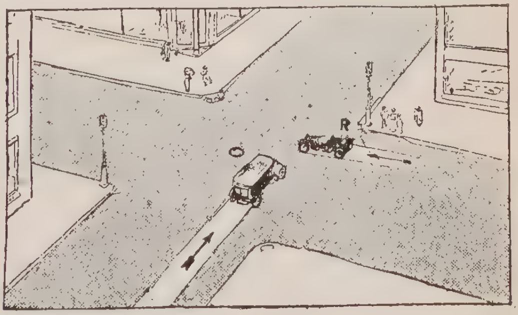


Fig. 4. **When crossing a street,** the right-hand vehicle has the right-of-way.

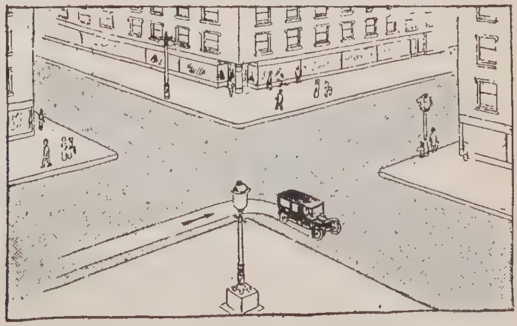


Fig. 5. **When turning to the right,** keep near right-hand curb.

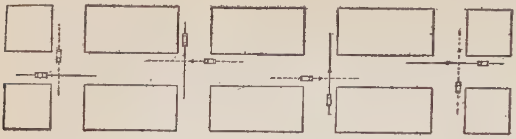
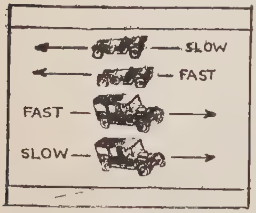


Fig. 6. It is the rule in many cities that **when two vehicles approach a street intersection simultaneously** in the manner illustrated, the vehicle at the right, as indicated by the heavy lines, shall have the right-of-way, regardless of the direction traveled.



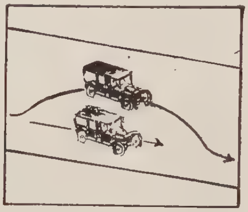
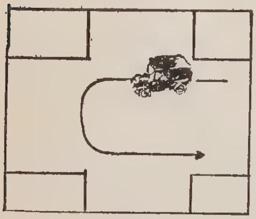


Fig. 7. **Slow-moving vehicles** should keep close to curb.

Fig. 8. **One car passing another going in the same direction,** should pass on the left of the car ahead. Do not cut directly in front of the car which you pass.



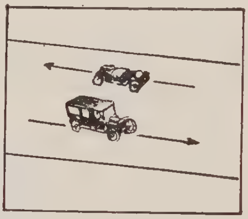
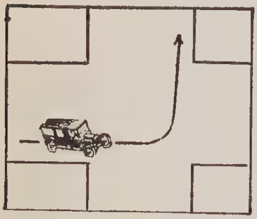


Fig. 9. **When turning,** go to the far corner, then make a wide swing.

Fig. 10. **Keep** over as near as practicable **to the right-hand curb when driving slowly,** so as to leave the center of the street free and open for faster traffic—the slower the speed, the nearer the curb.



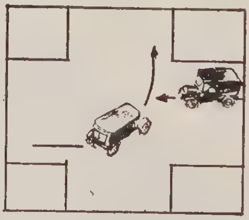
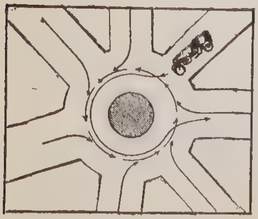


Fig. 11. Clear the center intersection of the street when making a turn.

Fig. 12. **In turning corners, with a car coming,** give a signal with your hand to indicate the direction in which you intend to go and as a hint for him to slow up. Always observe a central point in the intersection of streets, and clear it when turning.



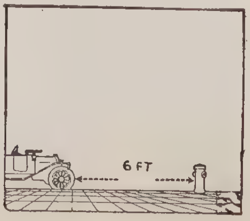


Fig. 13. **Approaching a circle;** arrows point the way in which to enter and leave.

Fig. 14. **Don't park closer than 6 ft. to a fire hydrant.** The distance varies; in some cities 10 and 15 feet is the limit.

Precautions

Approaching railroads: When approaching a railroad crossing, especially if there is an incline or grade, the car should be dropped back into second speed and the approach made carefully, first so that the driver may be in a position to determine whether to make the crossing or not, and second, to be in position to accelerate the car suddenly with very little chance of stalling the engine.

Many accidents have happened because inexperienced drivers have become confused and stalled their engine. On noting the approach of the train, they have thrown on their power, or let in their clutch suddenly, with the result that the egnine is stalled, and it is then too late to move out of danger.

When crossing street-car tracks and climbing out of ruts, skidding can be prevented and accidents avoided, and the life of your tires can be lengthened, if you will learn how to turn your car out of tracks and ruts. Make a sharp turn of your front wheel. Do not allow the wheel to climb along the edge of the rut and finally jump off suddenly, and do not attempt to climb out of these conditions at speed.

Rounding corners at speed: Driving a car around a sharp corner at twenty-five miles an hour does more damage to the tires than do fifteen or twenty-five miles of straight road work. This is an economical reason why one should drive around corners cautiously and slowly. The other reasons are obvious.

Excessive sounding of the horn is proof that the motorist is a novice. No accepted rules exist in regard to the meaning of horn blasts, but it is reasonable to assume that prolonged honking indicates that the car behind is going to pass and desires a clear road.

Headlight Courtesy on the Road and Signals when Stopping, Slowing down, or Turning

You know how very difficult it is to see when you are approaching another machine with glaring headlights. You are simply blinded, and cannot tell whether you are running off the road, are too close to the oncoming machine, or are striking obstructions. It is a peculiarly helpless feeling to be directing a car when confronted by the other fellow's glaring lights in this way.

If your headlights are on and are not equipped with non-glare devices, he is in just the same predicament, however, and the least either of you can do is to dim the headlights while passing. This is a safety factor as well, for it protects each from running into the other, or off the road. In most states a law prohibits the use of glaring headlights.

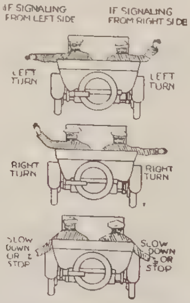


Fig. 15. Signals when turning or stopping.

If you are standing still on the side of a street and intend to start and turn out into the street, signal in the manner shown in Fig. 15, and look before you turn into the street. Many accidents have occurred from a failure to do this.

When you intend to slow down, stop, or turn, signal as suggested in Fig. 15. In many states the law requires closed cars to be equipped with a **stop signal** in the rear of the car, such as a red light which is automatically thrown on when the car slows down, or turns.

Stop Signals

In a number of states there are laws providing that all closed cars shall be equipped with a rear signal device which will indicate to the driver of the car in the rear that the car is going to slow down or stop.

There are a great number of devices on the market for this purpose, one of which deserves special mention, and is called the Neo-Lite. It derives its name from the fact that Neon is used in a glass tube which is subjected to static electricity, thus giving an orange-red glow which can be seen at a great distance.

Neon is an element of the air. When air is split up into its component parts: oxygen, nitrogen, argon, etc., Neon is one of the elements segregated, and it is this Neon that is used in a glass tube shaped like a hand, which is used as a stop signal. Neon is one of the air's rarest gases. There is only 1 cubic inch of Neon in approximately 100,000 cubic inches of air.

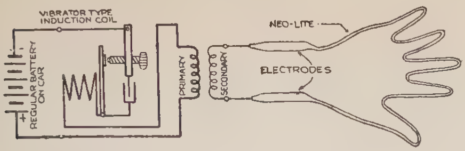


Fig. 16. The Neo-Lite; a stop signal.

An examination of Fig. 16 will show that a small induction or secondary coil is used, something like a vibrator type of spark coil. This is used to intensify the low voltage to a high voltage.

The glass tube (shaped like a hand) is filled with Neon, which has 75 times less resistance than air. For this reason, when connected with the secondary terminals of the coil and contact is closed, the Neon glows, giving an orange-red glow.

The connection for closing the circuit can be attached to the brake pedal, so that when the car is slowed down, the current from the battery is connected. The device is enclosed in a metal case mounted on the fender. Owing to the low resistance offered by Neon, the current consumed is approximately one-eighth less than that of an electric bulb generally used. Experiments have proved that Neon offers so little resistance to the passage of electricity that, where a 15,000-volt current is required in air, a 200-volt current will suffice in pure Neon. In other words, a spark that will jump 1 inch in air will jump 75 inches in pure Neon. The manufacturer of this device is the Federal Signal Co., Albany, N.Y.

Join the A. A. A.

"**A.A.A.**" stands for The American Automobile Association, which is the national organization of motor-car users. It was organized in 1902, and has a membership of over 200,000.

You should join your local club if it is affiliated with the A.A.A.; otherwise join the national body direct.

The A.A.A. is striving for a federal highways system; urging the adoption of uniform traffic laws; advocating federal registration; and mapping the roads of the country.

Members can always obtain exact and detailed information from the national bureaus of the Touring Board in Washington, D.C., and New York City, and also from the local clubs in practically every important city throughout the United States. Address; The American Automobile Association, Albee Bldg., Washington, D.C., or 501 Fifth Ave., New York City, N.Y. Mention Dyke's *Automobile Encylopedia* when writing.

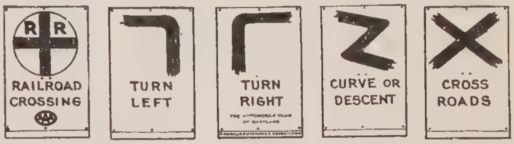


Fig. 17. The A.A.A. international road signs.

INSTRUCTION No. 59

TOURING: Touring Equipment and Pointers

A TRANSCONTINENTAL TOUR—THE LINCOLN HIGHWAY

The following offers full suggestions regarding the equipment necessary and other details incident to a long tour. A short tour, of course, would not require such an elaborate equipment as that suggested below, and it can, of course, be reduced accordingly.

The transcontinental tour is now comparatively easy and decidedly worth while to anyone who can possibly arrange to take it. We use the term "now," because such has not been the case in the past. Until very recently, a trip across the continent has been more or less of an adventure, a somewhat hazardous as well as an expensive and lengthy undertaking, requiring some measure of endurance.

The following is taken from an article which appeared some time ago in the *Motor Age.*

One can drive for nearly 2,000 miles across the country without once being more than half a mile from the familiar red, white and blue Lincoln Highway markers.

The only thing which might make a coast-to-coast automobile trip a hardship would be a lack of proper equipment and perhaps attempting the trip at the wrong time of year.

The greatest asset on a trip of this kind is "common sense." The next greatest asset is "efficient equipment."

The time required for the trip, with easy driving, will be nineteen days, driving approximately ten hours per day. This will make an average of approximately eighteen miles per hour, during the driving time.

Dress: White collars and cuffs are impossible in camp, and soiled linen looks a thousand times worse than a flannel shirt. The khaki and flannel are much more welcome in a hotel.

Make ready before starting—not after. Fit yourself as well as your car.

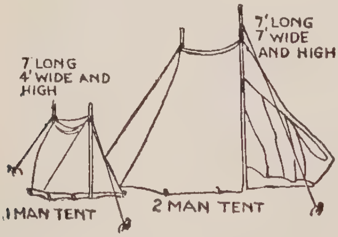


Fig. 1 Fig. 2

The tent: If a one-person affair where two sleep together, it should be a balloon silk tent, 7 x 7 x 7 feet, A-shaped, with waterproof canvas floor sewed in, and loops along the ridge to which to tie the rope when stretched between trees or in using poles. (See Fig. 1.)

The one-person tent (Fig. 1), called the Trego tent, can be A-shaped, 7 feet long, 4 feet high by 4 feet wide, with a ridge rope sewed on and extending about 10 feet beyond each end. Floor, waterproof canvas sewed into the side walls, which hang over slightly.

At the head end is a little window covered with mosquito netting sewed in, and outside of this is a curtain which may be raised and lowered at will from the inside of the tent. At the foot are two flaps, overlapping each other when closed, and equipped with snaps and rings for fastening, either open or closed. Sleep with the flaps and window of your tent open, unless it is storming. A rope loop is attached to each corner for stakes, but, as a rule, the stakes will not be necessary, as the bedding holds down the floor.

This tent may be slung between two trees. If not used in this manner, the ropes at each end should be led over 4-foot stakes of some kind, and the corners of the tent must then be staked down, so that the walls will act as cross-pieces to keep the end poles upright.

This size tent will take blankets folded once over, and all of the extra clothing, etc., can go under the blankets at the head, and serve as a pillow.

The blankets are to be pinned across the foot of the head end, with horse-blanket safety pins, procurable at any harness store, spacing them about 8 inches apart. There should be two pairs of heavy blankets, and one cheap cotton quilt. Fold this last mentioned over once, and place under blankets to serve as a mattress.

Always keep a small whisk broom handy.

Sleep with clothes on, unless the weather is warm; simply remove your shoes, leggings (use only canvas leggings, not leather), hat, and handkerchief.

Camp location: Pitch where natural drainage will carry water off in case of rain. In the forest, cut a lot of small pine branches, no thicker than your finger, and rip-rap these with the stems to the foot, making a pad the full width of your tent, and about a foot thick, before you lie upon it. If there are no trees to furnish this, dig a trench about 3 inches deep by 8 inches wide just where your hip will come when you lie upon your side. This will add wonderfully to your comfort.

It makes no difference how the tent is placed, except that care should be taken not to get the foot or open end toward the wind.

Protection from the wind: Try to get the camp out of the wind, on account of cooking. Alongside of the woods is much better than in them, on account of the mosquitoes, flies, bugs, etc. Get near running water, if possible, although by carrying a 5-gallon milk can on the running board you are independent of this.

Drinking water: Should be selected and carried in a 5-gallon milk can, which can be held in place by a wood circle placed on the running board, and by straps made on the order of a harness. Don't be dependent upon other water—keep a supply on hand.

When stuck in the mud[1]: If the rear wheels are stuck in the mud, dig holes in front of the front wheels for them to fall into, to give the initial start, and, if the car does not continue, then block the rear wheels instantly and repeat the operation. Place brush in front of the rear wheels and turn them as slowly as possible to keep from churning. If one rear wheel is on a good road, try putting on the handbrake fairly tight to destroy the action of the differential, or fasten the mired wheel so that it cannot turn, and the other wheel will do the work and slide the mired wheel along the ground.

The instant you realize you are getting stuck in sand or mud, stop right there and look over the situation, instead of fighting the car and burying it deeper and deeper.

Start early and stop before dark to select the camp site.

Use the windshield to keep the hot, dry air from burning your face, and have the top up all of the time for like protection.

Get all of your guide books before you start.

In asking directions, always apply to a garage or livery stable, but do not depend upon farmers, as their knowledge of the road does not extend very far.

In a party of four, let one do the cooking, another gather firewood, another put up the tents, and the fourth go over the car with oil can, turning up all grease cups, adjusting brakes, etc.

The Car Kitchen

This outfit is designed for four people and weighs about 10 pounds. All items marked* may be purchased at Von Lengerke & Antoine, Chicago, or Abercrombie & Fitch Co., New York, and the unmarked items may be obtained at almost any store dealing in such goods.

1 Arizona camp grate, 24″ by 12″.*

1 set pot hooks.*

1 aluminum folding baker, 8″ x 18″.*

1 canvas case for baker.*

The following Armorsteel pieces of cooking outfit may all be purchased of the firms mentioned above:

1 frying pan, 9⅞″ wide, with patent handle.

1 cooking pot, 9⅜″ wide.

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[1] Pull-U-Out Sales Co., 2024 Market St., St. Louis, Mo., manufacture a device suitable for this purpose, see Index.

1 cooking pot, 8⅛″ wide.
1 cooking pot, 7¼″ wide.
1 coffee pot, 6⅜″ wide.
4 soup bowls, 4⅜″ wide.
5 cups, 4″ wide.

Don't use aluminum cups.

6 plates, 8¾″ wide.
4 forks, with four prongs, 7¼″ long.
4 knives, 8¾″ long.
6 teaspoons.
2 cooking spoons.
1 carving knife, 10¼″ long.
1 sharpening stone.
1 set tin lids for the pots and frying pan.
1 pancake turner, 3″ by 4½″.
1 3-prong cooking fork.
1 collapsible wash basin, 12″ by 3″.*
1 camper's carbide lamp (Abercrombie & Fitch Co. No. 3A937; be careful to read the instructions).
1 lb. carbide for lamp.*
2 canvas duffle bags, 10″ by 24″ (use for food only).*
1 doz. food bags, 9″ by 9″.*
2 food bags, 9″ x 14″.*
1 agateware milk can with tight lid—2-quart. Use for stewed fruit only.
2 patent egg carriers.
1 tin bread pan, 10″ by 4″. Use also for washing dishes.
1 Inspirator, for camp fire (2 feet of small rubber hose, one end of which is slipped over one end of a 3″ piece of copper tubing, and the other end of this tubing is flattened to make a slit about 1/32″ opening). This is a wonderfully handy thing for getting a balky fire going.

Read matter under head of "The Car Kitchen" above. The Prentiss Wabers Stove Co., 34 Spring St., Grand Rapids, Mich., manufactures camp stoves. Marshall Field Co., Chicago, supply complete camping outfits.

Car Equipment

This equipment is suitable for a transcontinental trip or for a shorter one:

2 extra tires mounted on demountable rims.
2 extra tires with tubes, covers on them.
4 extra tubes in bags, under rear seat.
5 gallons good water.
60 ft. 5/16″ flexible steel cable.[1]
1 medium-size shovel, strapped to running board.
2 gallons engine oil, in 1-gallon cans. Under front seat.
1 set Weed chains, heavy type.
6 extra cross-chains.
1 set spring chain tighteners.
1 set regular tools for car.
1 car jack.
1 pair good cutting pliers.
1 piece hardwood 1½″ by 4 ft. by 10″.
1 2-quart canteen. Buy west of Missouri River.
1 blow-out patch for casing.
3 extra spark plugs.
8 ft. high-tension wire.
8 ft. low-tension wire.
1 extra valve and spring complete.
1 medium-sized axe. Strap to running board.
1 small can LePage's glue, for mending camera, etc.
1 hose, upper radiator connection.
1 hose, lower radiator connection.
1 canvas folding bucket for water; 9″ by 12″.
1 can cup grease; under front seat, and so packed that it cannot upset when melted.
1 set extra electric lamp bulbs.
1 set extra fuses for electrical system.
2 packages small, cheap towels, for wiping machinery, etc.; one dozen in each package.
150 feet ¼″ best Manila rope, for packing, etc.

Personal Equipment

When on a camping motor trip, the first thing of importance is common sense. The second is proper equipment.

Now for the list. This is the minimum for a long trip, and, of course, may be added to according to the tastes and ideas of the individual, but more is entirely unnecessary and should be avoided, if possible.

1 pair tan shoes, light-weight. Don't wear new shoes.
3 pairs light cotton lisle socks.
1 pair canvas puttees, light-weight. Don't wear leather.*
2 pairs khaki riding breeches, laced below the knee. Don't wear corduroy.*
2 pairs light wool drawers.
2 light-weight wool shirts to match above.
2 pairs B. V. D. under suits.
2 U.S. Army officers' brown shirts with patch pockets. These are twice as warm as $2.50 flannel shirts, and are practically wind-proof.*
1 light-weight khaki coat, to wear in towns.*
1 heavy mackinaw coat with shawl collar, for driving when it is cold at high altitudes, and by the camp fire.*
1 pair light-weight gauntlets, for driving.
1 pair old street gloves, for wear around camp.
1 khaki hat with narrow brim. Cut ½″ ventilating holes on each side.*
2 blue and white bandanna handkerchiefs. Tie up snug to your neck, and don't wear loose like the pictures of cowboys.
6 pocket handkerchiefs.
1 pair light-weight moccasins, for wear around camp and to sleep in.*
1 toothbrush.
1 hair comb.
1 pocket knife, three blades and strong.
1 pocket compass.*
1 safety razor and two extra blades.
1 can shaving powder.
1 shaving brush.
1 mirror, small.
1 Ingersoll watch, with fob.
1 pair yellow goggles; don't forget these.
1 pair white goggles.
1 tube toothpaste.
1 package bachelor buttons.
1 pair scissors, small.
1 set needles and thread.
1 pair manicure scissors; don't forget these; hangnails are a great source of trouble on long trips.
1 narrow leather belt.
1 stick camphor ice; much better than any form of cold cream and very handy in package. Use it only at night unless riding in the shade of the top, as the hot sun will blister the lips on account of the beads of moisture acting as lenses on the lips after using the camphor ice.
2 doz. cathartic tablets.
1 package gauze.
3 rolls gauze bandages, 2″ wide.
1 tube vaseline, for burns, guns, etc.
2 pairs 5-lb. wool double blankets.
1 cotton quilt.
1 tent (Trego sleeping tent). Purchase at Von Lengerke & Antoine, Chicago.
1 camera.
12 rolls film for camera.
1 Welcome photographic exposure record. This is a red book bought at any photo supply store.
1 small whisk broom, for use in tent, etc.
1 silk sleeping cap, to pull down over the ears.
2 coarse towels.
2 pipes, if you are a smoker, and plenty of your favorite tobacco.

* Items marked (*) may be purchased at Von Lengerke & Antoine, Chicago, or Abercrombie & Fitch Co., New York.

What to Cook and How

Bacon: This is the standby of all camping parties and is really the best meat to carry, as it keeps well and is easy to cook. It should be placed on bread and eaten as a sandwich; thus you will not miss butter. Fresh meat should be attempted only by the expert cook. There is a science in cooking bacon, and but few people seem to catch the idea. I will try to make it as clear as possible.

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[1] A good auto tow line (flexible wire) is manufactured by A. Leschen & Sons Rope Co., St. Louis, Mo. It is called "Hercules Wire Rope Towing Line," and is 25 ft. long between end fittings.

In the first place, do not buy the sliced bacon under any circumstances. Buy the bacon in the slab, as lean as possible, and of the very best quality. Buy one full slab at a time as you go along, and cut this into three pieces to go into one of the larger food bags. Now, when slicing the bacon before each meal, cut the slices at least 3/16″ to ¼″ thick. Bacon which is sliced thin cannot possibly be fried properly, as it will curl up in spite of you and burn one end while the other end is raw.

Cutting the bacon: After cutting the slices down to the rind, cut this off by passing the knife under the slices horizontally, with the slab lying flat. Lay the slices in the frying pan, putting in as many as may be required. regardless of whether they rest on top of each other or not. Set the pan on the grate, and, after the grease begins to form, tilt the pan this way and that, so that the grease flows all through the slices. Watch it carefully, and turn the slices frequently with your fork. In the meantime, have a plate warming on one corner of the grate, and as the slices become fairly brown on both sides, pick them out with the fork and pile them up as closely as possible on this plate. As soon as all are done, cover the plate with another, and set where it will be kept warm. This will keep the slices moist with the heat and grease left in them, and they will not become brittle and dry. The remaining grease in the pan can now be poured into one of the cups for future use, or for that meal, for **frying eggs,** etc. Eggs fried with bacon grease have a fine flavor.

It is astonishing how **few cooks know how to cook rice** so that the grains will be soft, and yet stand apart and separate. Boiled rice is a great dish for camp, if properly cooked, but is miserable stuff if cooked into a thick paste.

Take next to the largest pot and fill it about three-quarters full of cold water, and add about one half-teaspoon of salt; then put in three-quarters of a cup of rice and put on the lid, placing the pot over the fire on the grate where it will get a good heat to boil. The rice should boil for about 30 minutes, and, if desired, it may be tested by gathering a little in the spoon and chewing it, to see that the grains are soft. Stir frequently, and scrape the bottom of the pot with the spoon.

After the rice is done, take the pot to one side of the camp and pour off all the water you can by holding the lid in place and turning the pot almost upside-down. Now set it to one side with the lid on until needed, and the rice will steam so that the grains will stand apart. You will find this a delicious dish, which should be served with evaporated milk and sugar, or with a sauce of fruit juice. Cook a fresh lot for each time served, and do not try to save it for the next meal. If you have too much rice for the quantity of water, it will produce a mixture like glue, and is poor stuff to eat.

Fifteen-minute bread: Most campers will shy at making bread, but really it is very simple and is made in about 15 minutes. The patent baker is a marvel, and will brown the loaf equally on top and bottom, no matter how the wind blows. A special kind of fire is required to bake bread, so do not attempt it at the regular cooking fire.

To build the correct fire[1], drive two stakes in the ground about 2 inches apart, and 2 feet from there drive in two more likewise. Between the vertical stakes, lay a wall of sticks about 1″ to 1½″ thick, preferably green sticks, and against this wall set a lot of fire stuff which will burn rapidly and make a high flame with little smoke. You must have a high flame. This should be kept going brightly until the bread is done. (See Fig. 4.)

Test the bread by piercing the loaf with a sliver of wood. If no dough sticks to the sliver, then the bread is done. Of course, it should be fairly brown on top before testing. Leave the pan in the baker and remove from the fire, setting to one side where it will receive a little heat from the regular fire to keep warm. The aluminum baker will retain the heat for quite a while.

Carry whole wheat flour only, and in the larger food bag. Of this take one and one-half cups and put it into the bread pan for mixing. Add to this one and one-half heaping teaspoonfuls of baking powder, one level teaspoon of salt, three teaspoons of sugar, and one and one-half cups of water. Stir gently until thoroughly mixed, but do not beat. Warm the baking pan, and then grease it all over the bottom and around the sides and corners with a strip of bacon rind. Then pour in the batter you have made, and place the pan in the patent baker. Set this before the baking fire quite close, say one to two feet. It will begin to rise immediately, and will bake into a loaf about one to one-half inches thick, which will be just right for four hungry people. This bread is great, and will stick to your ribs on the long hike. It is so much better than baker's bread, and very little trouble after you once get the hang of it.

Dessert à la tour: You will find that stewed fruit is far ahead of the canned goods, and much better food. In the food list you will notice that peaches, prunes, and apricots are specified, dried. These will all be mixed together and used that way. The flavor is much better than when used separately.

Fill your 2-quart milk can about one-third full of this dried fruit, and then fill up with cold water, adding three tablespoons of sugar the day before you start, and then at the first night stop, place the can on the grate over the fire and allow to simmer, first loosening up the lid to let the steam escape. After serving the fruit, you can put in more fruit, add more water and sugar, and carry it with you to the next stop, repeating the simmering process. In this manner the mixture will become quite syrupy and of fine flavor. About every three days empty the can and wash out with hot water, beginning over again as you did in the first place.

The breakfast drink: Use 3 teaspoons of ground coffee to one cup of cold water in the coffee pot. Set on the fire until it comes to a boil; then pour one half-cup of cold water over the top, going round and round, and a little down the spout. Set the pot aside until served, and then pour carefully and slowly, and the coffee will be clear. No egg or anything of that sort is needed to make clear coffee. If the coffee food bag is tied tightly, it will keep in the ground state all right, so do not carry it in the can in which it is sold.

Tea: If tea is used immediately, pour boiling water over the tea leaves and let stand for a few moments only. If it stands very long with the leaves in the pot, it will make a mixture which will absolutely tan the lining of your stomach. If the tea is to be kept for any length of time, put the tea leaves in a piece of cheesecloth, and tie with a bit of string, fishing this out of the pot after the tea has soaked for a moment in the boiling water. Shake out the cloth and put away for the next time. If the cloth is used, you can save the tea for a long time, and serve cold, if desired. This is often handy for the late hunter in camp, if side hunting trips are made away from the car.

The army ration: Erbswurst (pea sausage in English), powdered pea meal, and bacon. This is a very palatable and nourishing food, and is used extensively as the perfect army food by the nations of Europe. It is sold in round packages about 1″ in diameter and 4″ long. Each package is marked in six divisions, one of which is to be used for each cup of water. Boil for 20 minutes. It is already seasoned.

Pancakes are very nice for a change, and should be served with maple syrup, as one craves sweets when living out of doors. Buy the syrup in small cans. For the cakes, buy self-rising buckwheat flour and mix with cold water, with possibly an egg added for richness, until the batter is quite thin and will run readily from the spoon. Rub the frying pan with grass or a rag thoroughly, to smooth its surface; then grease with a strip of bacon rind and pour in a large spoonful of batter at a time, while the pan is piping hot. The pan will hold three cakes of this size at a time. Cut them apart with the pancake turner as soon as you can, and loosen them from the frying pan by slipping the turner under the cake without lifting it. As soon as you can handle them on the turner, flop them over to brown on the other side. If the batter is not thin enough, the cakes will be tough and heavy.

Potatoes are really a necessary article of food on a long trip lasting several weeks, and should be served about once each day, if convenient. Peel the potatoes, and then boil them in the largest pot for about twenty minutes if you are going to fry them, and forty minutes if they are to be served boiled only.

In high altitudes, the boiling process will require much longer, as the water boils at lower temperature. "All that bubbles does not boil" in the high mountains.

To fry the potatoes, first boil them as directed above, and then cut into slices about ¼″ thick. Pour about 1/16″ of the bacon grease into the frying pan, covering it evenly. Heat this on the fire until it sizzles and put in the potatoes. Take a knife and immediately chop the potatoes into small pieces and put on the cover. Stir and turn over frequently with the knife and test them for softness with its point. When nice and soft they are ready to serve, and the bacon grease will give them the desired browning. The bacon grease has a much better flavor than lard.

Canned goods: These are good for a change, where they can be conveniently carried, but are not at all necessary. In all cases of vegetables and soups, simply pour the contents of the can into one of your pots and heat it over the fire. Do not forget to stir it to keep the mixture from sticking to the bottom of the pot.

Water: Be very careful of the water you drink, especially west of the Missouri River. If there is a white deposit around the edge of the lake or pond from which you wish to get the water, it is alkaline and will make you very sick. Fill your big milk can with good water in the towns, and then drink that instead of taking a chance on water found by the roadside. Animals can drink alkali water without harm, whereas it would seriously affect a human being.

This 5-gallon supply of water will be used for all purposes, as it will be required only for the radiator in case of accident. Fill the radiator when you fill the gasoline tank, and you will have all you need.

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[1] See Figs. 3 and 4 for building a "cooking fire" and "camp fire."

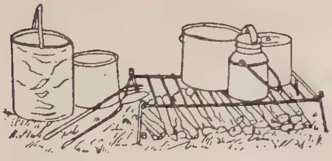

Fig 3.

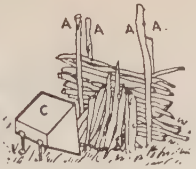

Fig 4.

Fig. 3. Explains the method of making a cooking fire as described. Note the iron rods (B) and iron frame with crossrods.

Fig. 4. Explains the method for building a baking fire, which must be high. Note that the sticks (A) are of green material, whereas the burning material is dry. (C) is the patented baker, made of aluminum.

Cooking fire: This fire is to be built under the grate the four legs of which have been driven into the ground until the grate is about 8″ high. Build this fire of small sticks, from the size of your finger to 1″ diameter, no larger. Have this fire at some distance from the cars and from the main camp fire, and on the lee side of both. The sticks should not be over 14″ long. The smaller the fire, the easier to keep the heat down, so that the cook is not roasted as well as the food. You may build the fire the full length of the grate if you wish, but keep it down. Do not attempt to cook at the camp fire, for the smoke and heat will make it a martyr's job. Fig. 3 shows the proper method.

A baking fire: Build this away from the other two, as shown in Fig 4.

Camp fire: Do not build this near the cars, and be sure to have it on the lee side of them on account of possible sparks. Build a moderate-sized fire only, so that you can gather closely around it and converse easily. "Injun build little fire and sit up close—white man build big fire and sit away off." Build yours the Indian style. Be sure to put out all fires with your shovel before breaking camp. The western forestry laws are very strict about this.

Packing: Packing the outfit on the car is quite important, and it should be standardized at the start, and then everything always should go back in the same place. Much time may be saved if this is carried out, as each member of the party becomes familiar with the location of each item, and the car will be loaded in an astonishingly short time.

Method of stowing is as follows:

Cooking grate—under floor mat in tonneau.
Large water can—right running board forward.
Extra tires not on rims—left running board forward.
2 tent beds—on end, each side of back of front seat. Tie to robe rail.
Cooking utensils—between these beds in tonneau.
1 tent bed—right running board; strapped on.
1 tent bed—left running board; strapped on.
Shovel—left running board behind tires.
Axe—tonneau floor; just back of beds.
Food bag—tonneau floor; passengers can rest feet on it.
Patent baker—hanging where it will not be crushed.

The cooking utensils all go into a canvas bag which is sold with them, and the outfit is very compact.

Food List

2 slabs best bacon—lean.
5 lbs. whole wheat flour.
5 lbs. sugar.
1 lb. salt.
2 lbs. best baking powder.
2 cans maple syrup, small cans
1 can pepper, small.
8 lbs. ground coffee.
12 cans evaporated milk, unsweetened.
1 roll surgeon's plaster 1″ wide—for sealing cans, etc.
5 lbs. dried fruit—apricots, peaches, prunes, in equal portions.
1 lb. tea.
1 can cocoa.
1 lb. self-rising buckwheat flour.
3 lbs. rice.
2 cans tomatoes.
2 cans corn.
2 boxes graham crackers.
4 quarts potatoes.
12 packages Erbswurst.
2 doz. eggs in patent carriers.
2 boxes bouillon cubes.

Some of the Concerns Who Make Camping Equipments

Marshall Field Co., Chicago, camping refrigerators, lunch equipment, tents and complete camping outfits.
Cozy Camp and Auto Trailer Co., Indianapolis, Ind.
Auto-Kamp Equipment Co., Saginaw, Mich.
Ideal Mfg. Co., North Kansas City, Mo., folding shovel.
Peoria Auto Kot Co., Peoria, Ill.
Boyle Mfg. Co., 5101 Santa Fe Ave., Los Angeles, Cal., camp grates, canteens, etc., for touring.

Touring Tents, etc.

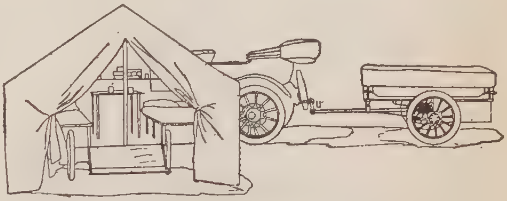

Fig. 7 Fig. 6

Fig. 6. Pictures a new idea of camping. A trailer (Fig. 6) is carried with you, and it is claimed that it will travel 50 miles an hour along with the car. The tent and all parts are placed into this trailer.

Fig. 7. Shows the tent when removed from the trailer, and the trailer used as the floor. The tail gate of the trailer is utilized for a step. This outfit is made by the Auto-Kamp Equipment Co., Saginaw, Mich. Another good outfit is made by the Tentobed Co., 3300 Jackson Blvd., Chicago, Ill.

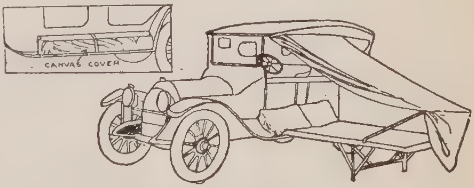

Fig. 8. Shows another principle. Note the compact form of the outfit (shown in the upper corner) when placed in a box on the running board and covered with canvas.

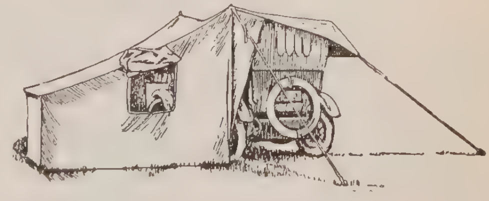

Fig. 9. Another outfit: The tent has a floor 8 feet square, which is sewed in. An extension of about 2 feet on the front edge of the floor can be fastened over the running board of the car. The front wall of the tent is 7 feet high and extends over the top of the car, when the tent is pitched in this way, or it may be used as a straight front for the closed tent when the car is not attached.

The illustration, Fig. 9, shows the arrangement of the tent in relation to the motor car. The tent can be used also without being attached to the car.

Two 7-foot poles prevent undue strain on the car top. The poles are cut with slip joints to be of proper 4-foot length to carry on the running board. The side walls have extensions of about 10 inches on the front edges to fasten to convenient places about the car, making a tightly closed tent in case of storm or cold wind. One side wall has a window, and the other has a door.

The rear wall is about 3½ feet high, and is kept at a convenient height by its location near a fence, tree or other object to which ropes could be attached.

The tent is made of khaki at a cost of $18. Folding camp cots are used. The use of heavy blankets on the tent floor during cool weather is preferred to the cots. The tent is adapted to an Overland by a 6-inch flap sewed to the front wall to make sure of protection for the car. The size given is suitable for a car having a 7½ or 8-ft. top.

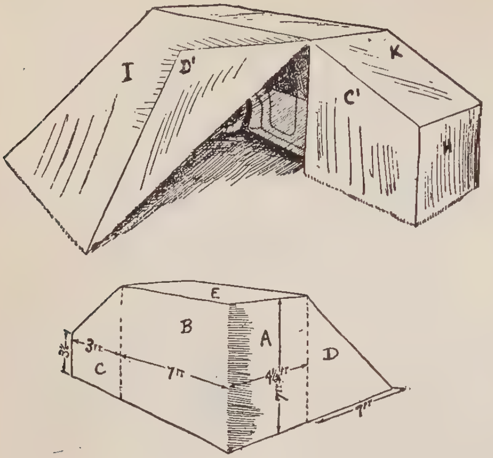

Fig. 10. A serviceable tent for touring. Use 8 oz. duck which comes in 36″ widths and can be purchased at 20c. per yard.

Dimensions of tent in square feet: (A) 4½′ x 7′=31½′; (B) 7′ x 7′=49′; (C) 3′ x 5¼′=15¾′; (C1) 3′ x 5¼′=15¾′; (D) 7′ x 3½′=24½′; (D1) 7′ x 3½′=24½′; (E) 4½′ x 7′=31½′; (H) 4½′ x 3½′=15¾′; (I) 7′ x 10′=70′; (K) 4½′ x 4½′=20¼′; total 298½ sq. ft. or approximately 33¼ yds. at 20c. per yard, making $6.65. (*Motor Age.*)

Note: Symbols expressive of feet (′) and inches (″).

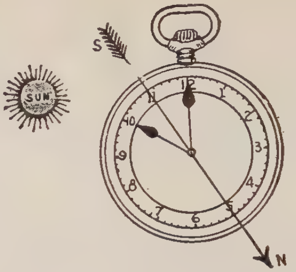

Fig. 11. **To use your watch as a compass:** Point the hour hand of your watch to the sun at any time of the day; then lay the watch flat in your hand. A point midway between the hour hand and 12 on the dial will be due south.

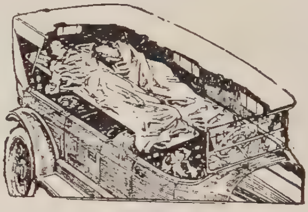

Fig. 12. **The Auto-Kot** is a very serviceable and compact adjustable cot which can be placed on the top of the rear seat, and the front seat of a 5 or 7-passenger car. It can be folded in a very compact form and placed back of the front seats. (Peoria Auto-Kot Co., Peoria, Ill.)

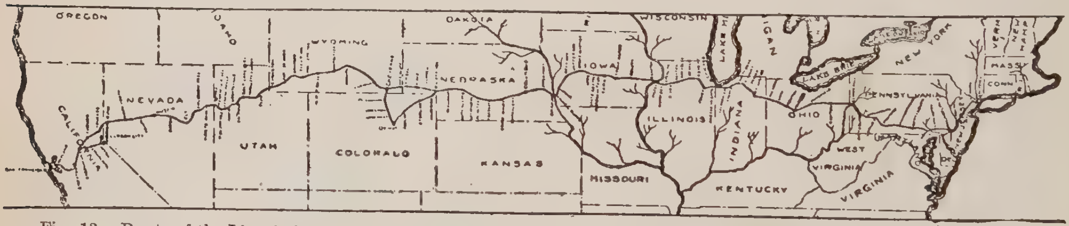

Fig. 13. Route of the **Lincoln Highway.** Further information can be had from Lincoln Highway Association, Detroit.

THE AUTOMOBILE BLUE BOOK, A TOURING GUIDE

These books cover the entire country in **four volumes.** They assist in planning a tour, show detailed running directions, road conditions, points of scenic and historic interest, city maps, and many other details of interest to a tourist.

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The price of each volume is $3.00. The address of the publishers is: Automobile Blue Books, Inc., 1056 W. Van Buren St., Chicago, Ill.

INSTRUCTION No. 60

THE AUTOMOBILE REPAIRMAN: Pointers for the Beginners; Starting in the Repair Business; Light Tool Equipment for the Auto Mechanician

POINTERS FOR THE BEGINNER

The auto repairman must know how to adjust any part of the car. To know how to adjust, he must first know the principles underlying the construction of the parts, as explained in previous Instructions, and must know when and where to look for trouble. (See Index under "Digest of Troubles.")

About one-half of the work of the automobile repairman is in making adjustments and fitting parts, such as carburetor adjustments, cleaning carbon, grinding valves, fitting horns, muffler cut-outs, diagnosing troubles, and numerous other little details, which do not require a machine shop, but do require a good assortment of tools, and a knowledge of the principles involved in the construction of a car.

A machine shop is not necessary, unless there is sufficient work to keep more than one machinist busy. A great number of small repair shops put in only the tools needed for the average repair work, and when they have a job of machine work to do, they take it to a machine shop. In other words, a machinist and an auto repairman follow two different trades. The auto repairman need not be a machinist; by machinist I mean one who can turn all kinds of metal parts on a lathe and do actual machine work.

System and Order

When beginning work on a car or engine, remember that system and order are two things every repairman ought to learn early. They mean success.

Fig. 1. Don't throw nuts or bolts on the floor. Place them in a box or pan.

There is nothing more disgusting to a man who owns a car, than to walk into a repair shop and find a careless workman dumping nuts, bolts, etc., here and there on the floor. That customer will say to himself: "If that workman is as careless as that, he is careless enough to leave a nut in my crank case and ruin my engine when it is started up, or he will leave off lock nuts or lock washers and cause me expense and damage."

A little piece of metal, such as a piece of a cotter pin or the like, accidentally dropped into a can of grease or oil and subsequently put into the gear case of a motor car has been known to cause much damage, and to cause the driver or owner of the car considerable trouble and expense.

A Careful Workman the One in Demand

If you do your work thoroughly and carefully and always do a little more than you agree to do, you will be sure to make a success.

It's the careful man the auto owner wants to handle his car, not the fellow he can't depend upon.

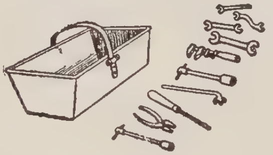


Fig. 2

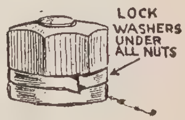


Fig. 3

Fig. 2. Keep your tools in a box or kit, not on the floor.

Fig. 3. Before turning a car over to the customer, be sure that all nuts have lock washers and are tight.

I will give you an example of a careless young man who lost his job. An auto owner had a young man overhauling his car; he told him to fill all the grease cups, and to be sure to see if the valve under the gasoline tank was tight; he had an idea it was leaking. He went away, and when he came back that afternoon he asked the young man if he had attended to the different things he told him to do. He said yes. Next day the auto owner was out on a country road and ran out of gasoline. He found that the young man had not examined the valve carefully, and the leak had exhausted the tank—the valve was in a difficult place to get at under the car, so he simply took it for granted that it was all right and let it go at that. So you see a careless man is worse than none at all—it's the dependable fellow who will win.

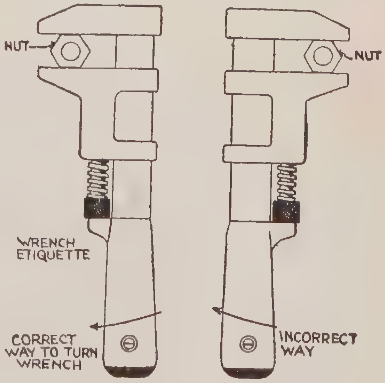


Fig. 4. Monkey-wrench etiquette. When using a monkey wrench or a Stillson wrench, use it as shown above. Most all nuts and bolts turn to the right to tighten and to the left to loosen. The proper method of using a wrench for the desired turn is shown above.

Don't Overcharge

We want to warn you that in the matter of charges, it pays to be liberal. Automobile repairmen, like plumbers, generally have a reputation for exorbitant charges. Make it a rule to do a little more than you agree to. It is well to comment on your work, in talking with the auto owner, like this: "I noticed that some of the nuts were loose around the springs, so I went over all the nuts on the running gear and found that many needed attention. You want to watch those little things, and then you won't need me so often." The owner may not say anything out loud, but he will certainly comment to himself, "There's a good repairman," and that is the most profitable reputation you can establish.

You are building a business for the future when you do your work right, and treat your customers fairly.

Don'ts for the Repairman

1. Don't lay wrenches, hammers, chisels, etc., on the fenders or on the seat cushions. Cover the fenders, and remove the cushions during the work.
2. Don't spill oil, or smear grease over the finish or upholstery.
3. Don't try to squeeze one car past another in the shop, even though the fenders will spring enough to let the car pass.
4. Don't pound the end of a shaft with a bare hammer. Use a babbitt hammer, or deaden the blow with a piece of brass or wood.
5. Don't push a car around the shop with greasy hands on the varnished surfaces. Either wipe your hands, or place a piece of dry waste between your hands and the car.
6. Don't leave a car standing in a pool of grease.
7. Don't use an 18″ Stillson on a ⅜″ nut.
8. Don't sit on the cushions with your greasy overalls. Spread a newspaper over them first, and don't put your greasy hands on doors, body, hood, etc.
9. Don't use the customer's gasoline just because its handier than to get some from the storeroom.

Starting in the Auto Repair Business

We will classify the automobile repair work into two classes: first, will be the automobile repairman who works in a shop under a foreman. His work is laid out for him and he is advised just what to do.

The second, is the automobile mechanician whom we will class as an expert; he will generally be found in the position of a foreman, or operating his own shop. We also find him doing work at the homes of automobile owners.

For the sake of classification and names to distinguish this latter class of work, suppose we call the "auto mechanician" the one who makes a specialty of doing work at the home of automobile owners, in the auto owner's private garage.

The Auto Mechanician—How to Start

Many men have found this work profitable and it has been the stepping-stone for a future. This work also applies to marine engine and stationary gasoline engine work.

In order to engage successfully in this work, it is necessary for the mechanician to provide himself with the necessary tools to do the average work around a car.

It is probably safe to say that nine cars out of ten need greasing; that is, the gears, the differential, the wheels, and the universal joints. This job is one that does not appeal to the auto owner, and the chances are that he is not prepared to grease his car if he wanted to. It is easy enough to put grease in the compression cups and screw them down, but to grease the rear axle parts and universal joints is a different job unless one is supplied with the proper tool. The auto repairman with the Townsend grease gun, as shown in Fig. 9, can do the job quickly and easily.

Then there are the valves to grind, carbon to clean out, lost motion in the valves to take up, compression to test—in fact, a general engine overhaul or a general car overhaul would constitute the work that the auto mechanician could do on these special jobs.

Very likely when the auto mechanician goes to an auto owner's garage to do repair work he will be provided with most material, such as oil, grease, waste, etc., but it is advisable to suggest a good oil and to request that the car be supplied with it, providing the oil in use causes a great deal of carbon. In other words, it will be necessary for the mechanician to be able to diagnose all troubles and suggest their remedy, as well as to make adjustment and overhaul the car.

The Auto Mechanician's Outfit

This is shown in Fig. 5, and is a suitable equipment for general work around a car, testing, etc.

The average workman carries more tools than are necessary to the job, and often finds that even then he does not have the right one. A careful study of the cars handled usually shows that twelve of the common tools will serve to do the ordinary job. It has been found that the following tools are most essential, and are adequate for most jobs: 4 open-end wrenches, Nos. 34, 25, 29, 734; 1 monkey wrench; 1 main-bearing wrench; 1 connecting-rod wrench; 1 screwdriver; 1 pair pliers; 1 valve cap wrench.

Repairman's Tool Kit

A well-assorted tool kit is shown in Fig. 5 Other tools and suggestions are illustrated below.

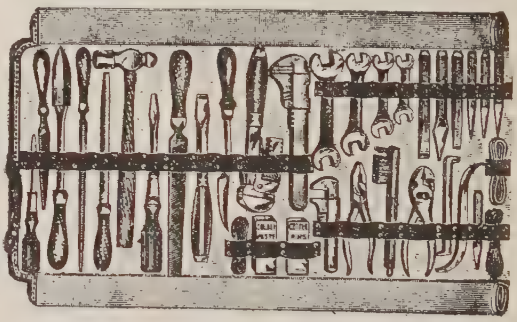


Fig. 5

6⅞″ drop-forged hardened wrench.
5⅞″ drop-forged hardened wrench.
4⅞″ drop-forged hardened wrench.
4″ drop-forged hardened wrench.
4½″ warding file with handle.
8″ square file with handle.
8″ flat file with handle.
7″ round file with handle.
5″ square shank screwdriver, polished.
Machinists' all-steel heavy screwdriver.
½-pound soldering iron with handle.
6″ side-cutting pliers.
6″ adjustable combination pliers, nickeled.
Machinists' bearing scraper.
9″ auto monkey wrench.
10″ Stillson wrench.
8-oz. machinists' hammer.
⅜″ cotter-pin extractor, polished.
⅜″ center punch.
½″ cold chisel.
Box solder paste.
Box cotter pins.
6″ offset screwdriver.
Spark-plug brush.
⅜″ cold chisel.
Bundle wire solder.
Bundle No. 15 copper wire.
Bundle No. 20 copper wire.
5″ bicycle wrench, nickeled.
½″ cape chisel.
⅜″ solid punch, 3/32″ point.
⅜″ solid punch, 3/16″ point.
⅜″ solid punch, ¼″ point.
3″ electricians' screwdriver.

The Vlchek Tool Co., Cleveland, Ohio, manufactures a complete line of tool kits.

A Trouble-Man's Repair Kit

The set shown in Figs. 6 and 7 is not designed for shop use, but for outside trouble calls. A leather-bound ¼ or ½-size suitcase (A) is fitted with four wooden trays made of 3/16″ hard maple. The thickness of the top piece (B) depends upon the

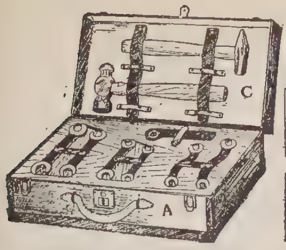


Fig. 6

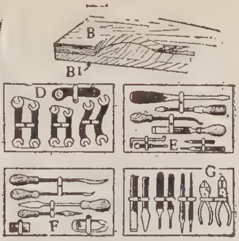


Fig. 7

size of the tools. Outlines are drawn on the wood with pencil and the wood is cut entirely away to permit tools to lie flush. The bottom piece (B1) is then glued on and fastened by wire brads. Buttons holding tools in place are made of sheet brass. General arrangement: hammers strapped in cover (C); wrenches in top tray (D); screwdrivers and punches in tray (E); bearing scrapers, oil stone, Prussian blue, tray (F); chisels, files, pliers, tray (G). (*Motor World.*)

Miscellaneous Light Tool Equipment

Such tools and devices as socket wrenches, large monkey wrench, a grease gun, oil guns, carbon scrapers, etc., are necessary. Electric testing instruments are shown elsewhere. The Weston instrument is shown below. See Instruction 63 for list of small tools for the repair shop.

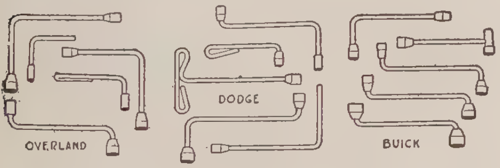


Fig. 8. Walden socket wrenches come in sets for various cars and are accurately made to fit the nuts on each car.

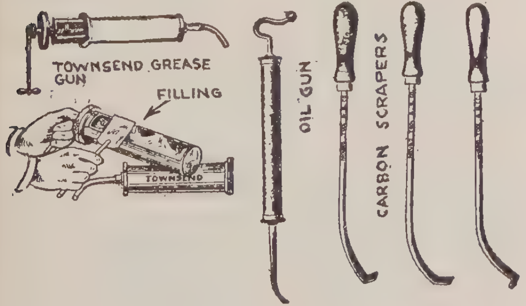
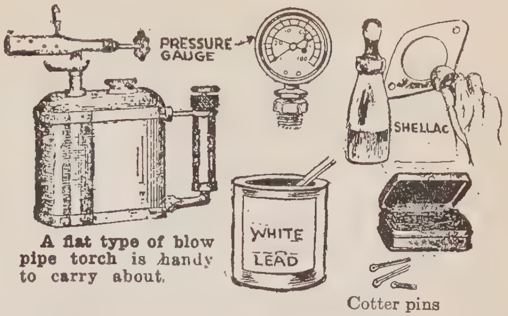
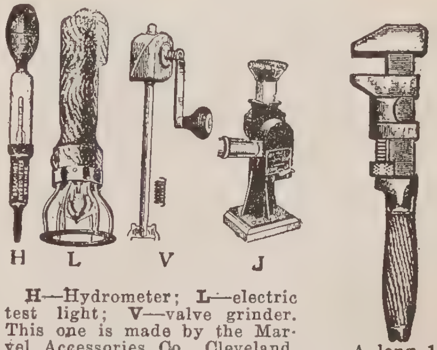


Fig. 9. A good grease gun is very essential. The Townsend grease gun can be obtained of the Townsend Co., Orange, N.J. An oil gun for general use is necessary. Carbon scrapers are shown at the right.



A flat type of blow pipe torch is handy to carry about.

Fig. 10. Miscellaneous tools and accessories are always needed.



H—Hydrometer; L—electric test light; V—valve grinder. This one is made by the Marvel Accessories Co., Cleveland, Ohio. J—jack.

A long 18 or 21 inch monkey wrench

Fig. 11. A hydrometer for testing storage batteries; a trouble light and a good jack are essential as is also a large 18 or 21-inch monkey wrench for removing hub caps, etc. See Index under "Magnet light" for an ideal trouble light.

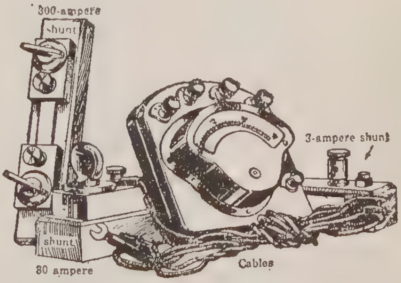


Fig. 12. An electric testing instrument is very necessary as 8 per cent of troubles are electrical. The instrument shown is the Weston model "280." Micrometers and a thickness gauge are also required.

A CAR OVERHAUL AT HOME GARAGES

The following enumerated list gives a detail of procedure in giving a car a general overhauling. Where the automobile owner keeps his car at home and cares for it himself, nine chances out of ten his car and engine need cleaning or greasing, the valves ground, or carbon removed. All of the work mentioned below can be done in the auto owner's private garage. This work then would require but a few well-selected tools, and the auto owner is likely to have most of them. Supplies such as oil, waste, etc., would be furnished by the auto owner. This class of work is well suited for the beginner or auto mechanician.

Cleaning the Engine

1. Clean the engine outside with gasoline.
2. Clean the engine inside.
3. Clean the drip pan.
4. Clean and pack the pumps.
5. Clean and adjust the spark plugs.
6. Clean the gasoline strainer.

Lubricating the Engine

7. Put fresh oil into the engine after cleaning.
8. Oil other parts of the engine, such as magneto, starter, generator, fan, etc.
9. Screw down on all grease cups, and refill.

Cleaning the Car

10. Wash the car (see Index under "Care of a car").
11. Polish the body with body polish.
12. Clean the clutch.
13. Clean the transmission and underneath the car.
14. Clean the steering device.

Lubricating the Car

15. Screw down all grease cups, and refill.
16. Grease the clutch shaft.
17. Grease the universal joints.
18. Fill the transmission with lubricants.
19. Fill the differential housing.
20. Grease the steering device.
21. Grease the front wheels.
22. Lubricate the springs.

Inspection and Adjustment

23. Inspect all bolts and nuts, and tighten. This will require a day's time, if properly attended to.
24. Inspect the gasoline line, and tighten all joints.
25. Inspect the balls of the front wheels when greasing to see if there are any broken balls. Jack the wheel, and listen for a clicking sound.
26. Inspect and tighten all loose water connections.
27. Inspect the tires and see if they are properly inflated.
28. Inspect the steering device and connections, and tighten and grease.
29. Inspect the springs and fenders and nuts, and tighten, and remove squeaks.
30. Inspect the rear wheels; see if loose; if so, draw up on the nut.
31. Inspect the differential; if noisy, take up lost motion.
32. Examine the brakes. If loose, adjust them, and also tighten spring bolts, nuts, and spring clips.

Inspection of Engine and Parts

33. Inspect the water hose on the engine, and replace with new hose if required.
34. Inspect the gaskets on the engine, and draw up on the cylinder head.
35. Inspect the bolts and nuts holding the cylinder to the crank case, and tighten.
36. Inspect all nuts, and tighten on the crank case.
37. Inspect the generator adjustment, and draw up nuts.
38. Inspect the nuts holding the exhaust and inlet manifold, and tighten.
39. Inspect for air leaks at the carburetor, manifolds, and spark plugs. If there is a leak, the engine will not idle properly.
40. Inspect all nuts and cotter pins, and tighten.
41. See that lock washers are under all nuts.
42. Inspect the muffler and clean if necessary, and tighten up.
43. Inspect the timer or magneto, and see if connections thereto are tight.
44. Inspect horn, magneto, switch, generator, starter and battery, and coil connections. See if there are any loose binding posts or connections. Don't forget to tighten all ground connections.
45. Inspect the battery. See if all terminals are tight.
46. Inspect and test the storage battery with a hydrometer.
47. Inspect the starting motor and generator to see if there are loose connections.

Engine Adjusting

48. Test the compression.
49. Clean carbon from the cylinders.
50. Grind valves.
51. Adjust valve clearance.
52. Test for weak exhaust springs.
53. Test the engine for knocks.
54. Take up on any loose bearings.
55. Fit piston rings, if necessary.
56. Check up the valve timing.
57. Clean and adjust the spark plug gaps.

Note. These subjects, as well as how to make adjustments and rep[illegible] are fully treated farther on.

INSTRUCTION No. 61

THE GARAGE: Building and Equipping

Many, after starting in a small way, soon earn enough to start up a shop of their own. We will now lay out a procedure for starting a shop or garage.

A garage is a place where cars are stored and cared for. Most garages also have shops in connection.

If only a shop for repairing automobiles is planned, then figure on enough room to take care of at least four or five cars while working on them.

A repair shop without the garage is profitable, and can be started for much less capital. If the repairman is just starting out and his capital is limited, the best plan is, of course, to start in a small way.

The question to decide is whether you intend to do strictly repair work, or to store cars and repair, and also whether you will conduct an agency for some car, and carry supplies.

Garage

A garage is termed a place for storing cars, but is subdivided into departments: storing, salesroom, auto-supply department, and repair shop.

The garage equipment consists of suitable space for the number of cars you intend to store, bearing in mind that the space devoted thereto should be utilized to the best advantage. For instance, cars which are used frequently and regularly should occupy that space where exit is easy, usually nearest the exit. The wash rack should be in a convenient location, and the garage supplies, such as oil and gasoline, should be where convenient, yet not interfere with the space occupied by the cars.

The salesroom, office, and stockroom should all be carefully planned. The stockroom quite often is utilized for small tools and accessories, but it is better to display the accessories in some sort of showcase or shelves in a space in the salesroom.

Repair Shop

The repair shop can be subdivided into departments as follows: machine shop, tire repair, welding room, electrical apparatus and testing department. The testing department should be a space allotted for the purpose of diagnosing the troubles, before actual work is begun. See also page 691.

The electrical repairs constitute recharging batteries, work on the electrical apparatus, etc.

By maintaining a system of departments in this manner, the parts belonging thereto are easily located, work is turned out quicker, and a higher degree of efficiency is maintained.

An extensive line of repair work can be carried on in even a small garage, and the sale of extras and sundries will add materially to the income.

LAYOUT FOR A GARAGE AND FOR SHOP BUILDINGS

Successful garage operation is largely a question of systematic economy. This holds true for smaller garages even more than large ones, and therefore such an establishment requires great care in its layout, construction, and subsequent operation. The more thought that is concentrated upon the system to be followed, once the building and equipment are ready for starting business, the fewer mistakes will be made and the greater will be the profit derived from the undertaking.

A Nine-Car Garage and Shop

The type of a small country garage, as described in Fig. 1, is designed for the storage and general care of nine automobiles. Besides the space necessary for garage work, the building contains a well-equipped repair shop and an office, which also serves as a reception room.

In the repair shop a limited supply of parts and supplies is kept, the latter being provided for the accommodation of the garage patrons. The supply stock consists of the most important accessories, tires, tubes, and ignition sundries, etc.

This garage is designed with a view to economy. It is a one-story brick building, 60 by 40 feet, with the longer side toward the street; the interior height is 14 feet from floor to roof, and the latter is carried on trusses 40 ft. long and spaced 8 ft. apart.

A skylight (L) 10 feet wide and 50 feet long with windows illuminates the garage during daytime.

Near the middle of the street side (1), 15 feet from one end, is located the main door, which is 10 feet wide. Entering through this door a row of four automobiles is arranged at the right, while at the left is the entrance to the garage office. Adjacent to the office door a board 3 by 3 feet is hung on the wall, on which checking forms, which constitute a part of the garage system, are kept.

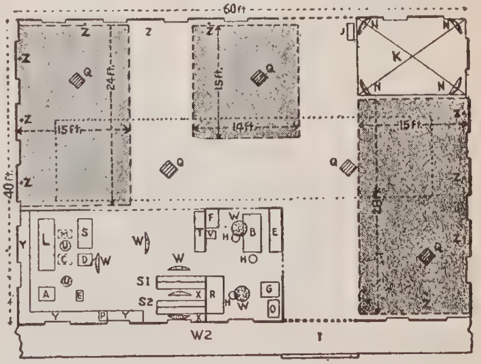


Fig. 1. Floor plan of the garage, showing location of departments, skylight, and arrangement of tools and lamps.

The office is 10 feet wide and 15 feet deep, and besides the entrance mentioned, has one door leading into the repair shop and another into the garage proper, which has a floor space of 1,275 square feet.

The space filled by automobiles is shown by shading, and there is enough room to accommodate nine cars of 124 inches wheel base and standard tread. The space between the dotted portions illustrate the passageway for automobiles driving to or from their assigned positions in the garage. From the garage proper a 10-foot door leads into the back yard, and adjacent to this door the wash rack and charging outfit are located.

The wash rack is formed by a rectangle deepening toward its center (K), whence a pipe for the flushing water leads to the sewer, or other drainage system. The water is supplied either through the medium of the ready-made car washer, or through one which can be readily made from ¾" standard pipe, a stuffing box, four elbows, and about 12 feet of ¾" water hose, at a cost of less than $8.00. The method of assembling the parts is shown elsewhere (see Index under "Wash racks").

The repair shop in this small 9-car capacity garage is but 24 feet long and 15 feet deep, and, besides the door connecting it with the office, has a sliding door between it and the garage proper. This door is sufficiently wide to permit of an automobile being passed through it into the shop, which also contains a small stock of raw material and repair parts stored in shelves (S1) and (S2), and a tool shelf (T). (*Motor Age.*)

A Fifteen-Car Garage

An arrangement and equipment of a garage and repair shop suitable for a town of 3,000 population with good transient and country trade is shown in Fig. 2. The size of the building is 50 by 120 feet, one-story brick or cement block, with the repair shop 40 by 50 feet at the rear.

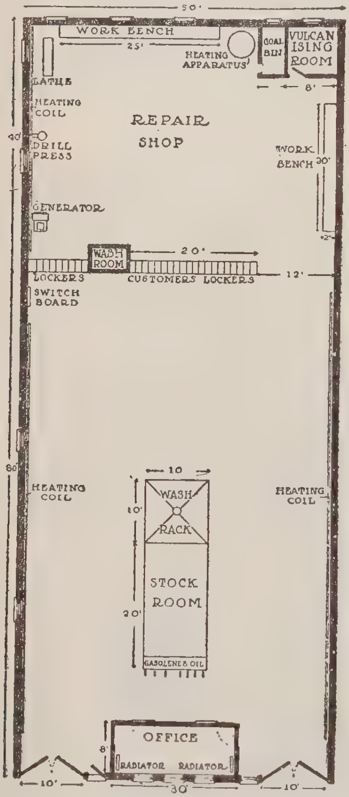


Fig. 2 shows a garage which would suit the requirements stated, beside being convenient and cheaply maintained. It allows of cars entering at one side and leaving at the other, thus avoiding any congestion in getting in and out. Gasoline and oil are handy to the street, beside being under the direct scrutiny of the office.

Posts should be barred and the roof supported by trusses, making the working space much more valuable and saving many accidents to lamps, fenders, and varnish. Heat is supplied by a hot-water apparatus located in the repair shop. It is of the overhead supply type—that is, the supply veins extend from the boiler at the ceiling height, and branches drop down to the coils and radiators and return just above or under the floor. Steam could be used, but the boiler would have to be sunk considerably in a pit before this could be used at all successfully.

A small gasoline-electric generator-set with a suitable switchboard is suggested for electric charging and running the lathe and drill-press, in case the local service is not direct current. Sky or other kinds of roof lights are a necessity if the garage is on an inside lot, and are desirable in any case to make things cheerful and airy and attractive to transients who use it.

Average space to allow for storage of cars: 7 feet is the usual width. The length varies from 13 to 18 feet, according to length of cars stored. (*Motor Age.*)

Another Fifteen-Car Garage

A one-story building for a garage, salesroom, accessory store and shop: The plan is shown in Figs. 3 and 4. The size of the lot is 60 x 100 feet. The building is erected so that another story can be added.

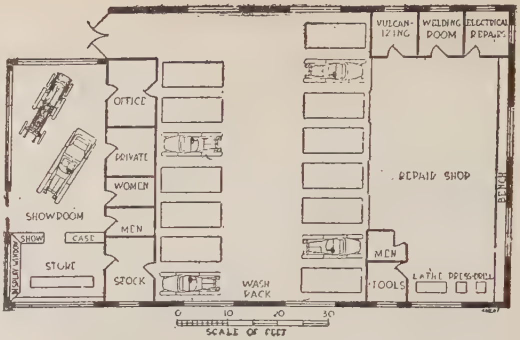


Fig. 3. Plan view. The cars in front, near the shop doors, should be the ones which are away from the garage the most.

The entrance to the garage is exposed so that light can be obtained from two sides into the showroom. Thus the building has practically all the advantages of being on a corner.

There is a small accessory store divided off from the showroom by showcases and an arch, a stockroom, private and general offices, rooms for men and women, garage space for fifteen cars, wash rack, and a shop big enough for five or more cars, and equipped with vulcanizing, welding, and electrical rooms. (*Motor World*, by Harold F. Blanchard.)

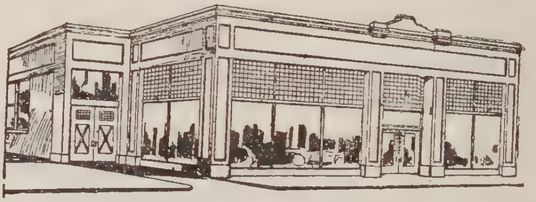


Fig. 4. Front view. Note that the driveway to the garage gives the showroom a corner appearance, and light.

A Twenty-Eight-Car Garage

A one-story corner building with alternative plans for garage, salesroom, accessory store, offices, toilets, garage and shop is shown in Figs. 5 and 6. Size of the plot is 66 x 112 feet.

There are two designs: Fig. 6 is probably the preferable one, considering all the conditions, but Fig. 5 is the one to use in case a front entrance to the garage is considered essential.

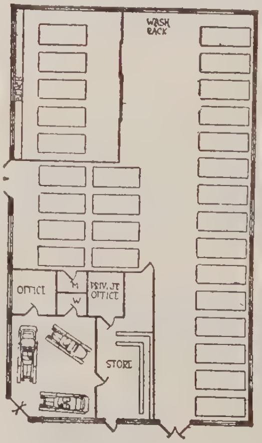


Fig. 5

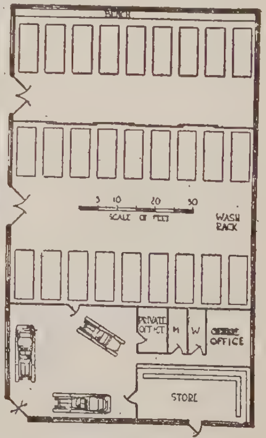


Fig. 6

Fig. 5. Complete establishment located on a corner and with a front entrance.

Fig. 6. Complete establishment, with no front entrance.

The objection to the front entrance is that it restricts the frontage so that the display space for the showroom and accessory store is rather small; but with the entrance on the side, full advantage of the front may be taken. And inasmuch as it may be considered as valuable advertising space, it is essential to use all of it for display purposes. The question to decide is whether the advantage of having the whole front for display more than offsets the disadvantage of having the entrance to the garage on the side street. Even if the garage trade is the most important part of your business, and evidently it is not, the side entrance is not very objectionable, provided there is a large sign at the front stating that the garage entrance is on the side street.

Fig. 5 has capacity for only five cars in the repair shop. Entrance to the garage is from both streets, but when the demand for space is strong, the last cars in at night may be placed in the side entrance-way.

Fig. 6, which has no front entrance for cars, not only is a more attractive building to look at, but also the layout of garage and repair shop is more convenient.

As far as storage capacity is concerned, there is little to choose, Fig. 5 having room for twenty-eight cars, including five in the shop, and Fig. 6 having space for one less, including nine in the shop. The shop in Fig. 5 may readily be enlarged if desired, by lengthening it. (*Motor World.*)

Steam Heating a Garage

The usual plan is to heat by steam, or hot water. The method of assembling the pipes or coils is illustrated in Fig. 8. For garages of larger capacity there would be more coils and a larger boiler.

As an example we will give the dimensions for a garage 48 x 62: It is assumed that it is heated by a steam-heating system working at a pressure of 5 lb. gauge, and for this an ordinary low-pressure steam boiler, such as is used in heating houses is appropriate. (See Fig. 7 for a suggested plan.)

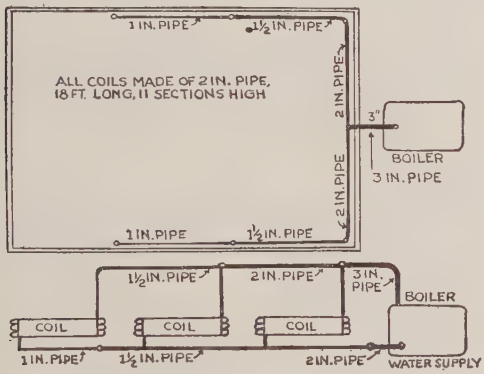


Fig. 7. Steam-heating system for garage 48 x 62. The heating coils are made of steel pipe 2 in. in diameter.

If you intend to place the boiler outside of the garage, you do not want to overlook the fact that it should be suitably housed, so that no heat will be wasted in warming the open atmosphere.

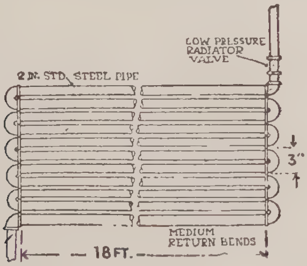


Fig. 8. The boiler must be set so that the water line will be below the level of the lowest radiator or coil, and so that the condensation will drain from the coils back to the boiler by gravity. If this is not done, the heating system will be very inefficient, as you will have to heat cold water up to the steaming point, instead of being able to reclaim some of the heated water. It is best to submit plans to a steam-heating specialist when installing a heating plant.

Lighting the Garage

Lighting the garage: This is a matter of providing the proper electric lights located to the best advantage. The local electrician is posted on this subject.

Artificial illumination of the garage proper is supplied by five 100-watt Mazda lamps, equipped with 12″ steel diffusers with white enamel finish (Fig. 9).

Special lighting provision is made for washing the cars; there are four 25-watt Mazda lamps located at the corners of the wash rack (N) (Fig. 1, page 665), and these lamps are held in Holophane D'Olier steel reflectors, directing the light to the lower part of the automobile being washed.

The repair shop requires even more elaborate lighting facilities than the garage space. It is therefore equipped with five 60-watt lamps and two 25-watt lamps, all of which are of the Mazda (tungsten) type. Three 60-watt bulbs (W), fitted with Holophane D'Olier steel reflectors (Fig. 9), and dropped from the ceiling to illuminate any part of the car being worked on, while two 25-watt lamps (W1) shown in the shaded circles (Fig. 1, page 665), are fitted with the same sort of reflector and are so located as to be useful in seeking parts stored on the stock shelves (S1).

Two 60-watt lamps (U) with Holophane intensive glass reflectors are dropped above the lathe, planer, and drill press, to shed a concentrated light on the work.

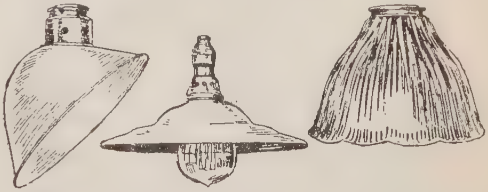


Fig. 9. Three types of reflectors for lighting a garage: Holophane type of D'Olier steel type; 12″ diffuser; Intense type, D'Olier.

Building a Garage Floor

Cement concrete is the acknowledged material par excellence for the garage floor.

Wood is condemned as being short-lived and usually out of repair. Boards placed as close to the ground as is usual with garage floors rot in a short time. They also tend to warp both transversely and longitudinally by reason of the under sides being damp and the top dry; thus they pull loose from the under-pinning on account of the timber rattling and failing to hold the nails.

Wood blocks make a good pavement, but, unless creosoted, are also short-lived, and the creosote is said to be injurious to rubber.

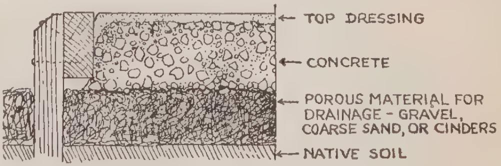

TOP DRESSING
CONCRETE
POROUS MATERIAL FOR DRAINAGE - GRAVEL, COARSE SAND, OR CINDERS
NATIVE SOIL

Fig. 10. Detail of construction

Before starting a concrete floor it is well to study the situation as regards water pipes and drains. If there is any filling to be done, the nature of the soil must be considered.

It is not safe to lay concrete over clay that has been filled, as the floor will surely settle. Gravel will immediately settle to a solid bed, as will sand if wet down sufficiently to wash it into any crevices that may exist under it. Clay is quite different from sand and gravel, though sandy clay is not quite as bad as gumbo or any of the more sticky clays.

If clay must be used, it should be placed when as dry as possible. After it is laid, it should be soaked with water until virtually soft and incapable of supporting a person's weight. When it has dried, it will be as dense as it can be made without process of time, and will have settled from 10 to 24 per cent of its original height.

The drainage of the floor should also be considered before the work actually begins; a puddle of water on the floor after a heavy rain is never desirable

Sometimes it is convenient to give the whole floor a slight pitch in one direction—towards the side, front, or back. The best method, however, appears to involve making the center the highest point. In a long garage, 50 ft. by 100 ft., this high point would be a line 75 ft. long through the center; from this line the floor should fall off towards the walls at the rate of about one inch to 10 ft. The lowest point may be close to the wall, or it may be four or five feet from the wall, so as to come under the row of cars. Along this low line a tile must be laid below the floor with drains, protected by cast-iron grills entering it every 10 to 14 ft.

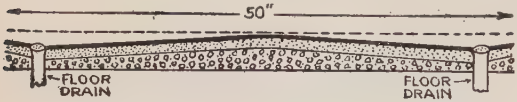


Fig. 11. Cross-section of the floor of a 50-ft. garage.

If the foundation soil is such that it becomes soft with moisture, it should be sloped slightly toward the drain tile, in the same way as the floor, so that no water can collect under the floor. When this is done, the bed material of cinders, coarse sand, or gravel is spread and tamped thoroughly to within three or four inches of the finished floor.

Strips of 2 by 4 are usually used as grounds; they are spaced 6 to 8 ft. apart, and are held in place by stakes and cross-divisions placed the same distance apart as the grounds, forming square blocks. When the filling is started every alternate space is filled; then the cross-pieces are taken out and the remaining spaces filled.

The proportions of cement and gravel for the base of a concrete floor are as follows:

Good quality bank gravel: 1 part cement; 5 parts bank gravel.

Washed gravel or crushed stone: 1 part cement; 2½ parts torpedo sand; 5 parts 1″ gravel.

The proportions for the top dressing are as follows:

1 part cement; 1½ to 2½ parts torpedo sand.

Fill the forms with the base mixture to within ½″ to ¾″ of the top. Tamp well and finish with the top dressing, smoothing and striking off with a perfect straightedge. Never let the base dry out before the top dressing is added, or they are liable to separate and the top to scale off.

After striking off, the dressing should stand an hour or so for the excess water to settle before troweling is started. A wooden trowel is best for use in evening up; then after an hour or more the steel trowel may be used, if a smoother job is desired. Some desire the rougher surface given by the wood float, but there is little chance of cars skidding inside the garage, and the smoother surface is more easily kept clean.

Sometimes, instead of the fine cement top dressing, asphaltic compositions are applied. They make a less harsh and less crumbly surface, but eventually get soft from the constant applications of oil. (*Motor Age.*)

THE GARAGE OFFICE

The illustration shown in Fig. 1, page 665, will be used as an example of a garage office, which is also equipped as a reception room, which contains a desk, table, chairs, safe, and couch. The office is lighted by two 40-watt Mazda lamps with 12-inch diffusers. The price of the office furniture and safe is about $100.

Pointers on Office Work

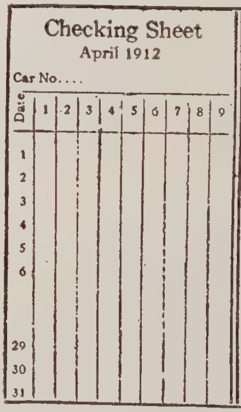
The system designed to take care of all the business of this garage is exceedingly simple. To carry it out, **only three forms are required:** a monthly checking sheet, a monthly supply sales sheet, and a repair card. In addition to these forms an ordinary ledger is used, in which each customer is given a page on which all his charges and credits are entered.

While it is very important to operate the office in a systematic manner, about seven out of ten neglect this part of the business.

Checking Sheet, Sales Sheet, and Repair Sheet[1]

There are very many different methods for keeping records, books, etc., for automobile garage and repairwork. The *Motor World* of New York supplies books for this purpose. A simplified system of checking sheets, etc., is explained below.

The checking sheet (Fig. 12) is 3 feet high by 11 inches wide, with nine 1-inch-wide columns, allowing sufficient space for checking one car in and out every day of the month. Thirty-one horizontal lines are ruled one inch apart and the dates are printed under the heading "Date." Thus one square inch of space is provided for car "out" and "in." The checking times are entered by the day workman, who spends his time keeping garage and cars in shape. After the end of the month the sheet is filed for future reference.

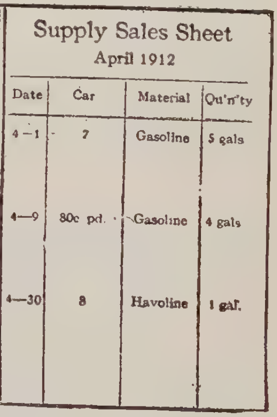


Checking Sheet
April 1912

Car No. . . .

Date	1	2	3	4	5	6	7	8	9
1									
2									
3									
4									
5									
6									
29									
30									
31									

Fig. 12



Supply Sales Sheet
April 1912

Date	Car	Material	Qu'n'ty
4—1	7	Gasoline	5 gals
4—9	80c pd.	Gasoline	4 gals
4—30	8	Havoline	1 gal.

Fig. 13

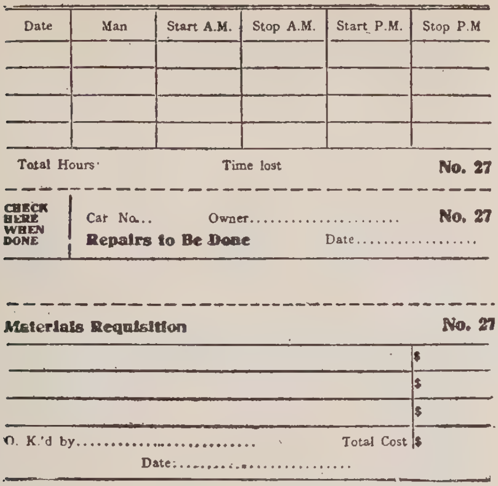
Fig. 12. Monthly checking sheet for cars housed in garage.

Fig. 13. Monthly supply sales sheet kept with checking sheet.

Gasoline, oil, and other supplies bought by garage patrons are noted on the supply sales sheet (Fig. 13). If this sheet is made as large as the checking sheet, it will last a full month. On the last day of the month the sheet is taken off its board, the sales are entered on the car owner's pages in the ledger, and the stock records corrected in accordance with the sales record. Then the monthly bills are sent to the patrons. Where materials of any kind are sold to any but regular patrons, the price and the notation "Paid" is entered on the sales sheet instead of the number of the car.

---

[1] The "Motor World" simplified system of accounting: A simple method of keeping accurate records of what you pay out and take in, telling how much you made or lost on each department, and showing you how much you received, how much the stock and labor cost, how much your customers owe you, the amount of your overhead expenses, etc. 800 pp., 11½ x 15 ins., leather index, heavy duck leather corners. Price $15. Can be secured of A.L. Dyke, Granite Bldg., St. Louis, Mo.



Date	Man	Start A.M.	Stop A.M.	Start P.M.	Stop P.M

Total Hours· Time lost **No. 27**

CHECK HERE WHEN DONE | Car No... Owner..................... **No. 27**
Repairs to Be Done Date.................

Materials Requisition **No. 27**

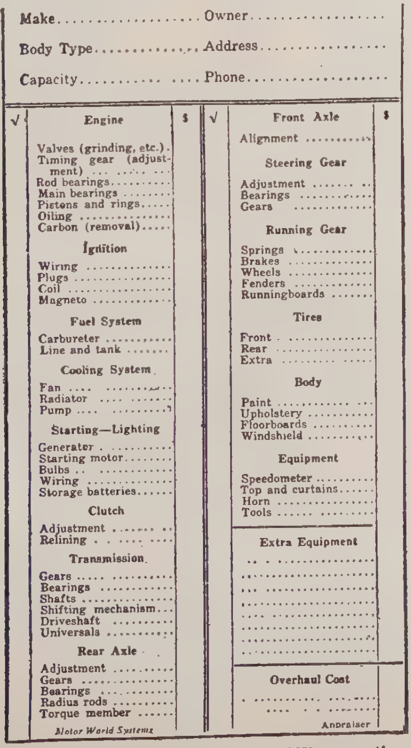
	$
	$
	$
O. K.'d by........................ Total Cost	$

Date:........................

Fig. 14. Practical repair card, combining repair order, material requisition, and time card of workman.

For the handling of repairs the repair card (Fig. 14) is designed. These cards are used in series and are numbered consecutively. They consist of three portions with perforations between. The middle portion is filled out when a car is brought in to be repaired, the name of the owner, number of the car, and date of the order being written on the blank. Then follow the specifications of the work to be done. The card is then attached to the automobile, and accompanies it to the repair shop.

The upper portion of the card is now used as a time card, the name of the workman and his starting and stopping times being entered upon it. As the work progresses the man checks every item of the work, and finally enters his total working time on the card. If it be necessary to draw upon the repair parts stock or buy material from outside, the lower portion of the repair card is used as a requisition, upon which the needed material is entered. If it is not in stock, and has to be bought, an order is made out after the requisition. In every case the cost of the repair part is entered on the requisition, which is O.K.'d by the owner before an order is sent out. The repair work being completed, a charge covering time and materials of the repair is made out from the parts of the repair card and entered on the ledger page of the car owner. Thus when the monthly bill is made out all charges against a patron come up at once.



Make.................. Owner.................
Body Type.............. Address.................
Capacity........... .... Phone..................

√	Engine	$	√	Front Axle	$
	Valves (grinding, etc.).			Alignment	
	Timing gear (adjustment)			**Steering Gear**	
	Rod bearings..........			Adjustment	
	Main bearings			Bearings	
	Pistons and rings.....			Gears	
	Oiling			**Running Gear**	
	Carbon (removal).....			Springs	
	Ignition			Brakes	
	Wiring			Wheels	
	Plugs			Fenders	
	Coil			Runningboards	
	Magneto			**Tires**	
	Fuel System			Front	
	Carbureter			Rear	
	Line and tank			Extra	
	Cooling System			**Body**	
	Fan			Paint	
	Radiator			Upholstery	
	Pump			Floorboards	
	Starting—Lighting			Windshield	
	Generator			**Equipment**	
	Starting motor........			Speedometer	
	Bulbs			Top and curtains......	
	Wiring			Horn	
	Storage batteries......			Tools	
	Clutch			**Extra Equipment**	
	Adjustment			....	
	Relining			....	
	Transmission			....	
	Gears			....	
	Bearings			....	
	Shafts			....	
	Shifting mechanism...			....	
	Driveshaft			....	
	Universals			**Overhaul Cost**	
	Rear Axle			....	
	Adjustment			....	
	Gears			Appraiser	
	Bearings				
	Radius rods				
	Torque member				

Motor World Systems

Fig. 15. **Repairman's Check Sheet.** When quoting prices on repair work, it is advisable to keep a statement of work necessary, marking after each item the cost. Keep the original with the owner's signature, and give a copy to him.

When the repair card is no longer needed it is filed away under its number, the file being kept, with the ledger, in the safe of the office. This makes a very compact system, all parts of which are accessible to the owner of the garage at a minute's notice, thus enabling him to keep his operations on a high plane of efficiency.

Extra equipment: Include here the tools left in his car; then there can be no dispute. Put them in the stockroom. This plan can be elaborated upon. (The check sheet shown [Fig. 15] is an example of *Motor World* system.)

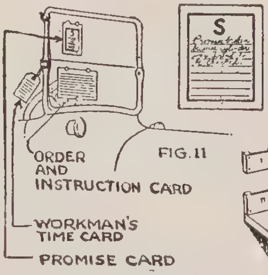


Fig. 16

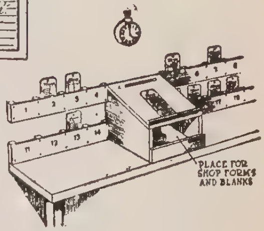

PLACE FOR SHOP FORMS AND BLANKS

Fig. 17

Fig. 16. **A visible promise-recording system** is shown. When the car reaches the repair-shop floor, the work to be done is noted from the instruction card, and the job is promised to be done at a certain time. This promise is recorded by means of a heavy-bordered card, pasted to the windshield and having the initial letter of the day of the promise printed at the top center. For example, if the car is promised for Saturday, a card having the letter "S" is used; if Monday, the letter "M." The foreman can then instantly see what must be got out each day, and what promises are broken, and why.

Fig. 17. **A foreman's desk:** System is essential in the repair shop, but because it is system it does not necessarily mean an elaborate equipment. An old packing box may be made into a foreman's desk, and a few strips of wood and tin may be used to construct a workmen's time and work-card filing rack. The blank cards are always available, and clean. Any of the workmen's cards may be seen at a glance, and are in order. A clock should be hung near at hand, so that the men will not have to guess at the time. (*Motor World.*)

Garage and Repair-Shop Prices for Storage and Repairs

The prices below are not standard but are about as near standard as can be compiled. Note the difference in prices to those who purchase gas, oil, and grease from the company, and who are regular customers and transients.

Per Month—(Regular Customer)

Roadsters, small, list under $1,400	$15.00
Roadsters, large, list over 1,400	20.00
Tour. cars, small, list under 1,400	17.50
Tour. cars, 5-pass., list over 1,400	20.00
Tour. cars, 7-pass., list over 1,400	25.00
Coupes and enclosed cars	25.00
Limousine	30.00

Electric—(Regular)

Runabouts	$30.00
Coupes, victorias, etc.	35.00
Cars with Edison equipment extra	5.00

Transient

Wash, polish, and storage, first night	$2.00
Wash, polish, and storage, each additional night	1.50
Storage only, per night	1.00

Dead Storage

One-third regular rate	Per month
Separate body storage, per month	$5.00

Repairs per Hour

Day labor, according to work	per hour	$1.25
Night work and outside work	per hour	1.25
Sunday and holiday labor	per hour	1.25
Shop room for chauffeurs when owners furnish tools	per day	1.00
Chauffeurs furnished to drive owner's car (day)	per hour	1.00
Chauffeurs furnished to driver owner's cars (night)	per hour	1.00

We will not be responsible for cars left for repairs or storage in case of fire, water, cyclone or other accidents, or if car is damaged in delivery to and from our garage.

We are not responsible for articles left in cars or in the shop.

Note: The foregoing is printed on a heavy card, 14 x 24 inches, framed, and placed in a conspicuous place.

FIXTURES AND SUPPLIES FOR A GARAGE

Fixtures for the repair shop should consist of such things as: shelves and racks for tools, such as stocks, hacksaws, etc.; these should be on the walls at the back of the vise. A set of stout drawers for keeping bolts and screws and brass rods should be provided. Some of the drawers should be fitted with locks and keys, for sometimes tools will disappear. Several shelves should be put up for storing various spare parts, mandrels, etc., but it must be remembered that the shelves when full may have to carry a very considerable weight; they should be stout and well secured.

Fixtures for the garage would also consist of such parts as lubricating oil tanks, gasoline tank, wash hose and washing rack, heating plant, turntable, stock room, etc. See Index under "Care of a car for constructing a wash rack."

A heating plant, either hot water or steam, with coil pipes or radiators must be provided. This plant should be in a cellar or on the outside of the building in a small brick enclosure.

A turntable is very handy for garages, but not altogether necessary. It should be placed in the center of the garage.

A wash rack is very essential.

For the lubricating oils, a small enclosure can be provided made of wire fencing with a lock and key.

Lubricating oils should be carried in about three grades: light, medium, and heavy gas-engine cylinder oil, as well as a supply of gear-case oil and greases. Sixty-gallon tanks are usually provided for lubricating oils, and all are placed near the gasoline pump.

A lubricating oil tank and a pump capable of delivering anything up to the consistency of transmission grease are made by concerns specializing in this work. Smaller and cheaper lubricating tanks can be had.

The gasoline supply should be stored in an underground tank, placed some distance from the building, from which it is piped to a pump located inside of the building near the wash rack. The gasoline tank should have from 120- to 280-gallon capacity.

A gasoline pump can be connected to a tank under the sidewalk or in the rear.

A Western gasoline pump, with the stroke adjustable for ¼, ½, 1, and 2 gallons, and equipped with a 280-gallon tank, is sold by the maker for about $200. A curb gasoline outfit is shown farther on.

Many useful devices, in the way of time-saving additions are shown under "Useful hints, suggestions and devices" (see Index).

An inspection pit is useful, placed at any convenient place where the auto can be run over it. The pit permits the repairman to get under the car and work, and should be installed. The pit can be made about 6 feet long, 2 feet 9 inches wide, and 2 feet 9 inches deep. A mirror is very handy for throwing the light in dark corners when at work in the pit under the car.

A chain hoist or crane, for lifting the engine and other heavy parts, will pay for itself many times over in time and labor.

Fire extinguishers should be kept handy. The only part of the building (if made of concrete or brick) that is subject to fire is the roof. In case of fire, keep two or three buckets of sand handy (or fire extinguishers) to put out a gasoline fire, as water is useless.

Gasoline often drips from a carburetor, and back-firing or a spark from a muffler will ignite the gasoline. Once a gasoline fire is started, it is difficult to extinguish. Never use water; it will serve only to float the gasoline and spread the flame. If a fire extinguisher is not at hand, keep a box of fine earth or sand and dash it over the flame. Flour will also do, if nothing else is handy.

A water connection in the repair shop will be handy, and should be installed.

Electric lamps with wire guards and a long cord for working around the car are very necessary.

There is no end to the number of useful devices which can be installed in a repair shop and garage.

For oil fires, a motor trade magazine advises to keep on hand a mixture of sawdust and soda (about 1 qt. of bicarbonate of soda to a bushel of sawdust).

A chemical fire extinguisher can be made by taking 7½ gallons of water and mixing about 10 or 11 lbs. of ammonia salts and 21 or 22 lbs. of common salts. Put into bottles and keep on hand.

The following few pages will be devoted to equipment and supplies usually required in a garage. By writing to some of the manufacturers, where names are given farther on, and who specialize in garage equipment, and to automobile supply houses useful catalogs can be obtained if this book is mentioned in the request.

Fixtures for Handling Lubricating Oils, Waste, etc.

Below are shown methods of handling lubricating oils. Very elaborate equipments can be obtained for those who desire large outfits. Write for printed matter to the concerns mentioned farther on.

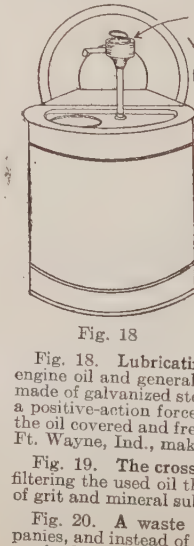


Fig. 18

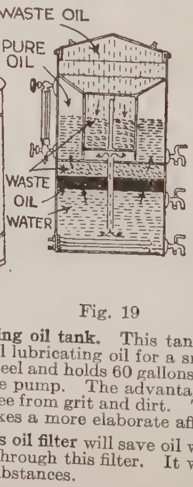


Fig. 19

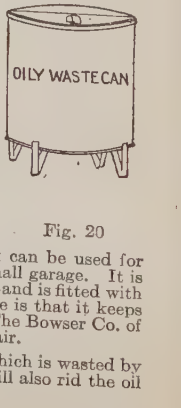


Fig. 20

Fig. 18. **Lubricating oil tank.** This tank can be used for engine oil and general lubricating oil for a small garage. It is made of galvanized steel and holds 60 gallons, and is fitted with a positive-action force pump. The advantage is that it keeps the oil covered and free from grit and dirt. The Bowser Co. of Ft. Wayne, Ind., makes a more elaborate affair.

Fig. 19. **The cross oil filter** will save oil which is wasted by filtering the used oil through this filter. It will also rid the oil of grit and mineral substances.

Fig. 20. **A waste can** is required by the insurance companies, and instead of throwing greasy, oily, inflammable waste on the floor, it is placed in this can. Every garage should have this waste can.

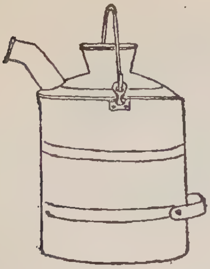


Fig. 21

Fig. 22

Fig. 21. **The Dover gasoline and radiator filler** will prevent spilling, and is very easy to handle. It holds 5 gallons. It is not advisable to put gasoline in the same vessel used for water, but if it is necessary, then place a chamois skin in the funnel, and pour the gasoline through it. No water will then pass into the gasoline tank.

Fig. 22. Illustrates a smaller size of Dover radiator and gasoline tank filler. It is advisable to have one each for gasoline and water. This filler is also suitable for lubricating oil.

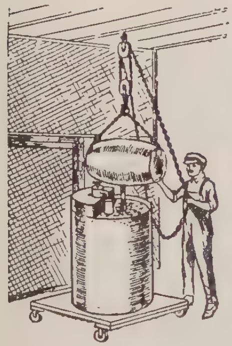


Fig. 23

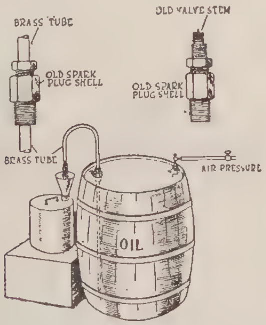


Fig. 24

Fig. 23. **Oil may be most readily transferred from the barrel** to the storage can by the aid of a differential pulley and suitable grab-hooks. The differential pulley may be fastened to the ceiling beams just over the oil-storage-room doorway, and if the storage cans are mounted on casters in the manner shown, they may easily be rolled under the suspended barrel, a hole drilled in the bung, and the oil transferred without further attention. The oil-storage room shown in the sketch has several valuable features. First, the oil may be locked up, and is accessible only to the proper persons; secondly, the upper part contains a shelf on which the surplus stock of heavy oils and greases are stored.

Fig. 24. It is difficult **to transfer oil** from the common oil barrel to a smaller container unless some special outfit is at hand, such as the one illustrated. The oil is forced by air pressure from the barrel. Air pressure is applied through a valve that is an ordinary tire valve soldered into an old spark-plug shell, which in turn is screwed into a hole in the barrel. The oil is delivered through a bent brass pipe, passing through a second spark-plug bushing, also screwed into a hole in the barrel. This pipe must be long enough to extend nearly to the bottom of the barrel, as shown by dotted lines. Packing is placed between the bushing of the plug and the shell, so that the tube may be adjusted to any barrel, and the amount of oil is readily regulated by the pressure applied.

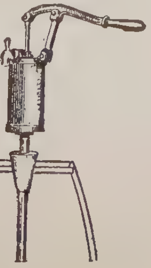


Fig. 24A. Oil pump which can be secured at supply houses for removing oil from a barrel.

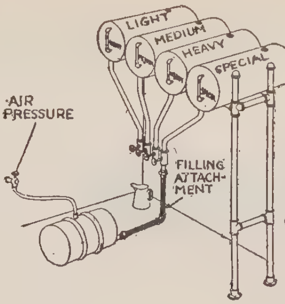


Fig. 25

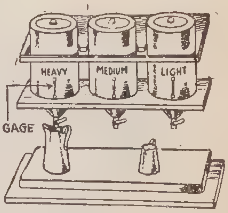


Fig. 26

Fig. 25. **An oil-storage system,** whereby the oil is discharged **by gravity.** It comprises several tanks, as many as there are kinds of oil to be stored, held close to the ceiling on pipe standards, and each pipe connected to its discharge valve. Oil is transferred from the original barrel by air pressure, through a special connection, in the manner illustrated. In addition to facilitating the withdrawal of oil, this method gets the storage tanks up out of the way, and saves much valuable room.

Fig. 26. The common type of oil-storage tanks requires a pump and does not provide a convenient place for keeping the measures. Gravity flow is somewhat handier, and the installation requires less floor space. **A simple method of storing several grades of oil** and having them on tap is illustrated here. The tanks may be made by any tinsmith, and are provided with gauge glasses that show at a glance the amount of oil on hand. The conical-shaped bottoms permit the draining of the last drop of oil, and prevent the collection of any sediment. A shelf provided with a drip-pan offers a convenient place for keeping the receptacles.

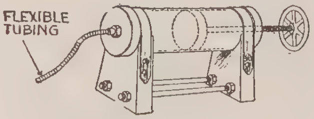


Fig. 27

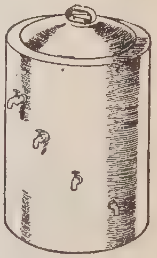


Fig. 28

Fig. 27. **A powerful grease gun** for filling universal joints and steering gears is illustrated here. The barrel of the gun is a piece of 6-in. pipe about 16 in. long, and carries a metal piston having a single ring. This piston is forced downward through the action of a threaded rod, screwed into a cap at one end, and operated by a hand wheel. The other end of the barrel is likewise covered with a cap and carries a length of flexible tubing, through which the grease is forced to the part. The barrel is mounted on wooden uprights, and is large enough to permit one loading to supply several joints. The amount of grease used each time may be readily determined by weighing the gun before and after using.

Fig. 28. The oil drained from the crank case is usually a dead loss, as it is unfit for further motor use. It is, however, suitable for lubrication of farm machinery or such light implements as the lawnmower and the wheelbarrow, and may be reclaimed by the **settling tank** shown. The old oil is poured into the tank as fast as it collects, and the sediment is allowed to drop to the bottom, the clean oil rising to the top and being drawn off as required. The resale price should be made low to attract the trade, and is almost a clear profit.

The foregoing are suggestions taken from the *Motor World*.

Sponges, Chamois, and Waste

In selecting sponges, chamois, and waste, it is advisable to use only the best.

Waste usually comes in bales of 50 or 100 pounds. It is economy to buy waste by the bale. Nothing but the very best white waste is suitable for automobile work. When waste has been used and is ready to throw away, place it in a can (see Fig. 20).

Chamois skins are used for washing and cleaning the body and fine surfaces. It is a difficult matter to obtain a good, genuine chamois skin, but it is worth the difference in price to get the best. The French chamois skin seems to be the most durable and pliable. Chamois skins come in sizes 28″ x 32″ and 19″ x 21″. A package of chamois generally contains a dozen.

Sponges often contain sand and grit, especially the cheaper grade. Many cars have received scratches which cannot be removed, by using the cheap gritty sponge. The best sponges are the Rock Island Sheepswool sponges. They come in bales of 15, 25, 30, and 50 pounds. This class of material can be obtained of automobile supply houses.

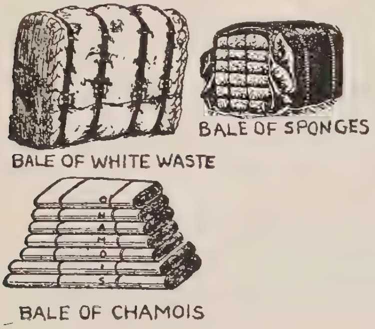


Fig. 29

Repair Pits and Methods for Working under a Car

An inspection pit, placed at a convenient place, or, still better, a floor level underworker, as shown in Fig. 30, is far better than working on your back under a car in a limited space. Several different methods are shown below.

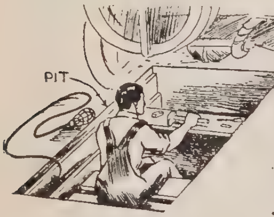


Fig. 30

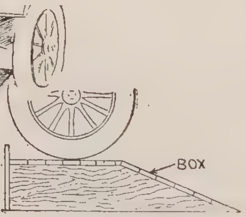


Fig. 31

Fig. 30. **A concrete repair pit,** the depth of which may be varied, is illustrated here. Ledges are provided at different heights, and boards may be placed across, giving the mechanic free access to the work. Much of the dampness of this type of pit is removed by the wooden floor and the space beneath. Several of the boards on one of the upper ledges may be left in place and used as shelves for the tools and for steps for getting into and out of the pit. Size of pit is usually 6′ long, 2′9″ wide, and 2′9″ deep.

Fig. 31. While not new, the **substitute for a pit** illustrated here is worth describing because of its merit. Two heavy wooden boxes, one for each wheel, with a slope of about 30°, and a flat space on top are used. The boxes are constructed of 1½″ or 2″ planks; the height is about 10″, and the length about 4 feet. Such boxes will support even a heavy car.

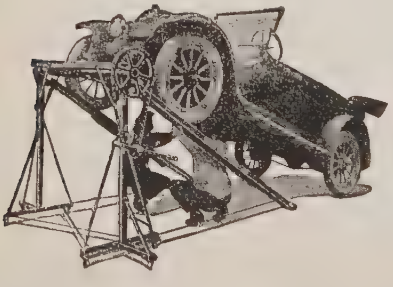


Fig. 32. **The Manley floor level underworker** elevates the car to any desired height, so that the mechanic can work to advantage while sitting in a perfectly natural position. Manufactured by The Manley Mfg. Co., York, Pa.

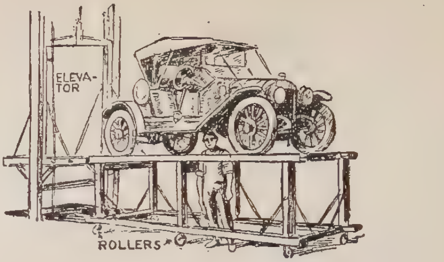


Fig. 33. Where there is an elevator and no pit. This structure serves the same purpose as a pit, with the additional advantages of being portable, more cleanly, and more accessible. It permits the workmen to perform most of their operations by daylight instead of subjecting them to the inefficient glare of an electric-light bulb. No skids are required with this structure in any garage where an elevator is provided; the elevator with the vehicle upon it is simply brought to a stop at the height of the truck, and the truck then adjusted so that the car can be rolled upon it. Being mounted on casters, the truck can be moved easily to the lightest portion of the shop.

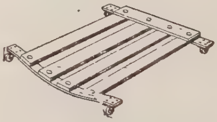


Fig. 34

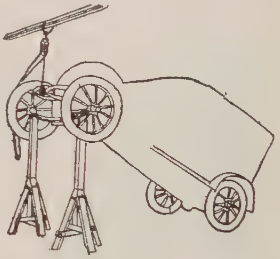


Fig. 35

Fig. 34. **A creeper** is easily made, and is strong enough to permit a car to run over it without injury. Cross strips are 2″ x ½″ steel and bent slightly to give clearance for the swivel casters and yet keep the body of the creeper low. Slats are 4″ x ¾″ hardwood. The Continental Auto Parts Co., Columbus, Ind., manufactures creepers, engine stands, hoists, etc., at very reasonable figures.

Fig. 35. **Another method for working under a car.** The front end of the car is hoisted by chain and specially made wood jacks are placed under the axle. The stands or jacks must be designed for the least space possible, in order to give working room between them. It is also advisable to have the car supported by the chain hoist securely, and then, in case the jacks give way, no injury will result; also block the rear wheels securely.

Gasoline Storage

This subject is one the garage man can learn more about by writing to the concerns mentioned below, and securing their catalogues.

A curb or road-side pump is shown in Fig. 36. An electric light fixture with globe is placed above. The storage tank is buried under ground, usually as close to the pump as possible. It is connected by a 1½″ suction pipe with a foot valve placed at the end of the suction pipe. Standard tanks range from 1 to 20 bbl. capacity. Parts are: foot valve, vented fill pipe with lock, suction pipe, and gauge stick. (The American Oil Pump & Tank Co., Cincinnati, Ohio.)

An air-pressure gasoline system is manufactured by the Allen Pressure System Co., 1926 Broadway, New York, N.Y.

The Bowser Co. manufactures a piston type of gasoline pump which separates the water from the gasoline.

The gasoline storage tank to supply gasoline inside of the garage to a pump placed away from the tank requires special installation on account of the insur-

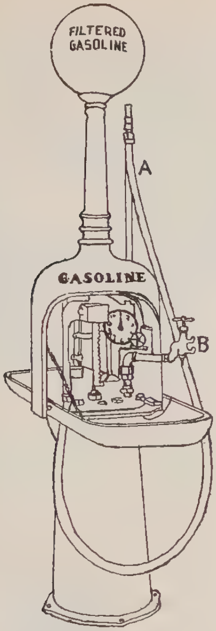


Fig. 36

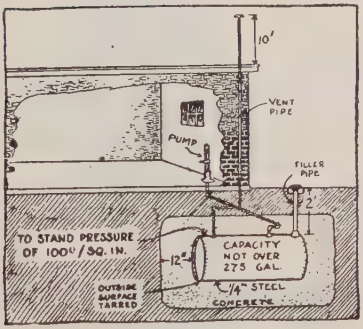


Fig. 37

ance. The tank can be placed in the ground 18″ below the surface. The insurance companies are very strict. The plan shown in Fig. 37 is one that passes inspection in New York. Give the tank 3 coats of asphaltum when placing it underground.

Addresses of some of the storage-tank manufacturers: Western Oil Pump & Tank Co., St. Louis, Mo.; O. K. Harry Steel Co., St. Louis, Mo.; Wayne Oil Tank Co., Ft. Wayne, Ind.; American Oil Pump Tank Co., Cincinnati, Ohio; S. F. Bowser Co., Ft. Wayne, Ind.; Tokheim Oil Tank and Pump Co., Ft. Wayne, Ind. By writing these concerns full information can be secured.

A Gasoline Filling Station Layout and Greasing Rack

A suggestion for the layout of a filling station is made by *Motor Age*, as shown in Fig. 38.

A good method of determining the probable trade in a certain location is to count the number of cars passing per day at the location selected. If there are about 3,000 cars or more per day, on an average, passing the filling station, this will no doubt insure a profitable investment. There is no surer method of getting gasoline business than going where the traffic is heavy. A corner where traffic passes both ways, especially around the corner, is the most valuable kind of a plot.

The biggest problem in making a layout is the finding of space where cars may take on air and water and where a greasing rack may be placed without interfering with or obstructing the passages to and from the gasoline pumps.

The driveways in the plan shown in the illustration are very liberal, but they should be so, as it is of the utmost importance to make it easy for customers to get in and out without interference. This building does not seem large, but will be found of ample size. The necessary tanks and pumps are provided, i.e., about four tanks, two 1,500-gallon tanks for commercial gasoline, one 550-gallon tank for high-test gasoline, and one 550-gallon tank for kerosene oil. Free air and water should be provided (see "Air compressors").

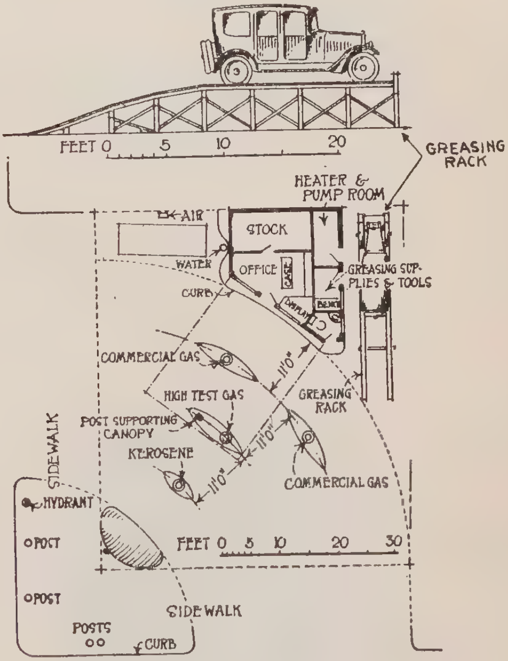


Fig. 38

A mistake is often made in planning filling stations, even by experts of the big oil companies. Many times they place their free air hose so that a car taking on air will obstruct one of the passages. At ordinary times this does not matter, but during rush hours it matters considerably, since if there are several cars waiting, other prospective customers will go on to another station, rather than stand in line.

The greasing and oil-changing branch is getting to be quite an important factor in motor-car service, and, if handled intelligently, should be a good source of profit. **A greasing rack** is shown in the illustration (Fig. 38).

Engine Stands, Axle Stands, and Hoists

Engine stands for working on the engine at various angles, and hoists for lifting the engine or transmission from the frame are very necessary. There are several firms who manufacture such devices: Continental Auto Parts Co., Columbus, Ind.; Service Station Equipment Co., Chicago, Ill.; The Manley Mfg. Co., York, Pa.; and the automobile supply jobbers mentioned farther on.

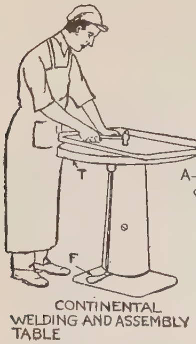

T
F
CONTINENTAL WELDING AND ASSEMBLY TABLE

Fig. 39

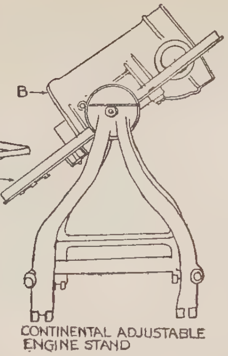


Fig. 40

Fig. 39. **The Continental assembly and welding table** greatly helps to speed up all kinds and types of assembly work. It is not necessary continually to change the position of the article being worked on, in respect to the table, as the table may be revolved and the work comes to the right position. The table is instantly locked (Continental Auto Parts Co., Columbus, Ind.).

Fig. 40. The Continental adjustable engine stand.

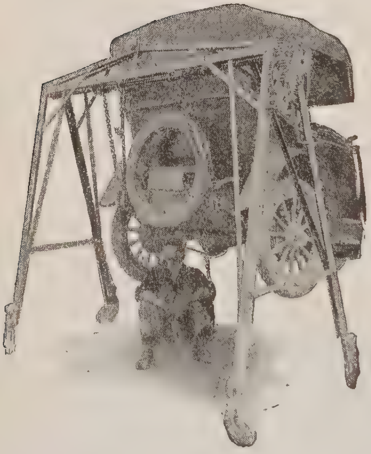


Fig. 41. **The Manley portable hoist.** This hoist is composed of steel angles thoroughly braced. The top frame is in the form of a standard bridge truss.

The hoist is wide enough to clear the fenders and allow the workman ample space to work efficiently between it and the car. The crank handle in the latest hoists has been brought down low enough for the most efficient operation.

The chains may be used single or double, giving in the first case twice the speed with one-half the leverage, and in the second case the reverse, thus proportioning the leverage to the power required to lift any load efficiently and quickly.

There is also provided a brake to lower the load—a feature of the greatest importance, as the lowering is done without effort and in one-tenth the time required by other hoists, which necessitate turning the handle both to raise and lower.

The gears have spur teeth with ample leverage ratio for the complete range of auto work.

The 4,000 lbs. capacity hoist is ample for all passenger cars and light trucks. The 8,000 lbs. capacity truck is intended for the heaviest truck service. (Manley Mfg. Co., York, Pa.)

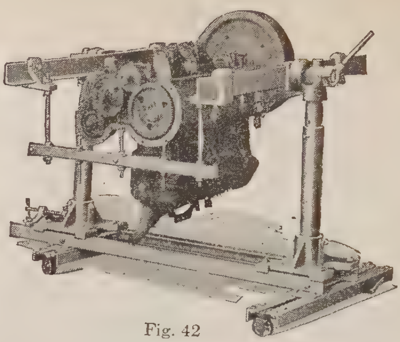


Fig. 42

Fig. 42. **The Manley Universal engine stand.** A cone locking clutch enables the operator to place and lock the engine in any position without the use of pins or other make-shift methods. The Cadillac, Dodge, and Overland 90 require special fittings, which can be furnished.

The unit construction enables this to be converted into an axle stand, thereby tripling the value to the garage. By removing the engine-stand parts, and putting on the axle-stand attachments, the machine is converted from one to the other in three to five minutes.

It will mount 85 to 90 per cent of all motors without special attachments, by means of the Universal suspension bar. Made in two types, geared and plain.

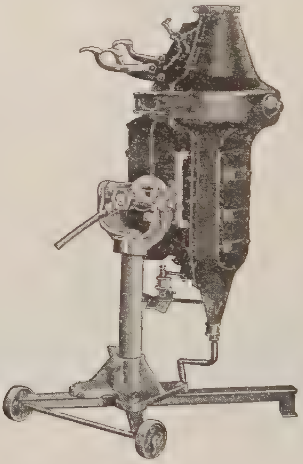


Fig. 43. **The Manley Ford-Chevrolet Universal engine stand.** The cone-clutch-locking method allows the mechanic to lock the motor in any position in a complete circle. The whole power plant, including the oil pans, can be assembled or disassembled while on the stand.

The axle stand parts shown in Fig. 44 may be attached in two to three minutes, converting it into an efficient axle stand.

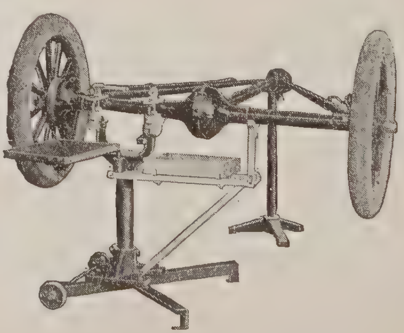


Fig. 44. **The Manley Ford-Chevrolet axle stand.** The engine stand (Fig. 42) is converted into an axle stand by removing two cap screws, releasing the clutch and fitting assembly, and applying to the yoke the two clamps. A collar is placed over the upright to support the grease pan and outboard support. Separate support is included for torque tubes. It is adapted to all types of split rear axles and to any front axle

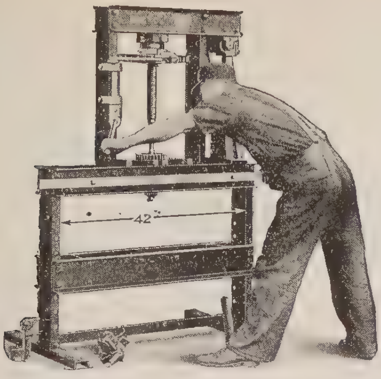


Fig. 45. **The Manley 22-ton press.** The illustration shows the Manley combination press, consisting of a powerful screw press, a high-speed rack and pinion sensitive press, and a straightening attachment all in one unit. This combination covers the range of auto service work completely. Its 42" clearance is necessary for wide work and straightening jobs; its 30-ton capacity is required to handle all auto work; the rack and pinion press is essential for light work, and the straightening attachment is used continuously in every garage. Combining the three in one unit is very much superior to three separate units, and the cost is much less.

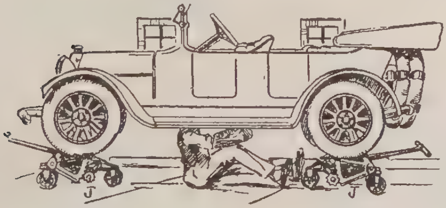
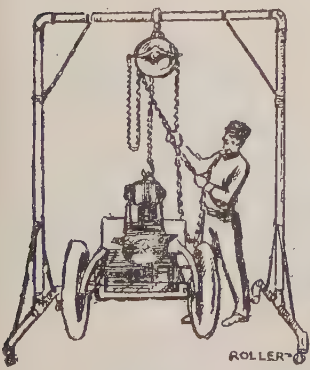


Fig. 46. Car raised by specially made jacks for the purpose of working underneath.



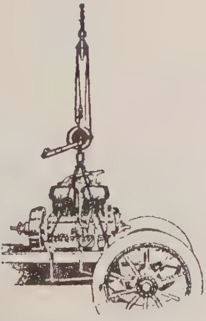


Fig. 47 Fig. 48

Fig. 47. A home-made chain hoist and frame for lifting engines from the chassis. The frame is made of heavy iron pipe with rollers.

Fig. 48. **The Pull-U-Out** is a combination device. It can be used as a hoist and also for pulling cars out of mud holes, etc. Can be carried in a car.

This device has advantages over the old-fashioned block and tackle, being lighter and more powerful. A pressure of 30 lbs. exerted on the handle will lift one ton, whereas a triplex chain block would require 82 lbs., and an ordinary block and tackle 176 lbs. See also Index.

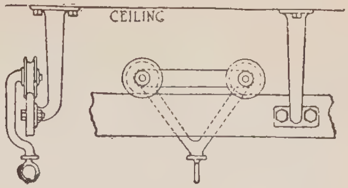


Fig. 49. **An overhead railway for repairshop use** may be patterned after those in use in large butcher shops. It consists of a track made out of stock about ½" x 2", and suspended from the ceiling by arms at frequent intervals. On this track is placed a cap, to which the block and tackle is attached.

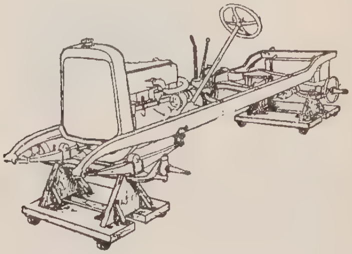


Fig. 50. **Axle stand.** Work is faciliated by the use of this special stand. The one illustrated is fitted with rollers and permits the chassis to be moved about, rendering the parts more accessible.

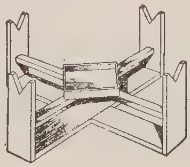


Fig. 51. Though designed for work on the Ford rear axle, this stand could readily be adapted to the requirements of many makes of axles. The ends of the axle are supported on notched uprights, about 30 in. from the floor, and the torque tube is placed on either of two uprights similarly notched.

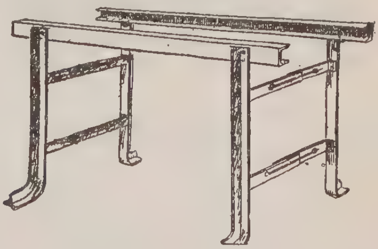


Fig. 52. **A home-made engine stand that is adjustable** as to width, and that is very light yet strong, can be made out of structural steel. The top members are 4" channels, the legs 2" x 3" T-iron, and the cross-members are made of flat stock ¼" x 1".

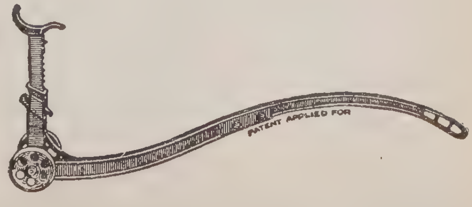


Fig. 52A. The Hovey garage jack for general garage use Can be secured of J. H. Whetstone Co., Lapeer, Mich.

TOWING TRUCKS, WRECKING CRANES, SERVICE CAR, ETC.

A towing truck with devices for towing in disabled cars is a necessity and a profitable investment for a garage.

With the proper equipment one man can accomplish in an hour's time what would ordinarily require two or three men several hours to perform under the former methods of towing. Towing trucks are suitable for towing in cars where either the front or rear axle is disabled. For instance, if the rear axle is out of commission and the car cannot be towed from the front end, then it is necessary to place a dolly under the rear axle and to tow the car backwards, or from the rear end. In this instance the steering wheel can be tied by passing a light rope around the windshield brace, and then tying it to the steering wheel and then to the other side of the windshield brace, which will keep the front wheels in line.

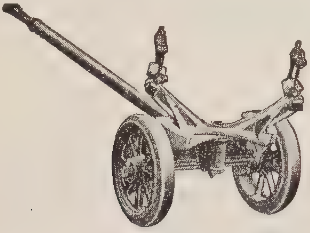


Fig. 53. **The Manley towing truck** is simple in construction. The load is carried on an off-set saddle directly over the center of the axle. It is equipped with roller bearings, located in the hubs, which are lubricated through large grease cavities; 14" wheels, 11 ft. massive two-inch telescoping towing pole, made from malleable iron and steel. It can be attached to the front or rear axle of any car.

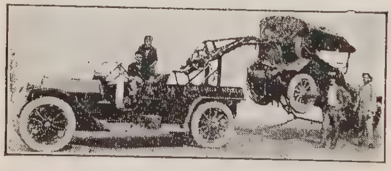


Fig. 54. **Manley wrecking crane:** This device is intended to be attached to the rear of a service car. The illustration shows how it is used. The crane can also be used as a portable floor crane for garage and shop use.

A Home-Made Towing Truck

It will probably be cheaper to purchase a towing truck, but for those who have the time and inclination to make it themselves a brief description is given. (See Fig. 55.)

The heavy metal wheels are 11" di., 6" hub, 1½" spindle. A tongue, preferably an I-beam steel member about 8' or 10' long with a coupling pin to couple to the tow link of the service car (see Fig. 62, page 677), is mounted on the heavy metal axle of the dolly (towing truck). A hook-shaped flat piece with a hook at each end is provided to set the axle or differential housing on and to hold the axle in place.

Then chains are passed around the axle housing and fastened to the axle of the dolly, in order to keep the axle from moving sidewise. The rear end of the service car is then coupled to the end of the dolly and the car is towed backwards. The axle of the dolly, in fact all parts, must be very substantial, as the vibration is very great.

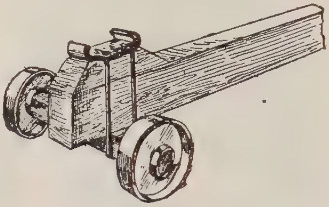


Fig. 55

Chains with catch hooks should be provided to pass over the axle to prevent side play.

Towing Pole

A towing pole is shown in Fig. 56 and a towing bar in Fig. 57. Methods of using a rope for towing are shown in Fig. 58.

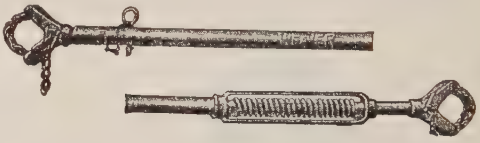


Fig. 56. **The Weaver towing pole.** With this device a car can be pushed or pulled.

Construction: The pole proper is made of double-strength steel tubing, and is constructed in two sections, one telescoping within the other. A convenient pin adjustment provides for varying the length from 5 feet 6 inches to 8 feet. The heads or sockets are well designed of malleable iron, and carry a convenient spring latch for securing the end of the heavy chain. The heavy coil spring is amply strong to meet the requirements of the heaviest passenger car service. The yoke which encases the spring is of malleable iron. Shipping weight, 30 pounds. (Manufactured by Weaver Mfg. Co., Springfield, Ill.)

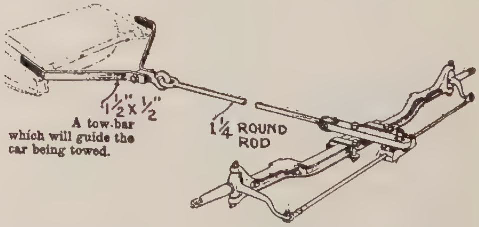


Fig. 57. **A tow-bar** whereby two cars may be brought in by one driver. A towing bar, attached to the rear of the driven car, pulls the towed car by a clamp in the front axle. The bar extends behind the axle, and a stud on a clamp on the tie rod goes in a hole in the bar. In this way, when the bar turns, it moves the tie rod, and the towed car follows its leader.

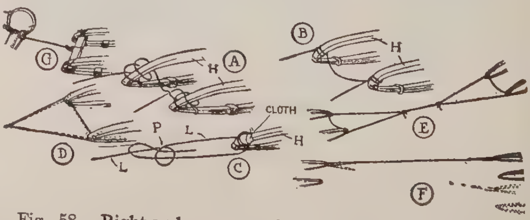


Fig. 58. **Right and wrong methods of securing the tow rope to the vehicle to be towed.** The best way is shown at (G), a piece of wood being tied under and across the frame horns as illustrated, and a single rope connecting it to the rear axle of the towing vehicle. The rope should be as long as convenient, and should be attached as near the outer end of the axle of the towing car as possible.

To loop the rope under the frame as at (D) is very bad, as a severe strain would bend the horns inward, as indicated by the dotted lines.

The bowline knot is the best to use at all times, as it is easy to make and just as easy to untie; it is illustrated at (C). Attention is called to the cloth wrapped (H).

When a bar of wood is not readily obtainable, and a heavy car is to be towed, the rope may be secured as illustrated at (E), two half-hitches being used, as shown at (A), to secure the rope to the horns of the frame, the rope between the two horns being left slack. When using this method, the bights also should be as long as possible. Two long bights are shown at (E); an undesirably short bight is depicted at (D). (A) shows how the two half-hitches are made, and (B) shows how they look when drawn taut, the slack being shown in the rope between the horns (H) to prevent their being drawn together at (D).

The knots at (A) and (C) are the most useful. Their advantage over other knots is that they will neither slip nor jam. (*Motor Age* and *Automobile.*)

How to Make a Service Car

A service car is necessary in all up-to-date garages. It bears the same relation to a service station as does an ambulance to a hospital. It is a traveling representative of the service station, and should impress the public that quick, clean, and efficient service is given.

Any old chassis can be utilized for the purpose, and by following the dimensions in the table below (Fig. 59), a very attractive and serviceable car can be constructed.

Table of Service Car Body Dimensions

As Taken From Representative Detroit Service Cars

Car	Model	A	D	E	F	G	H	I	J	L	M
Hudson	4–37	70	39½	20	14	12	15	12	70	43½	18
Cadillac	53	84	28	23	12	12	19	14	53	55	15
Studebaker	4–58	58	25½	25	8	10	18	12½	55	45	11
Ford	T	48-up	O-up	15¾	...	..	..	..	48	34	15¾
Chevrolet	4–90	55	29	16	8	9	..	13*	43	32	13½
Dodge	...	60	35	19	11	8	16	12	43	47	17
Chalmers	5–15	68	31	24½	10	11	12	10	48	45	20
Hupmobile	32	47	23	15	9	5	..	..	50	41	13
Paige	6–46	68	30	22	10	10	..	12	52	54	12

(*—seat on one side only.)

All dimensions in inches

Fig. 59. Dimensions referring to Fig. 61.

The figures given are intended to be for the average requirements of the average service car built on the various chassis which are listed in the table.

One very important point to bear in mind is that the service wagon must be attractive in appearance—clean, well-painted, and it must run smoothly and quietly. It will be one of the best investments you can make.

Painting: Cars giving Chalmers service are painted English vermillion, with black hood and running gear. Hudson service cars are white, with black trimmings. If the dealer is giving service on a particular make of car, he should find if a standard service car color is used; if not, the car may be painted any bright color that will give distinction.

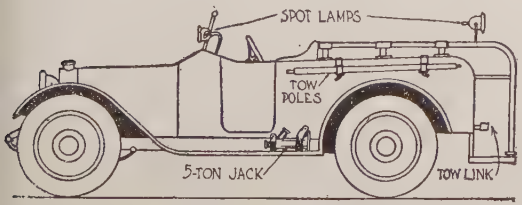
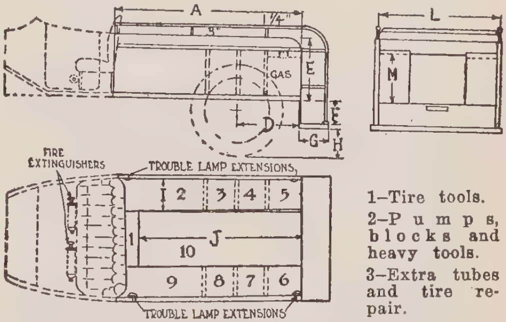


Fig. 60. After studying hundreds of service cars in dozens of the largest cities and many smaller ones, *Motor World* believes that a design of this general kind is best. Note particularly the method of carrying the towing pole, the jack mounting on the running board, and the location of the several spot lamps.



1–Tire tools.
2–Pumps, blocks and heavy tools.
3–Extra tubes and tire repair.
4–Bolts, nuts, and small repair parts.
5–Gas can.
6–Oil can.
7–Bolts, nuts, screws.
8–Small repair parts.
9–Tools.
10–Towing dolly, shovel, axe, pick, bars, battery, spare tires, etc.

Fig. 61. Here is a detail drawing of the body shown above. The lettered dimensions on the drawing are given in the table (Fig. 59). The figures refer to the location of the various tools and accessories.

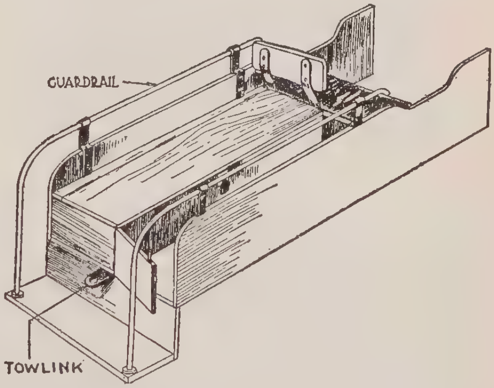


Fig. 62. An alternative type of body, built especially for very light chassis, is often desirable, in which case the arrangement can be made something like this. This is a body that is used quite successfully by the Chevrolet Co. in Detroit. There is an almost endless variety of arrangements, and in laying out a car a shop foreman should be guided by the particular class of work he expects to be called upon to do.

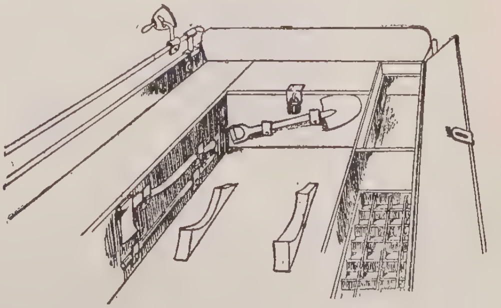


Fig. 63. This is a view of the interior of the service car shown in Fig. 60. Note the chocks and the neat arrangement of the tools, the seat at the right not being shown, so that the compartments are visible.

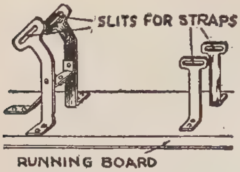


Fig. 64

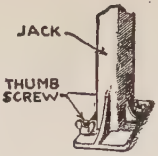


Fig. 65

Fig. 64. This is a detail drawing of the jack mounting shown on the service car illustrated in Fig. 60. In this case 5-ton jacks are carried, though any size can be substituted. Get them big enough to care for the heaviest work to be done, and they will also serve for light work.

Fig. 65. The service jacks can be carried bolted to the running board, like this, thumb-screws being used for quick action.

Several of the foregoing illustrations are by Mr. S. Thornton Williams, the *Motor World.*

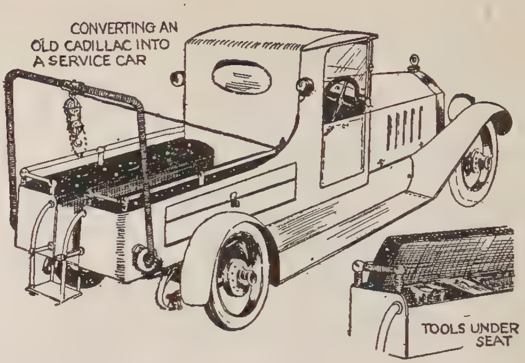

CONVERTING AN OLD CADILLAC INTO A SERVICE CAR
TOOLS UNDER SEAT

Fig. 66. Another example of a service car as suggested by *Motor Age.*

THE STOCK ROOM

More money is lost in the repair shop and garage than in any other part of the business by having supplies scattered over the shop promiscuously.

Every repair shop, no matter how small, should provide a stock room with a good lock and key, and everything in the way of supplies should be kept therein. (See Fig. 67.)

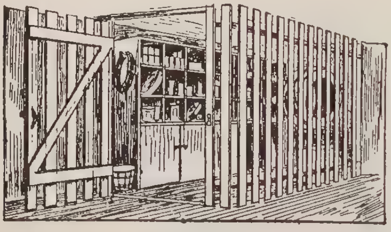


Fig. 67

Systematic arrangement and a place for everything and everything in its place will save time and money.

The **stock room** is generally placed in some convenient place in the garage or repair shop. It is usually constructed of lattice work with a good Yale lock on the door. In large shops the stock room is in charge of a responsible person, whose business it is to keep the stock replenished and deliver material to the workmen and customers.

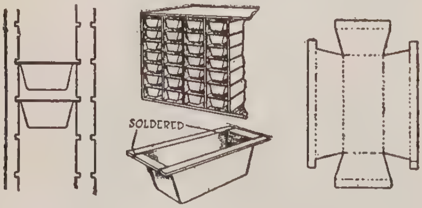


Fig. 68. Small parts, such as screws, bolts, washers, nuts, gaskets, and the like, are conveniently kept in tin drawers, as illustrated. The drawers are cut from a single piece of tin and are soldered, as shown by the heavy lines. The drawers slide in grooves cut in planks placed vertically. The grooves are made with a saw and chisel. The advantage of this method of storing parts is that the construction of the receptacles is very inexpensive, and maximum convenience is afforded. It is possible to see what is in the various drawers without pulling them out, which is a feature peculiar to this design, and saves considerable time when the exact drawer a certain part is in is not known.

Supplies in the rubber line: Repair shops can make extra money by carrying rubber supplies which are generally made by tire concerns. Some of these are as follows: Automobile rubber mats which come in rolls 3/32″ to ⅛″ thick and 35″ to 48″ wide; matting also comes corrugated and perforated; radiator hose; tire tape; rubber tubing; tire inflating tubing (comes in black, white, or red; sizes ⅛″, 5/32″, 3/16″, and ¼″ inside diameter).

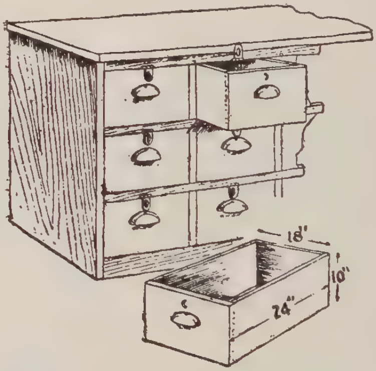


Fig. 69. Substantial drawers of large size provide convenient means **for storing parts removed from cars that are being repaired.** The usual method is to place the parts on the bench but this is objectionable because there is always danger of their being mislaid or used on other cars. A drawer 10″ x 18″ x 24″ is large enough to take all the ordinary parts, such as bolts, nuts, washers, carburetor, magneto, pistons, connecting-rods, bearings, etc. The drawer may be placed at the side of the car, and as soon as all the parts have been removed it may be put back in the cabinet. A padlock safeguards the parts until they are needed again. These drawers also aid in keeping the shop neat and protect the parts from dirt. The top of the cabinet may be used as a bench or table.

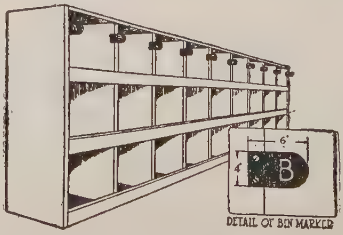


Fig. 70. **This stock-bin marker** permits ready location of any bin in the stock room. It is a sheet metal tag, bearing the number of the bin to which it is attached. As it projects out into the aisle, and is large enough to be easily read, the location of any desired bin may be seen at a glance.

Parts of Cars for the Stock Room

Parts for axles, engines, transmissions, steering gears, etc., should also be carried if there is very much work on any particular car in the vicinity. Otherwise secure a Parts Book of the manufacturer of the cars you are likely to be called to work upon, and order them as required.

Minor parts, such as windshields, radiators, ball cups, bearings, springs, fenders, wheels, rims, tires, bodies, ignition coils, distributors, generators, starting motors, batteries, axles, frames, gears, etc., can be secured from automobile parts supply houses, such parts not usually being made by the manufacturer of the car. Automobile parts supply houses also wreck cars of different makes and sell the parts, and very often a part can be secured at a very reasonable figure. Reliable concerns in this line issue circulars giving the description of such parts and their condition.

It is a good plan always to ask your customer if he wants genuine parts from the manufacturer, or parts from an automobile parts supply house.

Automobile Parts Supply Houses

Some of the automobile parts supply houses are given below:

Puritan Machine Co., Detroit, Mich.
Auto Parts Co., 4114 Olive St., St. Louis, Mo.
Auto Salvage & Exchange Co., 2823 Locust St., St. Louis, Mo.
American Automobile Parts Co., 125 W. 52d St., New York, N.Y.
Auto Parts Exchange Co., 621 Van Ness Ave., San Francisco, Cal.
Auto Wrecking Co., 1413 McGee St., Kansas City, Mo.
Machined Parts Corporation, 245 W. Larned St., Detroit, Mich.
See also "Orphan Car List" for other supply houses in this line.

See also page 687 for "Automobile Jobbers," and, if in the repair business, send for catalogue of nearest firm.

Manufacturers of Automobile Parts

Some of the manufacturers of parts for standard makes of cars are as follows:

Standard Metal Goods Co., 2080 E. 30th St., Cleveland, Ohio.
C. A. Cathart, 222 Massachusetts Ave., Boston, Mass.
Jos. Gorey & Co., 354 W. 50th St., New York, N.Y.

Gear Manufacturers

Concerns who specialize in the manufacture of transmission and rear axle gears and shafts, etc., are:

Automotive Gear Works, Atlanta, Ga.
Auto Gear Co., 844 Eighth Ave., New York, N.Y.
Auto Gear Co. of Boston, Boston, Mass.
Auto Gear Co. of Chicago, 1461 S. Michigan Ave., Chicago, Ill.
Auto Gear Co. of Los Angeles, 1213 S. Hope Ave., Los Angeles, Cal.

Some of the Small Supplies and Fittings for Stock Room

The assortment listed below, as well as all other supplies, can be secured of automobile supply houses.

Asbestos—sheet and wicking.
Babbit metal—for bearings.
Blue, Prussian, for "spotting in" bearings.
Body polish—brass and nickel.
Bolts—stove and carriage, assorted sizes.
Brake band rivets, Nos. 7, 8, 9, and 10 (copper).
Brake lining—see Index.
Brushes—for generator and motor.
Brushes—paint, scratch, file.
Bushings—for crank shafts.
Candle wicking—for pump packing.
Carbide—in cans.

CAP SCREWS
U. S. S. AND S. A. E. THREADS

An assortment of 12 in a box. Two each, ¼ inch bolt, 1 and 1¼-inch long. Two each, ⅜-inch bolt, 1 and 1¼-inch long. Two each, ⅝-inch bolt, 1¼ and 1½ inch long.

S. A. E. CASTELLATED
HEXAGON NUTS

An assortment of 15 in a box. Four each, ¼, ⅜-inch; three ⅞-inch; two each, ½, ⅝-inch. All perfect, well-finished nuts.

STANDARD HEXAGON NUTS

An assortment of 24 in a box. Standard threads. Eight each, ¼, 5/16, ⅜-inch. All perfect, well finished nuts.

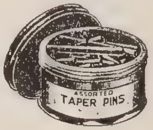
LOCK WASHERS

An assortment of 10 each in the following sizes: ¼, 5/16, ⅜-inch; three each, ⅞ ½ ⅝ inch.

CAMPBELL SPRING COTTERS

100 spring cotter pins assorted sizes; all sizes for automobile work put up in boxes.

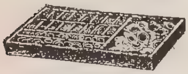
TAPER PINS



An assortment of 40 in a box. Six sizes, from 0x1 to 5x2¾ inches. High grade, turned pins.

Celluloid sheets—for top curtains.
Chalk line—for aligning wheels.
Chamois—for washing car.
Clamps—hose and screw.
Cloth—crocus and emery.
Cocks—compression and pet.
Cotter-pins—assorted sizes.
Cup and transmission grease.
Cylinder oil—light, medium, heavy.
Drill rods and drills.
Dry cells—testing not less than 25 amperes.
Electric lamp bulbs—see Index.
Ells—brass; for gasoline and oil lines.
Emery Cloth—No. 00 to No. 1.
Felt—sheet and washers.
Fibre—sheet and block.
Flux—for soldering aluminum and brass, etc.
Gaskets assorted—copper, asbestos lined for valve caps, carburetor, exhaust and inlet manifold, spark plugs, etc.
Gas tank keys—for Prest-O-Lite gas tanks.
Gas tips—½ ft. and 1 ft. sizes.
Graphite—powdered and flake.
Grease cups—⅛", ⅜".
Hand washing compound.
Hemp wicking—for packing.
Hose—for radiator and gas.
Hose clamps—for radiator hose.
Inner shoes—for blow outs.
Inner valve parts—for tire valves.
Iron—bars and rods.
Iron—sheet.
Kerosene—for general cleaning.
Key stock—in bars.
Keys—Woodruff, Whitney and straight.
Lard oil—for thread cuttings, tapping and drilling.
Leather—(heavy) for under radiator and bodies and refacing cone clutches.
Lock washers—¼" to ⅝".
Moboline, Raybestos, multibestos, etc.—for packing.
Nails—assorted.
Neatsfoot oil—for clutch.
Outer shoes—for cuts in casing.
Paper—heavy brown, sand, emery.
Pipe plugs—iron and brass ⅛" to ¾".
Platinum points—for interrupters, and magneto.
Priming cups.
Rivets—iron and copper, assorted.
Rubber—matting.

Rubber—sheet packing 1/32″ to 3/16″.
Rubber—tubing for gas, air, tire hose, etc.
Screws—machine, cap, lag, wood and set.
Sheet—iron, brass, copper, tin and lead.
Shellac—for gaskets, etc.
Shims—laminated.
Solder—half and half, string and aluminum.
Soldering compound and acid.
Spark plugs—½″, S. A. E., metric.
Spring—steel and assorted springs.
Steel bars: a few feet of ¼″, ⅜″, ½″, ⅝″, ¾″, ⅞″, and 1″ iron bars; also steel, brass, and wire rods.


Gasket, Assortment

License Bracket Bolt and Nut

Copper Wire Terminals

Spring Assortment

Machine Screws and Nuts, Assorted

Steel rods—bar, tool.
Switches—push, snap
Tacks—assorted sizes.
Tape—adhesive; for electric wiring.
Taper pins—¼″ to ⅜″.
Tees—⅛″, ¼″ brass for gas lines.
Tubing—copper, brass, for gas and oil lines ⅛″, ¼″. This tubing generally comes hard, but can be annealed (softened) by heating it.
Unions—brass, ⅛″, and soldering connections for gasoline lines.
Valve caps—for leading engines, valve caps for tire valves.
Valve grinding compound.
Valves—for gasoline and oil lines, tire valves and oversize valves for engine.
Washers—punched, split, and brass.
Wire—copper, brass, spring, piano, and insulated.
Wire—for wiring cars, such as: primary flexible cable and secondary cable.

Copper Gaskets for Spark Plugs

S. A. E: ⅞″ (inside diameter ⅞″; outside diameter, 1⅛″).
Half inch: (inside diameter, 27/32″; outside diameter, 1 3/32″).
Metric: (inside diameter, 23/32″; outside diameter, 63/64″).

Assorted Piston Rings

For new and older model cars. Can be secured of piston ring manufacturer. See Index under "Piston ring sizes."

S. A. E. Flared Tubing Fittings and Couplings[1]

These are made of cast brass for use on carburetors, oil and gasoline pipe lines, etc.

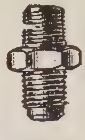
Union Nut

Nos.	65	66	67
Size tube	¼″	5/16″	⅜″
Tapped, S. A. E.	7/16 x 20	½ x 20	⅝ x 18
Length	1 15/16″	1 ⅛″	1 15/16″
Weight each (oz.)	1	1½	2

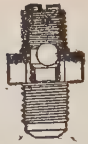
Single Union

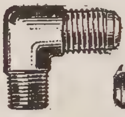
Nos.	68	69	70
Size tube	¼″	5/16″	⅜″
I. P. thread	⅛″	⅛″	¼″
S. A. E. thread	7/16 x 20	½ x 20	⅝ x 18
Length	1 1/16″	1 5/32″	1 5/16″
Weight each (oz.)	1	1½	2

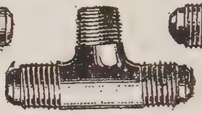
UNION NUT

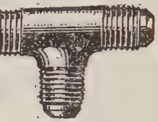

SINGLE UNION

DOUBLE UNION


BALL CHECK VALVE


ELBOW


THREE WAY TEE PIPE THREAD


THREE WAY TEE ALL SIDES S.A.E. THREAD

Double Union

Nos.	71	72	73
Size tube	¼″	5/16″	⅜″
S. A. E. thread	7/16 x 20	½ x 20	⅝ x 18
Length	1 3/16″	1 11/32″	1½″
Weight each (oz.)	1	1½	2

Ball Check Valve

Nos.	74	75	76
Size tube	¼″	5/16″	⅜″
I. P. thread	⅛″	⅛″	¼″
S. A. E. thread	7/16 x 20	½ x 20	⅝ x 18
Length	1 1/16″	1 5/32″	1 5/16″
Weight each (oz.)	1	1½	2

Elbow

Nos.	77	78	79
Size tube	¼″	5/16″	⅜″
I. P. thread	⅛″	⅛″	¼″
S. A. E. thread	7/16 x 20	½ x 20	⅝ x 18
Weight each (oz.)	1	1½	2

Three-Way Tee Pipe Thread

Nos.	80	81	82
Size tube	¼″	5/16″	⅜″
I. P. thread	⅛″	⅛″	¼″
S. A. E. thread	7/16 x 20	½ x 20	⅝ x 18
Length	1¾″	1⅞″	2″
Weight each (oz.)	2	2½	3

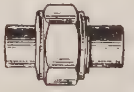
Three-Way Tee; All Sides S. A. E. Thread

Nos.	83	84	85
Size tube	¼″	5/16″	⅜″
S. A. E. thread	7/16 x 20	½ x 20	⅝ x 18
Length	1¾″	1⅞″	2″
Weight each (oz.)	2	2½	3

Pipe Fittings

See Index for "Pipe specifications," and for "Pipe threads.[2]"

ELBOW


UNION

TEE-STRAIGHT SIZE

STREET ELBOW

DOUBLE MALE ELBOW

CLOSE NIPPLE

COUPLINGS

PLUG

REDUCING BUSHING

Elbow

Nos.	40	41	42
Size	⅛″	¼″	⅜″
Weight each (oz.)	½	1	1½

Union

Nos.	43	44	45
Size	⅛″	¼″	⅜″
Weight each (oz.)	2	2½	3

Tee—Straight Size

Nos.	46	47	48
Size	⅛″	¼″	⅜″
Weight each (oz.)	½	1	1½

---

[1] Can be secured of automobile supply houses. S. A. E. means Society of Automotive Engineers.

[2] I. P. means iron pipe size.

Street Elbow

Nos.	49	50
Size	⅛″	¼″
Weight each (oz.)	½	1

Double Male Elbow

No.	52
Size	⅛″
Weight each (oz.)	1

Close Nipple

Nos.	55	56	57
Size	⅛″	¼″	⅜″
Weight each (oz.)	½	½	1

Couplings

Nos.	58	59	60
Size	⅛″	¼″	⅜″
Weight each (oz.)	½	1	1½

Plug

Nos.	61	62	63
Size	⅛″	¼″	⅜″
Weight each (oz.)	1	1½	2

Reducing Bushing

Nos.	64	65	66
Size	⅛″	¼″	⅜″
Weight each (oz.)	½	½	1

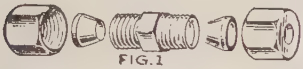


FIG. 1

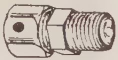


FIG. 2

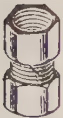


FIG. 3

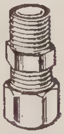


FIG. 4

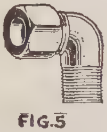


FIG. 5

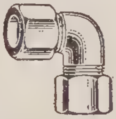


FIG. 6

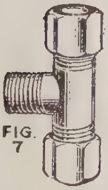


FIG. 7

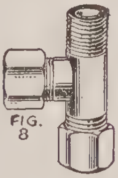


FIG. 8

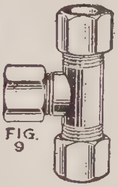


FIG. 9

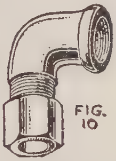


FIG. 10

Solderless fittings for gasoline, gas lines, used for connecting tubing on gasoline and oiling systems without swaging or soldering. They are made for ¼″ and 5/16″ outside diameter tubing; ¼″ size is generally used. (1) Showing how ends are drawn together. (2) Check valve, straight. (3) Tapered female ⅛″ pipe, one end. (4) Nipple union, male ⅛″ pipe, one end. (5) Elbow male. (6) Elbow coupling. (7) Tee coupling on opposite ends, ⅛″ pipe thread (male) on other. (8) Tee angle coupling, male thread one end. (9) Tee angle on three ends. (10) Elbow coupling on one end, female pipe thread on other.

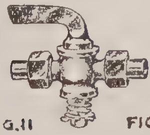


FIG. 11

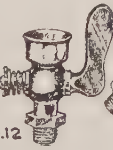


FIG. 12

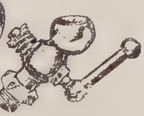


FIG. 13

Fig. 11. Shut-off cocks.

Fig. 12. Priming cups.

Fig. 13. Priming cups for V-type engine.

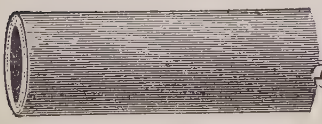


FIG. 15

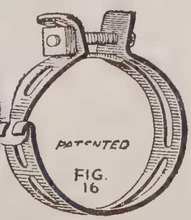


FIG. 16

Fig. 15. **Rubber hose** for radiators should be carried in all stock rooms.

Fig. 16. **Hose clamps** are necessary. This type is the Sherman wrought brass clamp to fit radiator hose.

4-ply hose	4-ply hose	4-ply hose
¾″ inside diam.	1½″ inside diam.	2½″ inside diam.
1 ″ inside diam.	1¾″ inside diam.	2¾″ inside diam.
1⅛″ inside diam.	2 ″ inside diam.	3 ″ inside diam.
1¼″ inside diam.	2¼″ inside diam.	

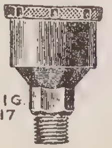


FIG. 17

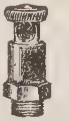


FIG. 18

FIG. 19

FIG. 20

Fig. 17. **Grease cups** ought to be carried in every stock room. The sizes of grease cups run as follows: 000—⅛″ pipe thread; 00—⅛″ pipe thread; 0—⅛″ or ¼″ pipe thread. The diameter of 000 is ¾″; 00 is 1″; and 0 is 1¼″.

Fig. 18. **Oil cups** run as follows: No. 1—¼ x 32 thread, ⅜″ diameter. No. 2—5/16 x 32 thread, 7/16″ diameter. No. 3—⅜ x 24 thread, ½″ diameter. No. 4—7/16 x 24 thread, 9/16″ diameter.

Fig. 19. **Oil cans** which are in demand.

Fig. 20. **Cotter pins:** An assortment of cotter pins, ¾″, 1″, 1¼″, 1¾″, and 2″ lengths.

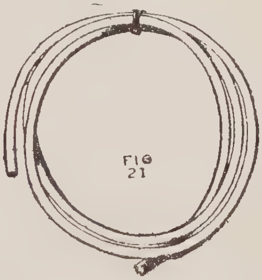


FIG 21

Fig. 21. **Brass tubing:** Annealed seamless brass, size ¼″, 5/16″, and ⅜″.

Fig. 22. **Armored cable:** This type of cable is used in all high-grade wiring installations. Conductor is standard copper No. 16 gauge insulated with rubber and varnished fabric. Sherardized protecting cover on outside. Diameter, 3/16″.

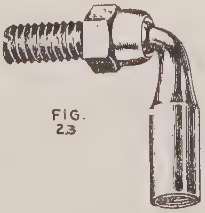


FIG. 23

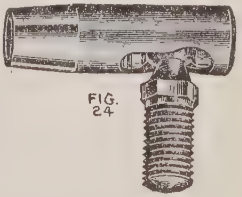


FIG. 24

Figs. 23, 24. **Spark and throttle ball-joints,** used for connecting magneto timer levers and carburetor throttle lever, with levers on steering wheel. They eliminate all lost motion and give more perfect control. The screw end fits the timer and carburetor lever; the tapped hole fits the connecting rod. They come 25 in a box, assorted (Stevens & Co.).

MONEY-MAKING ADDITIONS TO THE GARAGE

There are several departments which can be added to the garage, all necessary and well worth the investment.

Tire department: A small or large vulcanizer for repairing tires. See the discussion of the subject of "Tires."

A battery charging and repair department: For recharging, starting, lighting, and ignition batteries. See "Storage Battery" Instruction.

During the winter months, there is much more of such battery recharging work brought to the garages because the cold weather reduces the charge-holding capacity of the storage batteries, while at the same time the cold engines require more current from the batteries to start them.

Electric testing and repair department. See Index under "Electric testing and repairs."

Oxy-acetylene outfit: For welding and carbon cleaning, see index. Of course, with all this, more room will be necessary, but it is surprising in how small a space all these departments can be carried on, if properly planned.

Carbon cleaning outfits for removing carbon. See Index.

Radiator repairs. See Index.

There is quite a profit in handling lubricating oils, grease, and gasoline. If possible, an equipment for handling these should be added.

The car rental and towing service is something worth considering, and can be added in time.

Sell Supplies

A supply department is very remunerative, providing the proper supplies are carried.

It is necessary, however, to display your goods so that customers can see them and ask for them. Sales follow as a natural sequence. A very serviceable and attractive display bin is shown in Fig. 25. Fireproof metal bins are of course preferable to wood construction.

Ask for an illustrated booklet of the Walker Bin Co., Penn Yan, N.Y.

When the motorist drives up to your garage for gas or oil, or for air for his tires, give his car the quick once-over and see if you can't sell him some accessories.

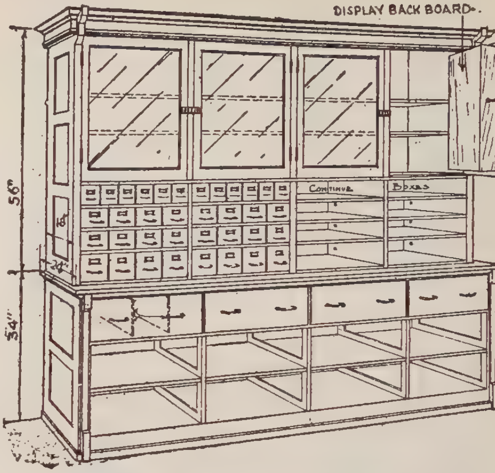


Fig. 25. Display bin for supplies.

When a motorist asks for an accessory, this should suggest something else that you can sell him. But it is not enough to ask him if he wants it. You have got to tell him why he ought to have it. That's what these selling arguments are for. Use them!

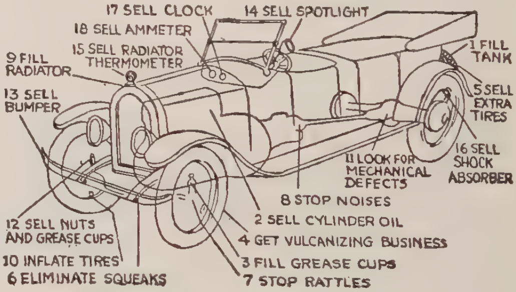


Fig. 26. Sales and service chart.

Fig. 26 shows a brief list of merchandise or auto supplies, etc., which the garage dealer ought to sell to his customers. The illustration is taken from *Motor World*, and is intended to be kept in front of the dealer that he may memorize the list.

ORPHAN CARS;[1] WHERE TO OBTAIN PARTS

A list of cars no longer manufactured and where the parts can be obtained follows:

Abbott: The Boneyard, Washington, Iowa; Auto Salvage Co., 1701–03 Main St., Kansas City, Mo.; Auto Salvage & Exchange Co., 1317–19 Locust St., Des Moines; Iowa; Auto Parts Co., 4116–18 Olive St., St. Louis, Mo.; Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.; Standard Motor Parts Co., Detroit, Mich.

Adams: Longaker Co., V. A., 448–50 N. Capitol Ave., Indianapolis, Ind.

Aerocar: Auto Gear & Parts Co., 291–93 Marietta St., Atlanta, Ga.; Auto Salvage & Exchange Co., 1317–19 Locust St., Des Moines, Iowa.

Alco: Alco Service Co., 158–62 N. Twenty-Second St., Philadelphia, Pa.; Auto Salvage Co., 1701–03 Main St., Kansas City, Mo.; American Locomotive Co., Providence, R.I.; International Motor Co., West End Ave. and 64th St., New York, N.Y.; Levene Motor Co., 2200–18 Diamond St., Philadelphia, Pa.; Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Alden-Sampson: Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.; Standard Motor Parts Co., New Castle, Ind.

Allis-Chalmers: Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Alma: Dayton Auto Parts Co., 1777 Broadway, New York, N.Y.

Alpena: Auto Gear & Parts Co., 291–93 Marietta St., Atlanta, Ga.; Auto Salvage & Exchange Co., 1317–19 Locust St., Des Moines, Iowa; Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Alter: American Motors Parts Co., 430 N. Capitol Ave., Indianapolis, Ind.; Auto Gear & Parts Co., 291–93 Marietta St., Atlanta, Ga.; Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

American: American Motors Parts Co., 430 N. Capitol Ave., Indianapolis, Ind.; Purt Motor Car Co., W. J., Pico & Hope Sts., Los Angeles, Cal.; Longaker Co., V., 448–50 N. Capitol Ave., Indianapolis, Ind.

American Mors: St. Louis Car Co., 8000 N. Broadway, St. Louis, Mo.; Wichita Auto Wrecking Co., 805–809 W. Douglas Ave., Wichita, Kan.

American Underslung: American Motor Parts Co., 430 N. Capitol Ave., Indianapolis, Ind.; Auto Gear & Parts Co., 291–93 Marietta St., Atlanta, Ga.; Auto Salvage Co., 1701–03 Main St., Kansas City, Mo.; Longauer Co., V. A., 448 N. Capitol Ave., Indianapolis, Ind.; Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Ames: Auto Gear & Parts Co., 291–93 Marietta St., Atlanta, Ga.; Auto Salvage & Exchange Co., 1317–19 Locust St., Des Moines, Iowa.

Amplex: Gillette Motors Co., Mishawaka, Ind.; Gorey & Co., Jos. C., 354 W. Fiftieth St., New York, N.Y.

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[1] An "orphan car" is one which is no longer being manufactured. From *Motor Age* and *Motor World*.

Anchor: Gustin Automobile Co., 18–20 E. Mitchell Ave., Cincinnati, Ohio.

Anhut: Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Arbenz: Auto Gear & Parts Co., 291–93 Marietta St., Atlanta, Ga.

Argo: Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Argo Electric: Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Atlantic: Auto Gear Co., 844 Eighth Ave., New York, N.Y. Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Atlas: Auto Gear & Parts Co., 291–93 Marietta St., Atlanta, Ga.; Auto Parts Co., 4116–18 Olive St., St. Louis, Mo.; Gorey & Co., Jos. C., 354 W. Fiftieth St., New York, N.Y. Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Austin: Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Babcock: Auto Gear & Parts Co., 291–93 Marietta St., Atlanta, Ga.; Dayton Auto Parts Co., 1777 Broadway, New York, N.Y.

Badger: Auto Gear & Parts Co., 291–93 Marietta St., Atlanta, Ga.; Auto Salvage & Exchange Co., 1317–19 Locust St., Des Moines, Iowa; Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.; Schultz & Harder, Columbus, Wis.

Barnes: Puritan Machine Co., 422 Lafayette Blvd., Detroit. Mich.

Bauer: Bauer Machine Co., 109 W. Eighteenth St., Kansas City, Mo.

Beaver: Auto Parts Co., 4116–18 Olive St., St. Louis, Mo.

Benham: Dayton Auto Parts Co., 1777 Broadway, New York, N.Y.; Gorey & Co., Jos. C., 354 W. Fiftieth St., New York, N.Y.; Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Benz: Gorey & Co., Jos. C., 354 W. Fiftieth St., New York, N.Y.

Bergdoll: Auto Gear & Parts Co., 291–93 Marietta St., Atlanta, Ga.; Auto Parts Co., 4116 Olive St., St. Louis, Mo.; Gorey & Co., Jos. C., 354 W. Fiftieth St., New York, N.Y.; Levene Motor Co., 2200–18 Diamond St., Philadelphia, Pa.; Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.; Schober, G.M., 3339 Market St., Philadelphia, Pa.

Berkshire: Auto Gear & Parts Co., 291–93 Marietta St., Atlanta, Ga.; Belcher Engineering Co., 43 Ames St., Cambridge, Mass.; Dayton Auto Parts Co., 1777 Broadway, New York, N.Y.; Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Berliet: American Locomotive Co., Providence, R.I.

Bessemer: Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Bimel: American Motor Parts Co., 430 N. Capitol Ave., Indianapolis, Ind.

Black Crow: Crow-Elkhart Motor Co., 1100 N. Main St., Elkhart, Ind.

Blomstrom: Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Borland: Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Briggs-Detroiter: Levene Motor Co., 2200–18 Diamond St., Philadelphia, Pa.; Midland Motor Co., 2029 Michigan Ave., Chicago, Ill.; Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Broc Electric: Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Brodesser: Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Brown: Great Western Automobile Co., Kalamazoo, Mich.; The Bone Yard, Washington, Iowa.

Brush: Auto Parts Co., 4116–18 Olive St., St. Louis, Mo.; Auto Salvage & Exchange Co., 1317–19 Locust St., Des Moines, Iowa; Auto Salvage Co., 1701–03 Main St., Kansas City, Mo.; Davidson Repair Shop, 227 W. Sixty-fourth St., New York, N.Y.; Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.; Standard Motor Parts Co., New Castle, Ind.

Burg: Wichita Auto Wrecking Co., 807 W. Douglas Ave., Wichita, Kan.

Bush: Victor Motor Co., York, Pa.

California: Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Carhartt: Auto Gear & Parts Co., 291–93 Marietta St., Atlanta, Ga.; Dayton Auto Parts Co., 1777 Broadway, New York, N.Y.; Gorey & Co., Jos. C., 354 W. Fiftieth St., New York, N.Y.; Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Car-Nation: Auto Gear & Parts Co., 291–93 Marietta St., Atlanta, Ga.; Car-Nation Motor Co., Detroit, Mich;. Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.; Standard Motor Parts Co., Detroit, Mich.

Cartercar: Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.; Wichita Auto Wrecking Co., 807 W. Douglas Ave., Wichita, Kan.

Carthage: Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Cavac: Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Century: Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Chadwick: Auto Salvage Co., 1701–03 Main St., Kansas City, Mo.; Louis Berkholz, 223 N. Fourth St., Philadelphia. Pa.

Chase: Auto Parts Co., 4116–18 Olive St., St. Louis, Mo.

Cinco: Auto Salvage Co., 1701–03 Main St., Kansas City, Mo.; Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.; Queen City Auto Parts Co., 633 Main St., Cincinnati, Ohio.

Cino: Northway Auto Parts & Sales Co., 223 Kearney St., Cincinnati, Ohio.

Clark: Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.; Wichita Auto Wrecking Co., 807 W. Douglas Ave., Wichita, Kan.

Clark-Carter: Erbes, L.C., 2654 W. University Ave., St. Paul, Minn.; Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Coates-Goshen: Coates, J.S., Goshen, N.Y.

Colburn: Colburn Automobile Co., 416 E. Tenth Ave., Denver, Colo.; Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Colby: Auto Gear Co., 1404 Hennepin Ave., Minneapolis, Minn.; E. V. Harper, 306 S. Federal St., Mason City, Iowa; Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Columbia (old): Columbia Auto Repair Co., 19 Buckingham St., Hartford, Conn.; Progress Auto Wrecking Co., 819 Bedford Ave., Brooklyn, N.Y.; Standard Motor Parts Co., Detroit, Mich.; Standard Motor Parts Co., New Castle, Ind.

Columbia Knight: Columbia Auto Repair Co., Hartford, Conn.; Standard Motor Parts Co., New Castle, Ind.

Columbus Electric: Butler Mfg. Co., Knightstown, Ind.; Columbus Buggy Parts Co., Dublin Ave., Columbus, Ohio.

Continental: Auto Parts Co., 4116 Olive St., St. Louis, Mo.; Continental Auto Parts Co., Knightstown, Ind.; Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Corbin: Barney's Auto Parts Co., Inc., 236 W. Fiftieth St., New York, N.Y.; Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Courier: Auto Gear Parts Co., 291–93 Marietta St., Atlanta, Ga.; Dayton Auto Parts Co., 1777 Broadway, New York, N.Y.; Gorey & Co., Jos. C., 354 W. Fiftieth St., New York, N.Y.; Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Courier-Clermont: Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.; Standard Motor Parts Co., New Castle, Ind.

Crescent: Auto Gear & Parts Co., 291–93 Marietta St., Atlanta, Ga.; Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.; St. Bernard Garage, St. Bernard, Ohio.

Crow: Auto Gear & Parts Co., 291–93 Marietta St., Atlanta, Ga.; Barney's Auto Parts Co., Inc., 236 W. Fiftieth St., New York, N.Y.; Crow-Elkhart Motor Co., 1116 N. Main St., Elkhart, Ind.; Progress Auto Wrecking Co., 819 Bedford Ave., Brooklyn, N.Y.; Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Croxton: Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Croxton-Keeton: Auto Gear Co., 844 Eighth Ave., New York, N.Y.; Auto Gear & Parts Co., 291–93 Marietta St. Atlanta, Ga.; Auto Salvage & Exchange Co., 1317–19 Locust St., Des Moines, Iowa; Dayton Auto Parts Co., 1777 Broadway, New York, N.Y.; Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich.

Cutting: Auto Gear Co., 1404 Hennepin Ave., Minneapolis, Minn.; Auto Gear Co., 844 Eighth Ave., New York, N.Y.; Auto Gear & Parts Co., 291–93 Marietta St., Atlanta, Ga.; Auto Parts Co., 2801–11 Preston Ave., Houston, Tex.; Auto Salvage & Exchange Co , 1317 Locust St., Des Moines, Iowa; Erbes, L. C., 3654 W. University Ave., St. Paul, Minn.; Gorey & Co., Jos. C., 354 W. Fiftieth St., New York, N.Y.; Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich.; Sattler's Machine Shops & Works, 1601 Spring Garden St., Philadelphia, Pa.; Service Gear & Machine Co., Reading, Pa.; The Boneyard, Washington, Iowa; Wolf Auto Parts & Tire Co., I., 619 N. Illinois St., Indianapolis, Ind.; Wycoff Auto Salvage Co., Sioux City, Iowa.

Dart: Auto Salvage Co., 1701–03 Main St., Kansas City, Mo.; Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Davis: Dayton Auto Parts Co., 351–55 W. Fifty-second St., New York, N.Y.

Dearborn-Detroit: Huron Motor Car Co., Dearborn, Mich.; Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Decauville: Gorey & Co., Jos. C., 354 W. Fiftieth St., New York, N.Y.

De Kalb: Dayton Auto Parts Co., 1777 Broadway, New York, N.Y.

De Luxe: Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Demot: Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich.

De Tamble: American Motors Parts Co., Indianapolis, Ind.; Auto Gear Co., 844 Eighth Ave., New York, N.Y.; Auto Gear & Parts Co., 291–93 Marietta Ave., Atlanta, Ga.; De Tamble Motors Co., Washington Ave., and Geisendorff St., Indianapolis, Ind.; Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich.; Shepard Auto Co., 106 Pennsylvania Ave., Brooklyn, N.Y.

Detroiter: Auto Gear & Parts Co., 291–93 Marietta Ave., Atlanta, Ga.; Auto Parts Co., 2801–11 Preston Ave., Houston, Tex.; Detroiter Motor Car Co., Detroit, Mich; Standard Motor Parts Co., New Castle, Ind.; The Boneyard, Washington, Iowa; Wichita Auto Wrecking Co., 801 W. Douglas Ave., Wichita, Kan.; Wycoff Auto Salvage Co., Sioux City, Iowa.

Diamond: Auto Gear Co., 844 Eighth Ave., New York, N.Y.

Dolson: Dayton Auto Parts Co., 1777 Broadway, New York, N.Y.

Dragon: Gorey & Co., Jos. C., 354 W. Fiftieth St., New York, N.Y.; Philadelphia Machine Works, 61–71 Laurel Ct., Philadelphia, Pa.; Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Drexel: Auto Auction Co., 519 W. Jackson Blvd., Chicago, Ill.; Auto Gear & Parts Co., 291–93 Marietta Ave., Atlanta, Ga.

Drummond: Auto Gear & Parts Co., 291–93 Marietta Ave., Atlanta, Ga.

Dupont: Auto Gear & Parts Co., 291–93 Marietta Ave., Atlanta, Ga.; Victor Motor Co., York, Pa.

Durocar: Auto Gear Co., 1044 Hennepin Ave., Minneapolis, Minn.; Auto Parts Co., 4116–18 Olive St., St. Louis, Mo.

E.M.F.: Auto Parts Co., 2801–11 Preston Ave., Houston, Tex.; Carey & Davis, 486 Louisiana Ave., Washington, D.C.; Gorey & Co., Jos. C., 354 W. Fiftieth St., New York, N.Y.; Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich.; Sattler's Machine Shops & Works, 1601 Spring Garden St., Philadelphia, Pa.; Service Gear & Machine Co., Reading, Pa.; Studebaker Corp., of America, Detroit, Mich.; The Boneyard, Washington, Iowa.

Edwards-Knight: Dayton Auto Parts Co., 1777 Broadway, New York, N.Y.; Willys-Overland, Inc., Toledo, Ohio.

Elmore: Auto Gear Co., 844 Eighth Ave., New York, N.Y.; Auto Gear & Parts Co., 291–93 Marietta St., Atlanta, Ga.; Auto Parts Co., 4116–18 Olive St., St. Louis, Mo.; Auto Parts Co., 2801–11 Preston Ave., Houston, Tex.; Auto Salvage Co., 1701 Main St., Kansas City, Mo.; Gorey & Co., Jos. C., 354 W. Fiftieth St., New York, N.Y.; Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich.; Wolf Auto Parts & Tire Co., I., 619 N. Illinois St., Indianapolis, Ind.

Empire: Auto Gear Co., 1404 Hennepin Ave., Minneapolis, Minn.; Auto Gear Co., 844 Eighth Ave., New York, N.Y.; Auto Parts Co., 2801–11 Preston Ave., Houston, Tex.; Empire Auto Co., Indianapolis, Ind.; Sattler's Machine Shops & Works, 1601 Spring Garden St., Philadelphia, Pa.; The Boneyard, Washington, Iowa; Wolf Auto Parts & Tire Co., I., 619 N. Illinois St., Indianapolis, Ind.

Enger: Auto Gear Co., 844 Eighth Ave., New York, N.Y.; Auto Gear & Parts Co., 291–93 Marietta Ave., Atlanta, Ga.; American Motors Parts Co., Indianapolis, Ind.; Enger Motor Car Co., Indianapolis, Ind.; Erbes Motor Car Co., L.E., 2654 W. University Ave., St. Paul, Minn.; Wichita Auto Wrecking Co., 807 W. Douglas Ave., Wichita, Kan.

Everett: Auto Gear Co., 1404 Hennepin Ave., Minneapolis, Minn.; Auto Gear Co., 844 Eighth Ave., New York, N.Y.; Auto Gear & Parts Co., 291–93 Marietta Ave., Atlanta, Ga.; Auto Parts Co., 2801–11 Preston Ave., Houston, Tex.; Auto Parts Co., 4116 Olive St., St. Louis, Mo.; Dayton Auto Parts Co., 1777 Broadway, New York, N.Y.; Gorey & Co., Jos. C., 354 W. Fiftieth St., New York, N.Y.; Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich.; Sattler's Machine Shops & Works, 1601 Spring Garden St., Philadelphia, Pa.; Service Gear & Machine Co., Reading, Pa.; Standard Motor Parts Co., New Castle, Ind.

Ewing: Gorey & Co., Jos. C., 354 W. Fiftieth St., New York, N.Y.; Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

F.A.L.: Auto Gear Co., 844 Eighth Ave., New York, N.Y.; Auto Gear & Parts Co., 291–93 Marietta Ave., Atlanta, Ga.; Auto Salvage Co., 1701–03 Main St., Kansas City, Mo.; Auto Salvage & Exchange Co., 1317 Locust St., Des Moines, Iowa; Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich.; Wichita Auto Wrecking Co., 807 W. Douglas Ave., Wichita, Kan.

Falcar: Wichita Auto Wrecking Co., Wichita, Kan.

Farmack: Auto Gear & Parts Co., Atlanta, Ga.

Firestone Columbus: Auto Gear Co., 844 Eighth Ave., New York, N.Y.; Auto Parts Co., 2801 Preston Ave., Houston, Tex.; Columbus Buggy Parts Co., Columbus, Ohio; Wichita Auto Wrecking Co., 801 W. Douglas Ave., Wichita, Kan.

Fisher: Auto Gear & Parts Co., 291–93 Marietta Ave., Atlanta, Ga.

Flanders: Auto Gear Co., 844 Eighth Ave., New York, N.Y.; Auto Parts Co., 2801–11 Preston Ave., Houston, Tex.; Auto Parts Co., 4116 Olive St., St. Louis, Mo.; Auto Salvage Co., Tulsa, Okla.; Dayton Auto Parts Co., 1777 Broadway, New York, N.Y.; Levene Motor Co., 2200–18 Diamond St., Philadelphia, Pa.; Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich.; Sattler's Machine Shops & Works, 1601 Spring Garden St., Philadelphia, Pa.; Service Gear & Machine Co., Reading, Pa.; Standard Motor Parts Co., New Castle, Ind.; Studebaker Corp., of America, Detroit, Mich.; The Boneyard, Washington, Iowa.

Flanders Electric: Levene Motor Co., 2200 Diamond St., Philadelphia, Pa.

Fuller: Jackson Auto Co., Jackson, Mich.; Wichita Auto Wrecking Co., Wichita, Kan.

Gaeth: Gaeth Motor Car Co., 2103 Lorain Ave., Cleveland, Ohio.

Garford: Auto Parts Co., 2801–28 Preston Ave., Houston, Tex.; Auto Parts Co., 4116–18 Olive St., St. Louis, Mo.; Elyria Belting & Machine Co., Elyria, Ohio; Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich.

G-J-G.: Grossman Auto Parts Co., White Plains, N.Y.

Gleason: Auto Salvage Co., 1701–03 Main St., Kansas City, Mo.; Bauer Machine Works Co., 109 W. Eighteenth St., Kansas City.

Glide: Auto Gear Co., 1401 Hennepin Ave., Minneapolis, Minn.; Auto Gear Co., 844 Eighth Ave., New York, N.Y.; Auto Parts Co., 2801–11 Preston Ave., Houston, Tex.

Grabowsky: Dayton Auto Parts Co., 1777 Broadway, New York, N.Y.; Gorey & Co., Jos. C., 354 W. Fiftieth St., New York, N.Y.; Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Gramm: Auto Salvage Co., 1701–03 Main St., Kansas City, Mo.; Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Gramm-Logan: Garford Motor Truck Co., Wapak Rd., Lima, Ohio.

Great Eagle: Auto Salvage Co., 1701–03 Main St., Kansas City, Mo.

Great Smith: Auto Salvage Co., 1701–03 Main St., Kansas City, Mo.

Great Western: Auto Gear Co., 844 Eighth Ave., New York, N.Y.; Auto Gear & Parts Co., 291–93 Marietta Ave., Atlanta, Ga.; Auto Salvage & Exchange Co., 1317 Locust St., Des Moines, Iowa; Great Western Auto Co., Kalamazoo, Mich.; Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich.; Wichita Auto Wrecking Co., 801 W. Douglas Ave., Wichita, Kan.; Wolf Auto Parts & Tire Co., I., 619 N. Illinois St., Indianapolis, Ind.

Grout: Red Arrow Auto Co., E. River St., Orange, Mass.

H.A.L.: Auto Gear & Parts Co., 291–93 Marietta Ave., Atlanta, Ga.; Standard Motor Parts Co., Detroit, Mich.

Halladay: Auto Gear Co., 1404 Hennepin Ave., Minneapolis, Minn.; Auto Gear Co., 844 Eighth Ave., New York, N.Y.; Auto Gear & Parts Co., 291–93 Marietta Ave., Atlanta, Ga.; Barley Motor Car Co., Kalamazoo, Mich.; Wichita Auto Wrecking Co., Wichita, Kan.

Hatfield: Auto Gear & Parts Co., 291–93 Marietta Ave., Atlanta, Ga.

Havers: Auto Gear Co., 844 Eighth Ave., New York, N.Y.; Auto Gear & Parts Co., 291–93 Marietta Ave., Atlanta, Ga.; Auto Salvage & Exchange Co., 1317–19 Locust St., Des Moines, Iowa; Dayton Auto Parts Co., 1777 Broadway, New York, N.Y.; Gorey & Co., Jos. C., 354 W. Fiftieth St., New York, N.Y.; Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich.; Sattler's Machine Shops & Works, 1601 Spring Garden St., Philadelphia, Pa.

Hazard: Puritan Machine Co., Detroit, Mich.

Henderson: Auto Gear Co., 1404 Hennepin Ave., Minneapolis, Minn.; Auto Gear Co., 844 Eighth Ave., New York, N.Y.; Auto Gear & Parts Co., 291–93 Marietta Ave., Atlanta, Ga.; Auto Parts Co., 2801–11 Preston Ave., Houston, Tex.; Auto Salvage Co., 1701–03 Main St., Kansas City, Mo.; Buda Co., Harvey, Ill.; Gorey & Co., Jos. C., 354 W. Fiftieth St., New York, N.Y.; Henderson Motor Car Co., Detroit, Mich.; Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich. Service Gear & Machine Co., Atlanta, Ga.; Smith Corp., A.O., Milwaukee, Wis.; Standard Motor Parts Co., Detroit.

Henry: Gorey & Co., Jos. C., 354 W. Fiftieth St., New York, N.Y.; Puritan Machine Co., 422 Lafayette Blvd., Detroit.

Hercules: Auto Gear & Parts Co., 291–93 Marietta Ave., Atlanta, Ga.

Herff-Brooks: Auto Salvage Co., 1701–03 Main St., Kansas City, Mo.; Wayne Works, Richmond, Ind.

Herreshoff: American Motors Parts Co., Indianapolis, Ind.; Auto Parts Co., 2801–11 Preston Ave., Houston, Tex.; Auto Parts Co., 4116–18 Olive St., St. Louis, Mo.; Gorey & Co., Jos. C., 354 W. Fiftieth St., New York, N.Y.; Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich.; Wichita Auto Wrecking Co., 801 W. Douglas Ave., Wichita, Kan.; Wolf Auto Parts & Tire Co., I., 619 N. Illinois St., Indianapolis, Ind.

Hewitt: International Motor Co., Sixty-fourth St. & West End Ave., New York, N.Y.

Houpt Rockwell: New Departure Mfg. Co., Bristol, Conn.

Hudson Franklin: Boston Auto Parts Co., 1221 Dorchester Ave., Boston, Mass.

Imperial: Auto Gear Co., 1404 Hennepin Ave., Minneapolis, Minn.; Auto Gear Co., 844 Eighth Ave., New York, N.Y.; Auto Gear & Parts Co., 291–93 Marietta St., Atlanta, Ga.; Erbes, L. C., 2654 W. University Ave., St. Paul, Minn.; Imperial Auto Part Co., Detroit, Mich.; Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich.; Sattler's Machine Shops & Works, 1601 Spring Garden St., Philadelphia, Pa.; Standard Motor Parts Co., New Castle, Ind.; The Boneyard, Washington, Iowa.

Indiana: Dayton Auto Parts Co., 1777 Broadway, New York, N.Y.

Inter-State: Auto Gear Co., 1404 Hennepin Ave., Minneapolis, Minn.; Auto Gear Co., 844 Eighth Ave., New York, N.Y.; Auto Gear & Parts Co., 291–93 Marietta Ave., Atlanta, Ga.; Auto Parts Co., 2801–11 Preston Ave., Houston, Tex.; Sattler's Machine Shops & Works, 1601 Spring Garden St., Philadelphia, Pa.; Standard Motor Parts Co., New Castle, Ind.; Wolf Auto Parts & Tire Co., 619 N. Illinois St., Indianapolis, Ind.

Jackson: Auto Salvage Co., 1701–03 Main St., Kansas City, Mo.; Jackson Automobile Co., Jackson, Mich.

Jeffery: Auto Parts Co., 4116–18 Olive St., St. Louis, Mo.; Auto Salvage Co., Tulsa, Okla.; Nash Motors Co., Kenosha, Wis.

Jenkins: Dayton Auto Parts Co., 1777 Broadway, New York, N.Y.; Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich.

Keeton: Car-Nation Motor Car Co., Detroit, Mich.; Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich.; Standard Motor Parts Co., New Castle, Ind.

Kermath: Puritan Machine Co., Detroit, Mich.

Kermet: Knox Motor Co., 53 Wilbraham Rd., Springfield, Mass.; Keith Bros., Elkhart, Ind.; Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Knox: Alco Service Co., 158 N. Twenty-second St., Philadelphia, Pa.; Auto Parts Co., 2801–11 Preston Ave., Houston, Tex.; Boulevard Motor Co, 276 River St., Cambridge, Mass.; Knox Motors' Association, Springfield, Mass.; Sattler's Machine Shops & Works, 1601 Spring Garden St., Philadelphia, Pa.; Wolf Auto Parts & Tire Co., 619 N. Illinois St., Indianapolis, Ind.; Wycoff Auto Salvage Co., Sioux City, Iowa.

Krebs: Dayton Auto Parts Co., 1777 Broadway, New York, N.Y.

Krit: Auto Gear Co, 1404 Hennepin Ave., Minneapolis, Minn.; Auto Gear Co., 844 Eighth Ave., New York, N.Y.; Auto Gear & Parts Co., 291–93 Marietta Ave., Atlanta, Ga.; Auto Parts Co., 2801–11 Preston Ave., Houston, Tex.; Auto Parts Co., 4116–18 Olive St., St. Louis, Mo.; Auto Salvage Co., 1701–03 Main St., Kansas City, Mo.; Connecticut Auto Parts Co., 583 Franklin Ave., Hartford, Conn.; Krit Motor Car Co., Detroit, Mich.; Motor Corp., 1309 Race St, Philadelphia, Pa.; Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich; Sattler's Machine Shops & Works, 1601 Spring Garden St., Philadelphia, Pa.; Service Gear & Machine Co., Reading, Pa.; Schober, G.M., 3339 Market St., Philadelphia, Pa.; Standard Motor Parts Co., New Castle, Ind.; Wolf Auto Parts & Tire Co., 619 N. Illinois St., Indianapolis, Ind.; Wycoff Auto Salvage Co., Sioux City, Iowa; The Boneyard, Washington, Iowa.

Lambert: Great Western Auto Co., Kalamazoo, Mich.; Lambert Auto Service Co., 430 N. Capitol Ave., Indianapolis, Ind.; Wichita Auto Wrecking Co., 801 W. Douglas Ave., Wichita, Kan.

Lansden-Electric: Kelland Motor Car Co., 58 Elm St., Newark, N.J.

Laurel: Auto Gear & Parts Co., 291–93 Marietta Ave., Atlanta, Ga.

Lenox: Puritan Machine Co., 422 Lafayette Blvd., Detroit.

Lewis: Longaker Co., V.A., 448 N. Capitol Ave., Indianapolis, Ind.; Puritan Machine Co., 409 Lafayette Blvd, Detroit.

Lion: Gorey & Co., Jos. C., 354 W. Fiftieth St., New York, N.Y.; Levene Motor Co., 2200–08 Diamond St., Philadelphia, Pa.; Lion Motor Parts Co., Philadelphia, Pa.; Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich.

Lippard: Standard Motor Parts Co., Detroit, Mich.

Little: Auto Gear Co., 1404 Hennepin Ave., Minneapolis, Minn.; Auto Gear Co., 844 Eighth Ave., New York, N.Y.; Auto Gear & Parts Co., 291–93 Marietta Ave., Atlanta, Ga.; Auto Salvage, Tulsa, Okla.; Chevrolet Motor Co., 1764 Broadway, New York, N.Y.; Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich.; Wichita Auto Wrecking Co., 801 W. Douglas Ave., Wichita, Kan.; Wolf Auto Parts & Tire Co., 619 N. Illinois St., Indianapolis, Ind.

Logan: Gramm Motor Truck Co., Lima, Ohio.

Longest: Longest Bros. Co., 725-29 So. Third St., Louisville, Ky.

Lozier: Auto Parts Co., 2801–11 Preston Ave., Houston, Tex.; Gorey & Co., Jos. C., 354 W. Fiftieth St., New York, N.Y.; Lozier Motor Car Co., Fort and Sixth Sts., Detroit, Mich.; Philadelphia Machine Works, Philadelphia, Pa.; Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich.; Standard Motor Parts Co., New Castle, Ind.; Wolf Auto Parts & Tire Co., 619 N. Illinois St., Indianapolis, Ind.

Lyons-Knight: Service Gear & Machine Co., Reading, Pa.; Wolf Auto Parts & Tire Co., 619 N. Illinois St., Indianapolis, Ind.

McIntyre: Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich.

Marathon: Auto Gear Co., 1404 Hennepin Ave., Minneapolis, Minn.; Auto Gear Co., 844 Eighth Ave., New York N.Y.; Auto Gear & Parts Co., 291–93 Marietta Ave., Atlanta, Ga.; Auto Parts Co., 2801–11 Preston Ave., Houston, Tex.; Marathon Service Co., Nashville, Tenn.; Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich.; Service Gear & Machine Co., Reading, Pa.; Wichita Auto Wrecking Co., 801 W. Douglas Ave., Wichita, Kan.; Wolf Auto Parts & Tire Co., 619 N. Illinois St., Indianapolis, Ind.

Marion: American Motors Parts Co., 430 N. Capitol Ave., Indianapolis, Ind.; Auto Gear Co., 1404 Hennepin Ave., Minneapolis, Minn.; Auto Gear Co., 844 Eighth Ave., New York, N.Y.; Auto Gear & Parts Co., 291–93 Marietta Ave., Atlanta, Ga.; Automobile Mechanics Corp., 159-61 W. 24th St., New York, N.Y.; Auto Parts Co., 2801–11 Preston Ave., Houston, Tex.; Auto Parts Co., 4116 Olive St., St. Louis, Mo.; Connecticut Auto Parts Co., 583 Franklin Ave., Hartford, Conn.; Dayton Auto Parts Co., 1777 Broadway, New York, N.Y.; Elyria Belting & Machinery Co., Elyria, Ohio; Gorey & Co., Jos. C., 354 W. Fiftieth St., New York, N.Y.; Longaker Co., V.A., 448–50 N. Capitol Ave., Indianapolis, Ind.; Marion Motor Co., 2450 Michigan Ave., Chicago, Ill.; Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich.; Sattler's Machine Shops & Works, 1601 Spring Garden St., Philadelphia, Pa.; Wolf Auto Parts & Tire Co., I., 619 N. Illinois St., Indianapolis, Ind.

Marion Handley: Auto Gear Co., 1404 Hennepin Ave., Minneapolis, Minn.; Auto Gear & Parts Co., 291–93 Marietta Ave., Atlanta, Ga.; Auto Salvage & Exchange Co., 1317 Locust St., Des Moines, Iowa; Dayton Auto Parts Co., 1777 Broadway, New York, N.Y.; Gorey & Co., Jos. C., 354 W. Fiftieth St., New York, N.Y.

Mason: Auto Salvage & Exchange Co., 1317–19 Locust St., Des Moines, Iowa; Erbes, L. C., 2654 W. University Ave., St. Paul, Minn.; Longaker Co., V.A., 448–50 Capitol Ave., Indianapolis, Ind.; Mason Motor Car Co., Detroit, Mich., Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich.; Standard Motor Parts Co., New Castle, Ind.; Wichita Auto Wrecking Co., 801 W. Douglas Ave., Wichita, Kan.

Matheson: Boulevard Motor Co., 276 River St., Cambridge, Mass.; Matheson Co., Frank F., 694 Wyoming Ave., Wilkes-Barre, Pa.; Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich.; Service Gear & Machine Co., Reading, Pa.; Wolf Auto Parts & Tire Co., 619 N. Illinois St., Indianapolis, Ind.

Maytag: Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich.; Wichita Auto Wrecking Co., 1801 W. Douglas Ave., Wichita, Kan.

Mercedes: Connecticut Auto Parts Co., 583 Franklin Ave., Hartford, Conn.

Meteor: Auto Gear Co., 844 Eighth Ave., New York, N.Y.; Auto Gear & Parts Co., 291–93 Marietta Ave., Atlanta, Ga.; Meteor Car Co., Piqua, Ohio.

Michigan: Auto Gear Co., 1404 Hennepin Ave., Minneapolis, Minn.; Auto Gear Co., 844 Eighth Ave., New York, N.Y.; Auto Gear & Parts Co., 291–93 Marietta Ave., Atlanta, Ga.; Auto Parts Co., 2801–11 Preston Ave, Houston, Tex.; Buda Co., Harvey, Ill.; Burt Motor Car Co., W. J., Pico and Hope Sts., Los Angeles, Cal.; Davis, Carey A., 486 Louisiana Ave., Washington, D.C.; Gorey & Co., Jos. C., 354 W. Fiftieth St., New York, N.Y.; Michigan Motor Parts Co., Detroit, Mich.; Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich.; Service Gear & Machine Co., Reading ,Pa ; Standard Motor Parts Co., New Castle, Ind.; Philadelphia Machine Works, 67 Laurel St., Philadelphia, Pa.; Wichita Auto Wrecking Co., Wichita, Kan.; Wycoff Auto Salvage Co., Sioux City, Iowa.

Midland: Auto Gear Co., 844 Eighth Ave., New York, N.Y.; Auto Gear & Parts Co., 291–93 Marietta Ave., Atlanta, Ga.; Auto Parts Co., 2801–11 Preston Ave., Houston, Tex.; Levene Motor Co., 2200–18 Diamond St., Philadelphia, Pa.; Midland Motor Co., Philadelphia, Pa.; Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich

Miller: Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Milwaukee: Erbes, L. C., 2654 W. University Ave., St. Paul, Minn.; Smith A. O., Corp., Milwaukee, Wis.

Mogul: Auto Salvage Co., 1701–03 Main St., Kansas City, Mo.

Moline: Auto Parts Co., 4116–18 Olive St., St. Louis, Mo.

Monarch: Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.; Wichita Auto Wrecking Co., 807 W. Douglas Ave., Wichita, Kan.

Mora: Philadelphia Machine Works, 61–71 Laurel St., Philadelphia, Pa.; Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich.

Morgan: Steele, W. M., 98–100 Beacon St., Worcester, Mass.

Moyer: Auto Salvage & Exchange Co., 1317–19 Locust St., Des Moines, Iowa.

Nance: Gorey & Co., Jos. C., 354 W. Fiftieth St., New York, N.Y.

Niagara: Auto Gear & Parts Co., 291–93 Marietta Ave., Atlanta, Ga.

Northern: Puritan Machine Co., 409 Lafayette Blvd., Detroit. Mich.

Northwestern: Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Nyberg: Auto Gear Co., 844 Eighth Ave., New York, N.Y.; Auto Gear & Parts Co., 291–93 Marietta Ave., Atlanta, Ga.; Auto Parts Co., 2801–11 Preston Ave., Houston, Tex.; Auto Salvage & Exchange Co., 1317–19 W. Locust St., Des Moines, Iowa; Longaker Co., V. A., 448 N. Capitol Ave., Indianapolis, Ind.; Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich.; Wolf Auto Parts & Tire Co., I., 619 N. Illinois St., Indianapolis, Ind.

Ohio: Auto Gear Co., 1404 Hennepin Ave., Minneapolis, Minn.; Auto Gear Co., 844 Eighth Ave., New York, N.Y.; Auto Gear & Parts Co., 291–93 Marietta Ave., Atlanta, Ga.; Auto Parts Co., 2801–11 Preston Ave., Houston, Tex.; Auto Salvage, Tulsa, Okla.; Northway Auto Parts & Sales Co., 223 Kearney St., Cincinnati, Ohio; Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich.; Smith Corp., A. O., Milwaukee, Wis.

Omaha: Dayton Auto Parts Co., 1777 Broadway, New York, N.Y.; Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Owen: Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Palmer-Moore: Dayton Auto Parts Co., 1777 Broadway, New York, N.Y.

Palmer-Singer: Auto Gear Co., 844 Eighth Ave., New York, N.Y.; Auto Parts Co., 4116 Olive St., St. Louis, Mo.; Auto Salvage & Exchange Co., 1317–19 Locust St., Des Moines, Iowa; Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich.; Service Gear & Machine Co., Reading, Pa.; Singer Motor Co., 102 West End Ave., New York, N.Y.

Parry: Auto Gear Co., 844 Eighth Ave., New York, N.Y.; Auto Gear & Parts Co., 291–93 Marietta Ave., Atlanta, Ga.; Auto Parts Co., 2801–11 Preston Ave., Houston, Tex.; Auto Parts Co., 2116–18 Olive St., St. Louis, Mo.; Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich.; Wolf Auto Parts & Tire Co., I., 619 N. Illinois St., Indianapolis, Ind.

Partin-Palmer: Auto Gear Co., 1404 Hennepin Ave., Minneapolis, Minn.; Auto Gear Co., 844 Eighth Ave., New York, N.Y.; Auto Gear & Parts Co., 291–93 Marietta Ave., Atlanta, Ga.; Auto Parts Co., 2801–11 Preston Ave., Houston, Tex.; Auto Parts Co., 4116–18 Olive St., St. Louis, Mo.; Commonwealth Motors Co., 326 W. Madison St., Chicago, Ill.; Sattler's Machine Shops & Works, 1601 Spring Garden St., Philadelphia, Pa.; Service Gear & Machine Co., Reading, Pa.

Pathfinder: American Motors Parts Co., Indianapolis, Ind.; Auto Gear Co., 844 Eighth Ave., New York, N.Y.; Auto Gear & Parts Co., 291–93 Marietta Ave., Atlanta, Ga.; Auto Parts Co., 2801–11 Preston Ave., Houston, Tex.; Dayton Auto Parts Co., 1777 Broadway, New York, N.Y.; Pathfinder Co., 1136 Division St., Indianapolis, Ind.; Wolf Auto Parts & Tire Co., I., 619 N. Illinois St., Indianapolis, Ind.

Penn: Buda Co., Harvey, Ill.

Penn-Thirty: Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Pennsylvania: Central Auto Supply Co., Philadelphia, Pa.; Dougherty, 1845 N. 19th St., Philadelphia, Pa.; Gorey & Co., Jos. C., 354 W. Fiftieth St., New York, N.Y.; Puritan Machine Co., 422 Lafayette Blvd. , Detroit, Mich.; Stehle, Remy W., 1523–25 Brandywine St., Philadelphia, Pa.

Peru: Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Petrel: Filer & Stowell, Milwaukee, Wis.

Pierce-Racine: J. I. Case T. M. Co., Racine, Wis.; Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich.

Pontiac: Auto Gear & Parts Co., 291–93 Marietta Ave., Atlanta, Ga.

Pope-Hartford: Auto Parts Co., 2801–11 Preston Ave., Houston, Tex.; Auto Salvage Co., 1701–13 Main St., Kansas City, Mo.; Boulevard Motor Co., Cambridge, Mass.; Hartford Motor Car Co., Hartford, Conn.; Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich.; Rosenfield, J., 521 Sixth St., Boston, Mass.; Walker & Barkman Mfg.Co., Hartford, Conn.; Wolf Auto Parts & Tire Co., 619 N. Illinois St., Indianapolis, Ind.

Pope-Toledo: Auto Parts Co., Houston, Tex.; Auto Salvage Parts Co., 1436 S. Wabash Ave., Chicago, Ill.; Connecticut Auto Parts Co., Hartford, Conn.; Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich.

Pope-Tribune: Auto Salvage & Exchange Co., 1317 Locust St., Des Moines, Iowa; Hartford Motor Car Co., 410 Main St., Hartford, Conn.; Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich.; Walker & Barkman Mfg. Co., Hartford, Conn.

Poss: Auto Parts Co., 1777 Broadway, New York, N.Y.

Pratt: Elkhart Carriage & Motor Car Co., Elkhart, Ind.

Princess: Auto Gear & Parts Co., 291 Marietta St., Atlanta, Ga.

Pullman: Auto Gear Co., 1404 Hennepin Ave., Minneapolis, Minn.; Gorey & Co., Jos. C., 354 W. Fiftieth St., New York, N.Y.; Levene Motor Co., 2200–18 Diamond St., Philadelphia, Pa.; Pullman Motor Car Co., York, Pa.

Queen: Auto Parts Co., 4116–18 Olive St., St. Louis, Mo.; Auto Salvage & Exchange Co., 1317–19 Locust St., Des Moines, Iowa; Gorey & Co., Jos. C., 354 W. Fiftieth St., New York, N.Y.; Johns Auto Machine Works, W. H., 908 W. Pico St., Los Angeles, Cal.; Philadelphia Machine Works, 69–71 Laurel St., Philadelphia, Pa.; Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Rainier: Garford Motor Truck Co., Lima, Ohio; Gramm Motor Truck Co., Lima, Ohio; Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich.

Rambler: Auto Parts Co., 2801–11 Preston Ave., Houston, Tex.; Auto Salvage & Exchange Co., 1317 Locust St., Des Moines, Iowa; Auto Salvage, Tulsa, Okla.; Nash Motors Co., Kenosha, Wis.; The Boneyard, Washington, Iowa; Wolf Auto Parts & Tire Co., I., 619 N. Illinois St., Indianapolis, Ind.; Wycoff Auto Salvage Co., Sioux City, Iowa.

Randolph: DeKalb Wagon Co., DeKalb, Ill.; Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Rapid: Auto Parts Co., 2801 Preston Ave., Houston, Tex.; Puritan Machine Co., Detroit, Mich.

Rayfield: Auto Parts Co., 4116–18 Olive St., St. Louis, Mo.

R.C.H.: Auto Gear Co., 1404 Hennepin Ave., Minneapolis, Minn.; Auto Gear Co., 844 Eighth Ave., New York, N.Y.; Auto Gear & Parts Co., 291 Marietta St., Atlanta, Ga.; Auto Parts Co., 2801–11 Preston Ave., Houston, Tex.; Auto Parts Co., 4116–18 Olive St., St. Louis, Mo.; Gorey & Co., Jos. C., 354 W. Fiftieth St., New York, N.Y.; Johns Auto & Machine Works, W. H., 908 Pico St., Los Angeles, Cal.; Philadelphia Machine Works, 67 Laurel St., Philadelphia, Pa.; Wolf Auto Parts & Tire Co., I., 619 N. Illinois St., Indianapolis, Ind.

Read: American Motors Parts Co., 430 N. Capitol Ave., Indianapolis, Ind.

Regal: Auto Gear Co., 1404 Hennepin Ave., Minneapolis, Minn.; Auto Gear Co., 844 Eighth Ave., New York, N.Y.; Auto Gear & Parts Co., 291–93 Marietta Ave., Atlanta, Ga.; Auto Salvage, Tulsa, Okla.; Auto Salvage & Exchange Co., 1317 Locust St., Des Moines, Iowa; Auto Parts Co., 4116 Olive St., St. Louis, Mo.; Auto Parts Co., 2801 Preston Ave., Houston, Tex.; Gorey & Co., Jos. C., 354 W. Fiftieth St., New York, N.Y.; Levene Motor Co., 2200–18 Diamond St., Philadelphia, Pa.; Sattler's Machine Shops & Works, 1601 Spring Garden St., Philadelphia, Pa.; Service Gear & Machine Co., Reading, Pa.; The Boneyard, Washington, Iowa; Wolf Auto Parts & Tire Co., I., 619 N. Illinois St., Indianapolis, Ind.

Reliable-Dayton: Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Republic: Republic Motor Car Co., Youngstown, Ohio.

Rider-Lewis: American Motors Parts Co., 430 N. Capitol Ave., Indianapolis, Ind.; Auto Parts Mfg. Co., Detroit, Mich.; Longaker Co., V. A., 448 N. Capitol Ave., Indianapolis, Ind.; Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich.; Wichita Auto Wrecking Co., 801 W. Douglas Ave., Wichita, Kan.

Ross: Auto Gear Co., 1404 Hennepin Ave., Minneapolis, Minn.; Auto Gear & Parts Co., 291–93 Marietta St., Atlanta, Ga.; Dayton Auto Parts Co., 1777 Broadway, New York, N.Y.; Great Western Auto Co., Kalamazoo, Mich.; Levene Motor Co., 2200–18 Diamond St., Philadelphia, Pa.; Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich.; Standard Motor Parts Co., New Castle, Ind.

Royal Tourist: Auto Parts Co., 4116 Olive St., St. Louis, Mo.; Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich.

Rush: Diehl Motor Truck Works, Thirtieth and Montgomery Aves., Philadelphia, Pa.; Levene Motor Co., 2200–18 Diamond St., Philadelphia, Pa.

Sampson: Standard Motor Parts Co., New Castle, Ind.

Schacht: Auto Gear Co., 844 Eighth Ave., New York, N.Y.; Auto Gear & Parts Co., 291–93 Marietta Ave., Atlanta, Ga.; Buda Co., Harvey, Ill.; Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich.; Schacht Motor Truck Co., G. A., Cincinnati, Ohio.

Selden: Auto Gear Co., 844 Eighth Ave., New York, N.Y.; Auto Gear & Parts Co., 291 Marietta St., Atlanta, Ga.; Auto Parts Co., 2801–11 Preston Ave., Houston, Tex.; Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich.; Sattler's Machine Shops & Works, 1601 Spring Garden St., Philadelphia, Pa.; Shepard Auto Co., 106 Pennsylvania Ave., Brooklyn, N.Y.

S.G.V.: Service Gear & Machine Co., Reading, Pa.

Speedwell: Auto Gear Co., 844 Eighth Ave., New York, N.Y.; Auto Gear & Parts Co., 291–93 Marietta St., Atlanta, Ga.; Auto Parts Co., 2801–11 Preston Ave., Houston, Tex.; Green Engineering Co., Dayton, Ohio; Kany, A. S., 633 Homewood Ave., Dayton, Ohio; Northway Auto Parts & Sales Co., 223 Kearney St., Cincinnati, Ohio; Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich.; Wolf Auto Parts & Tire Co., 619 N. Illinois St., Indianapolis, Ind.

Sphinx: Auto Gear Co., 1404 Hennepin Ave., Minneapolis, Minn.; Auto Gear Co., 844 Eighth Ave., New York, N.Y.; Auto Gear & Parts Co., 291 Marietta St., Atlanta, Ga.; Dayton Auto Parts Co., 1777 Broadway, New York, N.Y.; Sattler's Machine Shops & Works, 1601 Spring Garden St., Philadelphia, Pa.; Service Gear & Machine Co., Reading, Pa.

Standard Six: St. Louis Car Co., 8000 N. Broadway, St. Louis, Mo.

Star: Mier Carriage & Buggy Co., Ligonier, Ind.

States: Auto Auction Co., 519 W. Jackson Blvd., Chicago, Ill.

Staver: Auto Gear Co., 1404 Hennepin Ave., Minneapolis, Minn.; Auto Gear Co., 844 Eighth Ave., New York, N.Y.; Auto Gear & Parts Co., 291 Marietta Ave., Atlanta,Ga.; Auto Parts Co., 2801–11 Preston Ave., Houston, Tex.; Dayton Auto Parts Co., 1777 Broadway, New York, N.Y.; Puritan Machine Co., 409 Lafayette Blvd., Detroit, Mich.; The Boneyard, Washington, Iowa.

Sterling: Puritan Machine Co., 422 Láfayette Blvd., Detroit, Mich.

Stevens-Duryea: Boulevard Motor Co., 276 River St., Cambridge, Mass.; Colwell, F. C., 807–09 Race St., Philadelphia, Pa.; Frank Co., Paul, 2349 Michigan Ave., Chicago, Ill.; Walk Hill Garage, 726 Walk Hill St., Mattapan, Mass.

Stoddard-Dayton: Auto Gear Co., 844 Eighth Ave., New York, N.Y.; Auto Gear & Parts Co., 291 Marietta Ave., Atlanta, Ga.; Auto Parts Co., 2801 Preston Ave., Houston, Tex.; Boulevard Motor Co., 276 River St., Cambridge, Mass.; Dayton Auto Parts Co., 1777 Broadway, New York, N.Y.; Gorey & Co., Jos. C., 354 W. Fiftieth St., New York, N.Y.; Green Engineering Co., Dayton, Ohio; Sattler's Machine Shops & Works, 1601 Spring Garden St., Philadelphia, Pa.; Service Gear & Machine Co., Reading, Pa.; Standard Motor Parts Co., New Castle, Ind.; Warshawsky & Co., 1918 S. State St., Chicago. Ill.; Wichita Auto Wrecking Co., 801 W. Douglas Ave., Wichita, Kan.; Wolf Auto Parts & Tire Co., I., 619 N. Illinois St., Indianapolis, Ind.

Suburban: Dayton Auto Parts Co., 1777 Broadway, New York, N.Y.; Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Sultan: Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.; Auto Gear & Parts Co., 291–93 Marietta St., Atlanta, Ga.

Thomas: Auto Parts Co., 2801 Preston Ave., Houston, Tex.; Gorey & Co., Jos. C., 354 W. Fiftieth St., New York, N.Y.; Johns, W. H., 908–12 W. Pico St., Los Angeles, Cal.; Rosenfield, J., 521 Sixth St., Boston, Mass.; Thomas Motor Car Co., Buffalo, N.Y.; Wolf Auto Parts & Tire Co., I., 619 N. Illinois St., Indianapolis, Ind.

Thomas-Detroit: Jahns, W. H., 908–12 W. Pico St., Los Angeles, Cal.; Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Toledo: Dayton Auto Parts Co., 1777 Broadway, New York, N.Y.

Touraine: Gorey & Co., Jos. C., 354 W. Fiftieth St., New York, N.Y.

Tourist: Burt Motor Car Co., W. J., Pico and Hope Sts., Los Angeles, Cal.

Traveler: Single Center Buggy Co., Fifth and Locust Sts., Evansville, Ind.

Trumbull: Levene Motor Co., 2200–18 Diamond St., Philadelphia, Pa; Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Victor: Auto Gear & Parts Co., 291–93 Marietta St., Atlanta, Ga

Virginian: Auto Salvage & Exchange Co., 1317–19 Locust St., Des Moines, Iowa.

Vulcan: Savage Arms Corp., Sharon, Pa.

Wagenhall: Puritan Machine Co., 422 Lafayette, Blvd., Detroit, Mich.

Wahl: Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Warren: Davis, Carey A., 486 Louisiana Ave., Washington, D.C.; Dayton Auto Parts Co., 1777 Broadway, New York, N.Y.; Gorey & Co., Jos. C., 354 W. Fiftieth St., New York, N.Y.; Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Washington: Davis, Carey A., 486 Louisiana Ave., Washington, D.C.

Waverly Electric: Longaker Co., V. A., 448–50 N. Capitol Ave., Indianapolis, Ind.

Wayne: Auto Salvage Co., 1701–03 Main St., Kansas City, Mo.; Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Welch-Detroit: Auto Salvage & Exchange Co., 1317–19 Locust St., Des Moines, Iowa; Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Welch-Pontiac: Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Whiting: Chevrolet Motor Co., 1764 Broadway, New York, N.Y.; Chevrolet Motor Co. of N.Y., Tarrytown, N.Y.; Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Woods-Modilette: Fohrman-Leterstone Co., 1808 S. State St., Chicago, Ill.

Yale: Puritan Machine Co., 422 Lafayette Blvd., Detroit, Mich.

Zimmerman: Auto Gear & Parts Co., 291–93 Marietta St., Atlanta, Ga.; Auto Salvage & Exchange Co., 1317–19 Locust St., Des Moines, Iowa.

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Chanslor & Lyon Co.	San Francisco
Electric Appliance Co.	San Francisco
E. A. Featherstone	Los Angeles
P. W. Gavin Co.	San Diego
Inland Iron Co.	Fresno
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McCoy Motor Supply Co.	San Francisco
Motor Hardware & Equipment Co.	San Diego
James S. Remick Co., In.	Sacramento
Waterhouse & Lester Co.	San Francisco
Weinstock-Nichols Co.	San Francisco
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Colorado

Auto Equipment Co.	Denver
Denver Auto Goods Co.	Denver
Foster Auto Supply Co.	Denver
General Auto Supply Co.	Colorado Springs
Hendrie & Bolthoff Mfg. & Supply Co.	Denver
Motor Accessory & Tire Co.	Pueblo
Quinn & McGill Motor Supply Co.	Denver
B. K. Sweeney Electrical Co.	Denver

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Horton-Gallo-Creamer Co.	New Haven
C. S. Mersick & Co.	New Haven
Post & Lester Co.	Hartford

District of Columbia

Chas. Rubel & Co.	Washington
Rudolph & West Co.	Washington

Florida

G. Norman Baughman Co.	Tampa
Consolidated Grocery Co.	Jacksonville
C. W. Greene Co.	Tampa
Wholesale Auto Supply House	Tampa

Georgia

Alexander Seewald Co.	Atlanta
W. E. Cody Co.	Columbus
A. S. Hatcher Co.	Macon

Illinois

Automobile Supply Co.	Chicago
Chicago Auto Equipment Co.	Chicago
Chicago Automobile Supply House	Chicago
E. B. Collins Co.	Danville
Electric Appliance Co.	Chicago
Graham-Seltzer Co.	Peoria
Hine-Watt Mfg. Co.	Chicago
E. D. Kimball & Co.	Chicago
Motor Car Supply Co.	Chicago

National Electric & Auto Supply Co.	Peoria
Sheridan Auto Supply Co.	Chicago
Universal Automotive Supply Co.	Chicago
Washington Auto Supply Co.	Washington

Indiana

Lomont & Co.	Fort Wayne
Orr Iron Co.	Evansville
Terre Haute Automobile Co., Inc.	Terre Haute
W. R. Wheeler Co.	Indianapolis

Iowa

Cedar Rapids Pump & Supply Co.	Cedar Rapids
Robt. Donahue Iron & Hardware Co.	Burlington
Downing Electrical Co.	Des Moines
John Ernsdorff Iron Co.	Dubuque
R. F. & W. B. Fitch Co.	Oskaloosa
Herring Motor Co.	Des Moines
Hippee States Co.	Des Moines
Mid-West Auto Supply Co.	Dubuque
Repass Auto Co.	Waterloo
Schultz Auto Supply Co.	Sioux City
Sieg Co.	Davenport
Wm. Warnock Co., Inc.	Sioux City

Kansas

Auto Supply Co.	Hutchinson
Johnson Bros. Auto Supply Co.	Wichita
Motor Equipment Co.	Wichita
Shattuck-George Co.	Wichita
Southwick Auto Supply Co.	Topeka
Watson, Weldon Motor Supply Co.	Salina

Kentucky

Andrew Cowan & Co., Inc.	Louisville
Louisville Auto Supply Co.	Louisville
Peaslee-Gaulvert Co.	Louisville
Robinson Bros. Co.	Louisville

Louisiana

Electric Appliance Co.	New Orleans
Interstate Electric Co.	New Orleans
Shuler Auto Supply Co.	New Orleans

Maine

The James Bailey Co.	Portland
Farrar-Brown Co., Inc.	Portland

Maryland

Auto Supply Co.	Baltimore

Massachusetts

Alsten-Goulding Co.	Worcester
American Motor Equipment Co.	Boston
Automotive Equipment Co.	Worcester
Butts & Ordway Co.	Boston
Linscott Supply Co.	Boston
Tarbell-Waters Co.	Springfield
Wetmore-Savage Co.	Boston

Michigan

Automobile Supply Co.	Detroit
Becker Auto Co.	Grand Rapids
Bowman-Gould Co.	Detroit
Cumings Brothers	Flint
General Sales Co.	Detroit
Michigan Tire & Accessories Co.	Grand Rapids
Tisch Auto Supply Co.	Grand Rapids

Minnesota

Duluth Auto Supply Co.	Duluth
Minneapolis Iron Store Co.	Minneapolis
Nicols, Dean & Gregg	St. Paul
Reinhard Bros. Co.	Minneapolis
C. J. Smith & Co.	St. Paul
Western Motor Supply Co.	Minneapolis
Williams Hardware Co.	Minneapolis

Missouri

Ayers-Farmer Auto Supply Co.	St. Joseph
Beck & Corbitt Iron Co.	St. Louis
Bonniwell-Calvin Iron Co.	Kansas City
Fred Campbell Auto Supply Co.	St. Louis
The Equipment Co.	Kansas City
Geller, Ward & Hasner Hardware Co.	St. Louis
Holthaus Saddlery & Auto Supplies Co.	St. Louis
Kansas City Automobile Supply Co.	Kansas City
The Faeth Co.	Kansas City
Ozark Motor Supply Co.	Springfield
The Straus Co.	St. Louis

Montana

Northwestern Auto Supply Co.	Billings

Nebraska

W. M. Dutton & Sons Co.	Hastings
J. H. Haney & Sons	Omaha
Master Sales Co.	Omaha
Nebraska-Buick Auto Co.	Lincoln
Powell Supply Co.	Omaha
Western Automobile Supply Co.	Omaha

New Jersey

Automotive Equipment Co.	Newark
Economy Auto Supply Co.	Newark
Elin Auto Supply Co.	Newark

New York

Julius Bindrim	Brooklyn
Chapin-Owen Co.	Rochester
Davis Brown Electric Co.	Ithaca
E. Krieger & Son	Brooklyn
Lowe Motor Supply Co.	New York
Martin-Evans Co.	Brooklyn
Thos. J. Northway, Inc.	Rochester
Onondaga Auto Supply Co.	Syracuse
W. E. Pruden Hardware Co.	New York
W. H. Rowerdink & Son	Rochester
Strauss Co., Jos., Inc.	Buffalo
Utica Cycle & Supply Co.	Utica
Whittemore-Sim Co., Inc.	New York

North Carolina

Carolinas Auto Supply House	Charlotte
Ko-Mo Supply Co., Inc.	Charlotte

North Dakota

J. D. Grant Co.	Fargo

Ohio

C. & D. Auto Supply Co.	Cincinnati
Dayton Iron & Steel Co.	Dayton
Dine-DeWees Co.	Canton
Griswold-Sohl Co.	Columbus
Justus & Parker Co.	Columbus
M. & M. Co.	Cleveland
Ohio Rubber Co.	Cincinnati
Pennsylvania Rubber & Supply Co.	Cleveland
Philectric Co., The	Cleveland
Roberts-Toledo Auto Co.	Toledo
G. W. Shroyer & Co.	Dayton
Toledo Rubber Co.	Toledo
Union Supply Co.	Toledo
York Supply Co.	Greenville

Oklahoma

J. B. Burwell Supply Co.	Oklahoma City
Southern Motor Supply Co.	Oklahoma City
Severin Tire & Supply Co.	Oklahoma City
R. V. Smith Supply Co.	Oklahoma City

Oregon

Ballou & Wright	Portland
P. J. Cronin Co.	Portland
The Wiggins Co., Inc.	Portland

Pennsylvania

Berrodin Rubber Co.	Philadelphia
Cahall Motor Supply Co.	Philadelphia
Front Market Motor Supply Co.	Harrisburg
Gaul, Derr & Shearer Co.	Philadelphia
General Auto Supply Co.	Lancaster
Jackson Motor Supply Co.	Pittsburgh
Johnstown Automobile Co.	Johnstown
Lansing Bros., Inc.	Scranton
Manufacturers Supplies Co.	Philadelphia
J. H. McCullough & Son	Philadelphia
Motor Accessories Co.	Allentown
Geo. W. Nock, Inc.	Philadelphia
Pittsburgh Auto Equipment Co.	Pittsburgh
H. C. Roberts Electrical Supply Co.	Philadelphia

Rhode Island

Goodby-Rankin Co.	Providence
Miller, Inc.	Providence
Providence Auto Equipment Co.	Providence
Waite Auto Supply Co.	Providence

South Carolina

D. W. Alderman, Jr., Inc.	Florence
C. D. Franke & Co., Inc.	Charleston

South Dakota

The Brownell Corp.	Sioux Falls
Spaulding Supply Co.	Aberdeen

Tennessee

Ozborn Abston & Co.	Memphis
Southern Auto Supply Co.	Chattanooga

Texas

Archenhold Automobile Supply Co.	Waco
Borderland Auto Supply Co.	El Paso
Electric Appliance Co.	Dallas
Equipment Co. of Texas	Ft. Worth
Ferris-Dunlap Auto Supply Co.	Dallas
L. Frank Saddlery Co.	San Antonio
Hans Johnsen	Dallas
McCauley-Ward Motor Supply Co.	Waco
Miller Co., Inc.	Waco
Roper, Harris & Dunn Co.	Greenville
Southern Equipment Co.	San Antonio
The Spencer Co.	Dallas
Texas Auto Supply Co.	Ft. Worth
Tri-State Accessories Corp.	El Paso

Utah

Capital Electric Co.	Salt Lake City
Inter-Mountain Electric Co.	Salt Lake City
Motor Mercantile Co.	Salt Lake City
Salt Lake Hardware Co.	Salt Lake City

Virginia

Benton-Bailey Co., Inc.	Richmond
Benj. T. Crump Co., Inc.	Richmond
J. L. Lindsay, Inc.	Richmond
Meadows-Price Co., Inc.	Roanoke
Owens-Merritt Co., Inc.	Danville
Piedmont Hardware Co.	Danville
Talman Auto Supply Co.	Richmond
E. L. Taylor & Co., Inc.	Richmond

Washington

Child, Day & Churchill, Inc.	Spokane
Reynolds & Reynolds	Tacoma
Whiton Hardware Co.	Seattle

West Virginia

H. P. Dils & Son Co.	Parkersburg
T. T. Hutchisson & Co.	Wheeling
Williams Hardware Co.	Clarksburg

Wisconsin

Clemons Auto Supply Co.	Eau Claire
Phillip Gross Hardware Co.	Milwaukee
Shadbolt & Boyd Iron Co.	Milwaukee
Wisconsin Auto Supply Co.	Wausau

Canada

Bowman Bros., Ltd.	Saskatoon
Canadian Fairbanks-Morse Co., Ltd.	Montreal, Que.
The Chapin Co., Ltd.	Calgary, Alberta
Cutten & Foster, Ltd.	Toronto, Ontario
R. G. Edgcombe Co., Ltd.	London, Ontario
Ludger Gravel & Fils	Montreal, Que.
Hyslop Bros., Ltd.	Toronto, Ontario
Independent Electric Co., Ltd.	Regina, Sask.
Keyes Supply Co., Ltd.	Ottawa, Ontario.
Lamontagne, Ltd.	Montreal, Que.
John Millen & Son, Ltd.	Montreal, Que.
Motor Car Supply Co., Ltd.	Calgary, Alb.
H. W. Petrie of Montreal, Ltd.	Montreal, Que.

Other auto supply jobbers are: Western Auto Supply Agency, Los Angeles, Cal., San Francisco, Cal., Denver, Colo., Seattle, Wash., Kansas City, Mo., Dallas, Tex., Phoenix, Arizona, St. Paul, Minn; National Auto Supply Co., Chicago, Ill.

A HOME GARAGE FOR ONE MACHINE

The home garage shown in Fig. 27 is designed for housing one machine, and to give a little space about it so that a person can clean the exterior of the automobile and do small repairs.

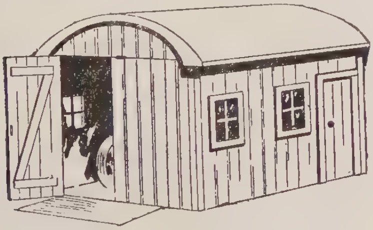


Fig. 27

The first thing to be considered is the foundation, or base, which is made of concrete (Fig. 28). The earth should be excavated for a depth of 6 inches, and to the exact dimensions given for the floor plan. The hole is then filled with cinders, well tamped in and leveled on top. A frame, about 4 inches high, is built up of cheap lumber, so that the space within measures 12 ft. wide and 16 ft. long, except at the double-door opening where a sloping runway is formed for the easy entrance of the automobile. A 2-inch layer of concrete—a mixture of 1 part cement, 2 parts sand, and 4 parts gravel, or crushed stone—is placed on top of the cinders, and a neat mixture of cement and sand, ½ inch thick, is placed on the concrete and made perfectly level. When putting in the concrete, ½-inch bolts, about 5 inches long, are set in the edge with the threaded end extended about 3 inches above the upper surface of the cement, and in line with the center of the 2 by 4 inch timber used as a sill. The detail of this construction is shown in the sketch. About four of these bolts should be set on each side, three on the end, and one on each side of the double doors.

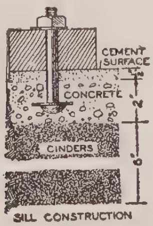


Fig. 28

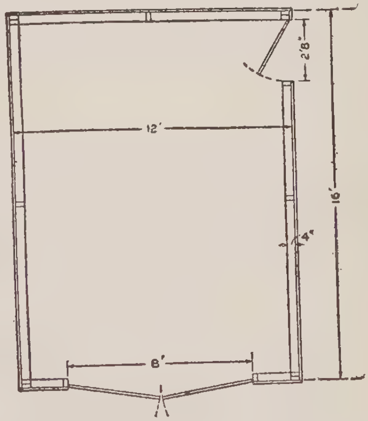


Fig. 29. Floor plan, showing the location of the sills, studs, and corner posts on the concrete floor.

The corner posts and studs are cut so that their length, together with the thickness of the sill and the two pieces for the plate, will measure 8 feet. This is the proper length to cut the boards without waste from standard lengths of lumber. After raising the corner posts and studs, and nailing the plate pieces on top, the siding boards are nailed on vertically to the plate and sill, and the battens are nailed over the joints.

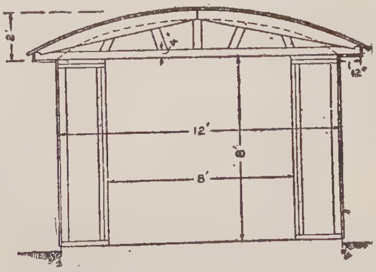


Fig. 30. End elevation, showing the rafter construction and the finishing facia boards on the eaves.

The rafters are built up in a manner similar to that used on large garages now so popular. Each one, or each pair, consists of a cross-piece that rests on top of the plates at the sides and is notched at the ends, to receive the ends of the convex rafter pieces. The pattern for one of these pieces, with dimensions, is shown in the drawing (Fig. 31). After the three main parts are fitted to form one rafter across the building, they are fastened together with short pieces of boards, which can be cut from scrap. The rafters are set on the plates 16 inches apart from center to center.

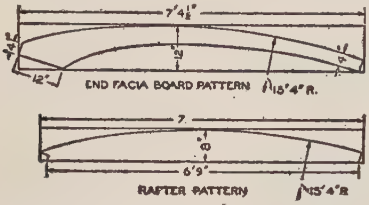


Fig. 31. Pattern layout for the rafter pieces and the finishing facia boards for the eaves at the ends.

The sheathing boards are nailed to the curved edges of the rafters lengthwise, and as the material list calls for boards 12 feet long, one and one-half lengths will cover the rafters and allow 1 foot projection at each end for the eave. The facia boards are cut on a curve in the same manner as the rafter pieces, and the under side is cut as shown in the detail, so as to make a neat-appearing connection to the end of the frieze boards. Straight facia boards are fastened on the eaves, at the sides, in the same manner, and a frieze board is nailed to the under side, the ends being finished, as shown in the detail drawing (Fig. 31).

Prepared roofing is fastened to the sheathing in the usual manner, beginning the layers at the eave and finishing in the center, allowing the center piece to overlap on both sides.

The windows consist of four single casements, two being placed on each side. These can be of any size to suit the builder, and can be bought from a mill ready to be set into the openings cut for them.

The doors can be made up of the same material as that used for the siding and battened together, or, if a more elaborate door is desired, they can be purchased at a reasonable price, paneled and with a glass in the upper part. If paneled doors are used, 18 boards can be deducted from the siding-material list. The double doors will require fastenings at the center, and, in placing the concrete floor, a keeper should be set in the surface cement for the foot latch. The upper keeper can be attached to the end rafter cross-piece. The usual hardware is necessary for the small door at the opposite end.

Material List

CONCRETE FLOORS

2 bbls. cement.
4.5. cu. yd. cinders.
2.2. cu. yd. sand.
4.3. cu. yd. gravel.

SILLS, PLATES, AND STUDS

6 pieces, 16 ft. long, 2 by 4 in.
4 pieces, 12 ft. long, 2 by 4 in.
20 pieces, 8 ft. long, 2 by 4 in.

SIDING

90 boards, 8 ft. long, ⅞ by 8 in.
90 battens, 8 ft. long.

RAFTERS

10 boards, 14 ft. long, ⅞ by 8 in.
10 boards, 14 ft. long, ⅞ by 4 in.

ROOFING

Enough sheathing boards, 12 ft. long to cover 260 sq. ft.
Enough prepared roofing to cover 260 sq. ft.

WINDOWS

4 single casements.

FINISHING PIECES

2 frieze boards, 18 ft. long, ⅞″ by 1 ft.
2 facia boards, 18 ft. long, ⅞″ by 4 in.
4 facia boards, 8 ft. long, ⅞″ by 1 ft.
8 corner boards, 8 ft. long, ⅞″ by 4 in.
6 door-facing boards, 8 ft. long, ⅞″ by 4 in.

HARDWARE

1 pair of door hinges.
1 door lock.
3 pairs of heavy door hinges.
1 foot latch.
1 upper latch.
1 large door lock.
10 lb. 20-penny nails.
20 lb. 8-penny nails.
10 bolts, with double washers, ½″ by 5 in.

A garage built up in this manner and well painted will last for years, and if it becomes necessary to move it, nothing will be lost except the concrete floor, as the building can be lifted from the bolts and taken away bodily. (*Popular Mechanics.*)

INSTRUCTION No. 62

THE REPAIR SHOP OR SERVICE STATION, and Its Equipment

EQUIPMENT FOR A SERVICE STATION

The repair shop can be incorporated as a part of the garage business, or as a separate enterprise. Where only repairing is done and supplies are sold with no storage, it is termed **a service station.**

The service station is divided into departments as shown in Fig. 1.

The 10 h.p. electric motor shown in the layout (Fig. 2) is designed to run at 1,800 r.p.m. This will give the line shafting a speed of 400 r.p.m. With a 20″ pulley on the shaft to drive the grinder, the latter will run at 2,000 r.p.m., which is about 4,000 ft. per minute surface speed for an emery wheel 7″ in diameter.

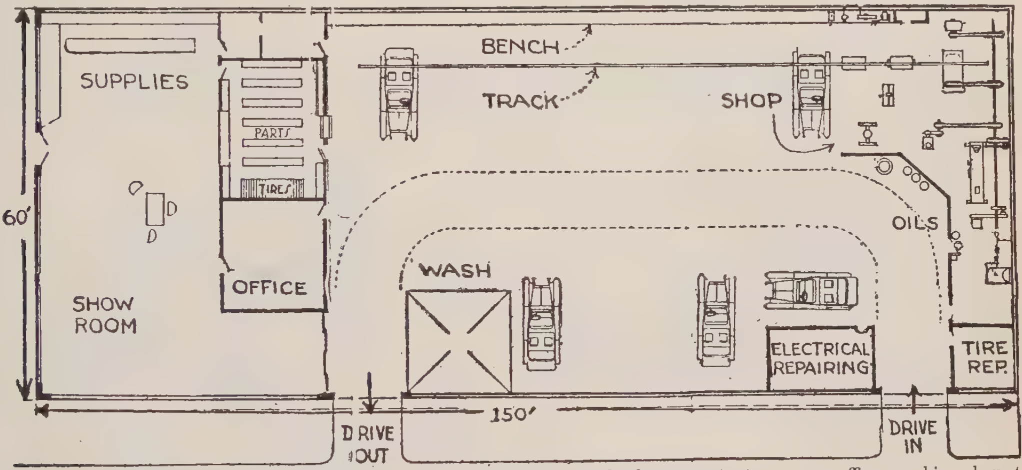


Fig. 1. Illustrates the layout for arranging a one-floor salesroom, supply department, store room, office, machine shop, tire repair, and electrical repair department as suggested in *Motor Age.*

Measurements are 60 ft. wide and 150 ft. long. Note the "drive in" and "drive out," also the track for the chain hoist to lift the engine from the frame to the work bench. Note further the space partitioned off for electrical repairing, tire repairing, and battery charging.

The air compressor driven by an individual electric motor instead of from the line shaft is shown in Fig. 2. The first cost of a 2 h.p. electric motor required to drive the compressor will be a little more, but we believe this will be absorbed in the saving of current. Furthermore, there is the advantage of

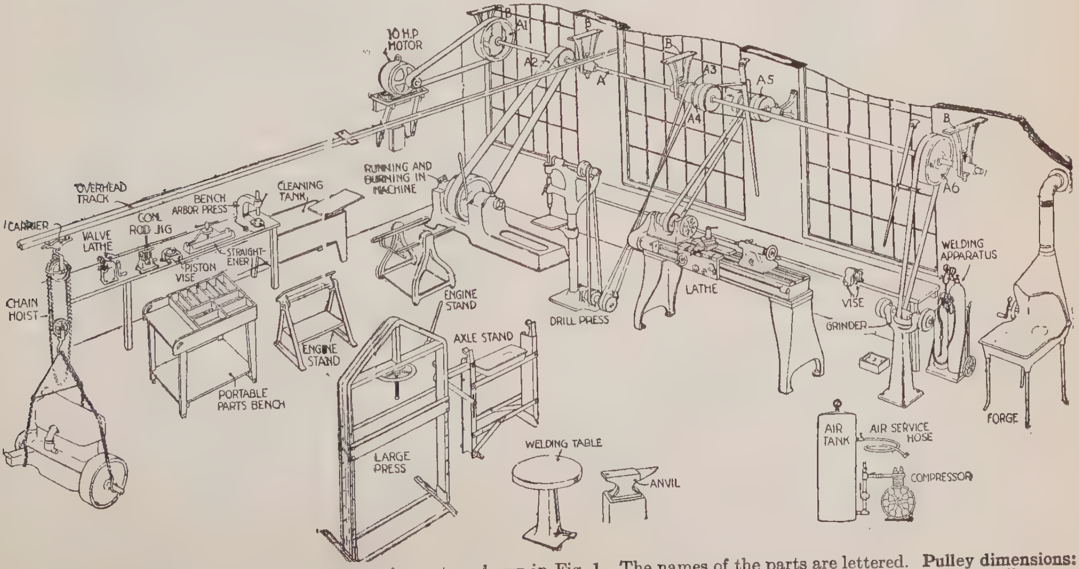


Fig. 2. Layout of the machine shop equipment as shown in Fig. 1. The names of the parts are lettered. **Pulley dimensions:** **(A)** line shaft 1½″; **(A1)** 32″; **(A2)** 20″; **(A3)** 7″; **(A4)** 10″; **(A5)** 14″; **(A6)** 20″; electric motor, 8″; grinder pulley 4″.

automatic starting and stopping, which cannot be done when the outfit is driven from the line shaft. A service station needs compressed air all the time, but it is not economy to keep a 10 or 15 h.p. motor going just for the air line.

Machine Tools and Equipment of Shop Shown in Figs. 1 and 2

Line shaft, 30 ft. long, 1½″ dia.	$ 11.00
Adjustable hangers	20.40
Electric motor, 10 h.p. Lathe countershaft, included in lathe price	335.00
Burning and running-in machine with fittings	490.00
Drill press, 14″	85.00
Lathe, 11¼″ swing over carriage	818.00
Grinder	33.00
Welding table	70.00
Forge	27.00
Welding apparatus	90.00
Anvil	15.00
Air compressor outfit	247.00
Axle stand	36.00
Engine stand	50.00
Engine stand	49.00
Overhead track, 100 ft. with brackets	48.00
Overhead carrier and hoist	34.00
Valve lathe	3.75
Connecting-rod jig	30.00
Piston vise	10.00
Crank-shaft straightener	34.00
Bench arbor press	35.00
Cleaning tank	40.00
Large press	76.50
Total	$2,687.65

These prices are approximate only. Write the Service Station Equipment Co., Chicago, Ill., or the Continental Auto Parts Co., Columbus, Ind., or to any of the auto supply jobbers for catalogs, if interested.

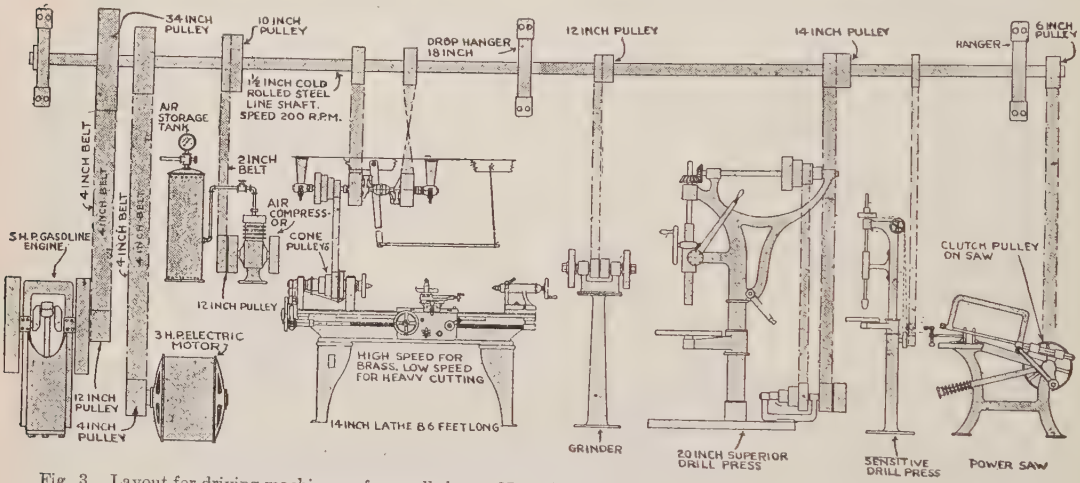


Fig. 3. Layout for driving machinery of a small shop. Note that either an electric motor or gasoline engine can be used.

ANOTHER MACHINERY EQUIPMENT FOR A SMALL SHOP

In Fig. 3 we have laid out a standard line of machinery suitable for a machine shop. The line shaft is arranged in a straight line, whereas in close quarters it may be necessary to place two line shafts.

Although a gasoline engine and an electric motor for power are both illustrated, only one is necessary; both are shown in order to explain the method for belting if one or the other is used. The electric motor is usually placed on the ceiling, or on a post or wall.

The gasoline engine ought to be equipped with a clutch in the drive pulley or in the pulley on the line shaft.

Approximate Prices

1—20″ superior drill press	$ 60.00
1—14 in. x 6 ft. lathe	234.00
1—emery stand with two 6 x 1 wheels	5.30
1—sensitive drill press for small work	60.00
1—Marvel No. 1, power-shop saw	15.00
25 ft. line shafting and 4 drop hangers and belting	50.00
Compressed-air outfit, belt driven from line shaft	43.75

We will assume that the electric motor is rented from the electric company. If not, add about $100 for the electric motor or gasoline engine.

For a large shop an 18″ swing, by 12 ft. lathe, is best..$400.00

To Find Diameter of Pulleys

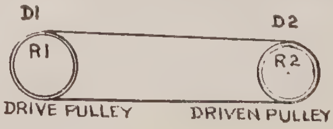
To find the diameter of the driver, the diameter of the driven and its revolutions, and also the revolutions of the driver being given: Multiply the diameter of the driven by its revolutions, and divide the product by the revolutions of the driver; the quotient will give the diameter of the driver.

To find the diameter of the driven, the revolutions of the driven, also diameter and revolutions of the driver being given: Multiply the diameter of the driver by its revolutions, and divide the product by the revolutions of the driven; the quotient will give the diameter of the driven.

To find the revolutions of the driver, the diameter and revolutions of the driven, also the diameter of the driver being given: Multiply the diameter of the driven by its revolutions and divide the product by the diameter of the driver; the quotient will give the revolutions of the driver.

To find the revolutions of the driven, the diameter and revolutions of the driver, also the diameter of the driven being given: Multiply the diameter of the driver by its revolutions and divide the product by the diameter of the driven; the quotient will give the revolutions of the driven.

The same rules may be applied to gearing by using the number of teeth instead of the diameter. See also page 624.



D1 × R1 ÷ D2 = R2.
D1 × R1 ÷ R2 = D2.
D2 × R2 ÷ R1 = D1.
D2 × R2 ÷ D1 = R1.
D1 represents diameter of driver.
D2 represents diameter of driven.
R1 represents revolutions of driver.
R2 represents revolutions of driven.

Fig. 4

MISCELLANEOUS MACHINERY, TOOLS, ETC.

The machinery equipment, together with a list of machinery necessary for a large or small shop, is given in the matter preceding.

Equipment for a fairly large shop in which almost any work can be done is shown on page 691.

Equipment for a smaller shop in which all average work can be done is shown on page 692.

An air compressor outfit is important. The air pump could be operated from the line shaft, but if in active use it would be best to run it from a separate electric motor. See Index under "Air compressors."

The battery charging outfit could consist of a motor-generator set. See Index.

For a still smaller shop, a Tungar or other type rectifier could be used instead of a motor-generator set, together with testing outfits for storage-battery work. Electrical testing instruments of smaller size costing less money, will suffice where there is not very much work to be done.

The cost of the tire repair outfit could also be reduced by obtaining a smaller outfit, as suggested in the discussion on the tire repair subject.

Power to run the machinery may be a gasoline engine or an electric motor. The electric motor is more convenient, and can, in many cities, be rented from the electric company.

Work benches should always be placed next to windows where there is light. Such a bench should measure at least 8 or 10 feet long, height about 3 feet, and width 2 ft. 6 in. and be made of 2-in. thick, well-seasoned pine, or, better, birch.

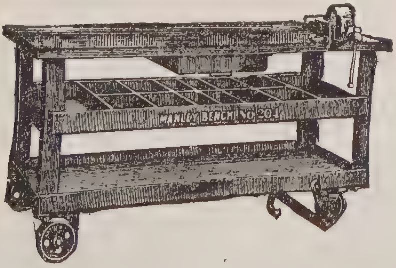


Fig. 5. **The Manley portable work bench,** or floating repair shop. In repair shops the stationary benches are built along the wall, and are located at considerable distance from the car upon which work is being done. This necessitates many steps, consuming time and the energy of the workman, all of which is saved by placing the bench at the car. Manley portable work benches are of a substantial construction, with hardwood top, steel drawer, shelf partitions of seasoned wood, roller-bearing casters, and provision is made for locking wheels. Made in two sizes. (Manley Mfg. Co., York, Pa.)

Lathes

The choice of a lathe depends upon the amount of work and kind of work one proposes doing. If equipment is desired capable of making repairs on axles, axle housings, and fly wheels, then a 16-in. swing 8 ft. bed lathe would be recommended.[1]

A smaller lathe for work on bearing bushings, pins, grinding piston pins and bolts, a lathe with a 4 ft. bed and 6 in. swing is required.

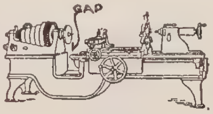


Fig. 6

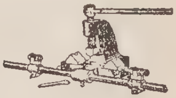


Fig. 7

Fig. 6. **Gap-bed lathe.** The distinguishing feature of this lathe is that the guides near the lathe head are cut away, thereby increasing considerably the size of the swing, without increasing the other dimensions. It is possible to handle much larger work with this style than could be handled on the regular type of the same dimensions.

Fig. 7. **A shaft-straightening press.** While this press is made mainly for straightening shafts, it is applicable for axle straightening as well. A tremendous power can be brought to bear by the action of the long lever and heavy screw. A section of perfectly true shafting is centered bewteen the adjustable tail stocks and is used as a guide or measuring point as the shaft is being straightened.

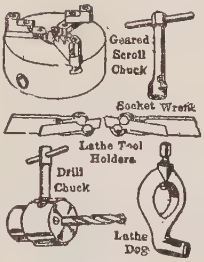


Fig. 8

Fig. 8. **Lathe tools:** 5″, 3-jaw geared scroll chuck; socket wrench ⅜″, ½″, and ⅝″; lathe tool holders 4″, to be used with 14″ lathe; drill chuck with Nos. 1 and 2 arbor to hold drills up to ½″; lathe dogs, ½″, 1″, 1½″ each.

Drill Press

A large drill press, of back-geared type, with a 16″ table, for work such as reaming cylinders, drilling holes in frames, etc. will be required.

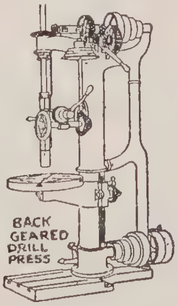


Fig. 9. **A back-geared drill press.** The advantage of the back-gear feature is obvious, as it is often very desirable to reverse the direction of rotation of a drill.

A sensitive drill press for light work, such as drilling cotter-pin holes, small shafts and rods, such as those on the steering device, timer, etc., is very necessary.

Some of the manufacturers of drill presses are: Barnes Drill Co., Rockford, Ill.; W. P. Davis Co., Rochester, N.Y.; Champion Blower and Forge Co., Lancaster, Pa.; Canedy-Otto Mfg. Co., Chicago Heights, Ill.

Portable electric drills are very handy for drilling holes in frames for attaching shock absorbers, horns, mufflers, etc. See page 700.

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[1] "How to Run a Lathe" and "First-Year Lathe Work" are two 64-page pamphlets, fully illustrated, which will be supplied to readers of this book for 10c. each. Address South Bend Lathe Works, South Bend, Ind., and mention the fact that you have this book. See advertisements of various lathes in the back of this book.

Power Hack-Saw

Power hack-saws are used for cutting all kinds of metal. They are made self-feeding with an automatic stop.

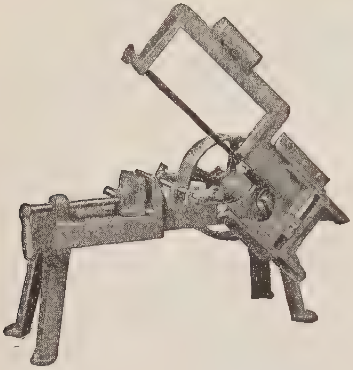


Fig. 10. This **power hack-saw** is especially designed and built for garage service. It is small enough to mount on a bench, if desired. It has a cutting capacity up to 4″ x 4″. It is well built, is equipped with an automatic stop, using a 9″ blade, and has all the features of the highest priced power hack-saw. (Manley Mfg. Co., York, Pa.)

Manufacturers are: The Manley Mfg. Co., York, Pa.; West Haven Mfg. Co., New Haven, Conn.; Millers Falls Co., Millers Falls, Mass.; Goodell Pratt Co., Greenfield, Mass.

Chain Hoist

The chain hoist can be secured in capacities of from ¼ to 1 ton, suitable for general automobile work. The lift varies from 6 ft. for the ¼-ton, 7 ft. for the ½-ton, and 8 ft. for the 1-ton capacity.

Manufacturers are: Edwin Harrington Sons & Co., Philadelphia, Pa.; Wright Mfg. Co., Lisboro, Ohio.

Emery Wheels and Stand

The emery wheel is used principally for finishing up tool work, taking off metal, and also for buffing and polishing brass parts. Two emery wheels, No. 40 and No. 60 grade at least, should be secured, and also cloth buffers for polishing.

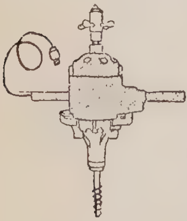


Fig. 11

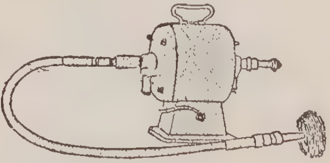


Fig. 12

Fig. 11. **A portable electric drill.** One of the handiest devices in the shop. See also page 700.

Fig. 12. A portable electric buffing machine.

A very compact electric emery wheel and buffer is made by the LeBron Electric Works, Omaha, Neb.

Machines for Cylinder Work

For cylinder enlarging work, a grinder, boring machine, or reamer is used. See Index for "Cylinder grinding."

Concerns manufacturing cylinder reboring machines and tools are: Storm Mfg. Co., Minneapolis, Minn.; Barnes Drill Co., Rockford, Ill.; South Bend Lathe Works, South Bend, Ind.; Sunderland Machine Shops, Omaha, Neb.

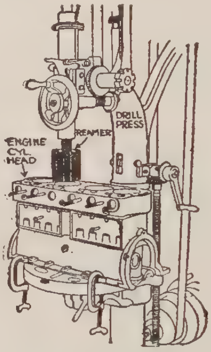


Fig. 13

Fig. 13. **A cylinder reaming machine for enlarging cylinders.** The reamer is built up with inserted blades and fitted with a No. 4 Morse taper shank. It can be used in any ordinary drill press which is geared down to run about 30 r.p.m.

The use of **cylinder grinders** for grinding cylinders to enlarge them instead of boring or reaming, is considered the best practice. See Index. The Heald Machine Co., Worcester, Mass., manufactures grinding machines, and also issues a very instructive catalog on the subject.

Blacksmith Equipment

Almost every shop needs some sort of a blacksmith equipment, even though it is only a small outfit, as shown below.

If a forge which burns coke or coal is used, it should be under a separate roof or piped, so that the smoke will pass outside. Gas is used quite extensively for heating purposes. Supplies of this nature can be secured of automobile supply houses.

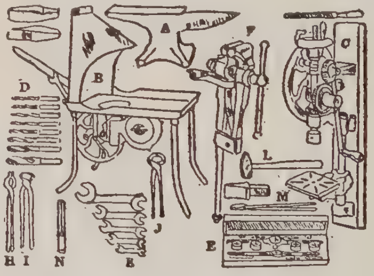


Fig. 14. **Blacksmith equipment:** (**A**) anvil, 100 lb.; (**B**) forge with 12″ fan, 25″ x 36″ hearth; (**C**) post drill; (**D**) drills ⅛″ to ¾″; (**E**) screw plate set; (**F**) blacksmith vise; (**H**) flat-lip tongs; (**K**) flat wrenches; (**L**) 3-lb. hammer.

INSTRUCTION No. 63

SMALL TOOLS FOR THE SHOP: Wrenches, Flat and Socket Type; S.A.E. Cap Screw and Bolt Sizes; U.S. Standard Bolt Sizes; Tap and Die Sets; Portable Electric Drills; Electric Bench Grinder

Some of the necessary small tools are shown on this and the pages following.[1] Farther on, explanations are given as to the use of small tools. These can be secured of automobile supply houses.

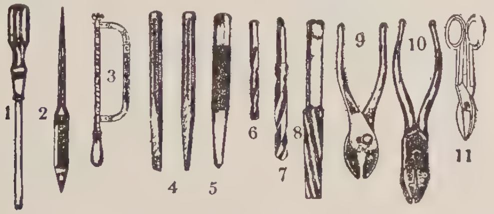
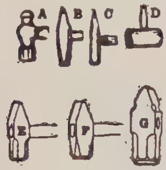
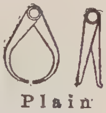


Fig. 1. (1) screwdriver; (2) soldering iron; (3) hack-saw; (4) chisels; (5) center punch; (6) straight shank drill (for hand and breast drill); (7) taper shank drill (for drill press); (8) reamer; (9) gas pliers; (10) cutting pliers; (11) tinners shears.





Plain calipers.

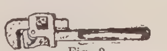


Fig. 3

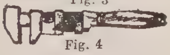


Fig. 4

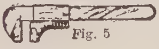


Fig. 5

Fig. 2. **Hammers:** (A) machinist's ball pein; (B) riveting; (C) tinner's riveting; (D) rawhide mallet; (E) engineer's hand hammer; (F) blacksmith's hand hammer; (G) blacksmith's sledge.

Fig. 3. Stillson pipe wrench.

Fig. 4. Monkey wrench.

Fig. 5. Adjustable flat wrench.

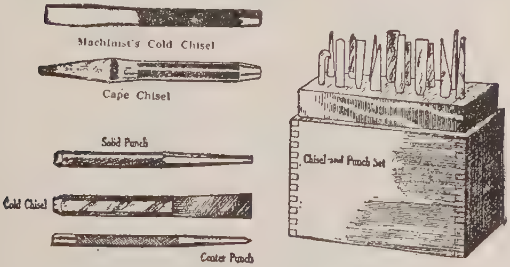


Fig. 6. **A center punch** is used to punch center marks in metal parts to be drilled, giving the drill a center to start in, and for reference marking, etc.

Chisels are made in many forms. The most popular is the cold chisel which is used for cutting metals. A cape chisel is the next most popular, and is used for cutting key ways and working in narrow grooves, channels, etc.

The diamond point chisel is used mostly for grooving in close places where a cape chisel could not be used.

Other popular chisels are round nose or gouge, used for cutting oil grooves in bearings and chipping out broken bolts or pipe threads from fittings. An assortment of small chisels and punches is shown in the illustration.

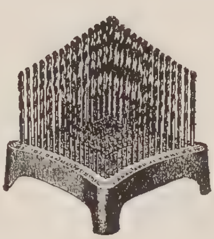


Fig. 7

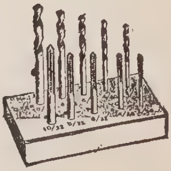


Fig. 8

Fig. 7. Set of straight shank drills for hand, breast, or bench drill—from No. 1 to 60. See Index under "How to read drill sizes."

Fig. 8. Tap and drill set for average small work, such as on lamps, speedometers, horns, etc. Tap sizes are 2/56"; 4/40"; 6/32", and 10/32", with drills to match. See Index under "How to read marks on drills."

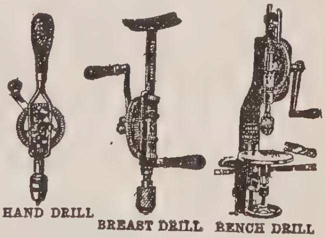


Fig. 9. Three types of hand-drilling machines are shown above, intended for light work.

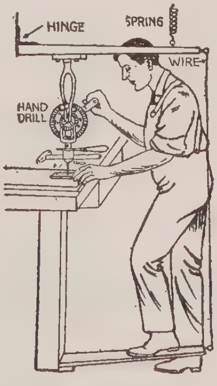


Fig. 10. Showing a method of applying pressure to an ordinary hand drill. The hand drill is attached to a bar, as shown. The bar is hinged to the wall.

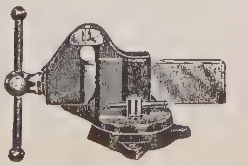


Fig. 11. Vise. Note that the swivel-base 4" or 6" jaw is generally used for average small work. A larger vise is also necessary.

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[1] **The Webster Magnet Light** is indispensable when night repair work around a car is necessary. It consists of a 4 c.p. light with reflector and 12 feet of cord which permits reaching any part of the car. The plug is inserted in the dash light socket. The main feature of this light is that it will "stick where stuck." It will hold tenaciously to any iron or steel surface, curved or flat, on fenders, axle housing, or engine. It exerts a pull of 3 lbs. and operates from the battery. Manufactured by the Webster Electric Co., Racine, Wis.; price $2.50.

List of Small Tools and Approximate Prices as Suggested by "Motor Age."

Wrenches	Price
18″ pipe wrench	$ 2.10
12″ pipe wrench	1.60
6″ pipe wrench	1.15
18″ monkey wrench	2.55
12″ monkey wrench	1.45
6″ monkey wrench	.95
Set double-end S-wrenches	2.30
Set 15° double end	2.45
Spark-plug socket	.60
Ratchet-handle socket set	24.00
Adjustable 6″ end wrench	1.00
Adjustable 8″ end wrench	1.20
Narrow-jaw monkey wrench	.85
Set speedwrenches	7.00

Files	
12″ bastard cut, flat	$ 0.56
12″ bastard cut, half round	.75
10″ bastard cut, round	.45
10″ bastard cut, square	.52
10″ bastard cut, three cornered	.50
8″ second cut, flat	.40
8″ second cut, half round	.50
8″ finishing cut, flat	.40
8″ finishing cut, half round	.52
8″ finishing cut, three cornered	.38
8″ finishing cut, rat tail	.70
6″ finishing, flat	.36
File for contact points	.20
File brush and handles	1.30

Measuring Tools	
24″ carpenters' square	$ 2.30
6″ machinists' square	3.80
Carpenter's 2 ft. rule	.45
Machinist's 12 in. scale	1.95
Machinist's 6 in. scale	.95
Machinist's 2 in. scale	.40
Combination protractor and square, 18 in.	6.85
Spirit level	.85
Thread gage	2.90
Thickness gage	2.65
Small and large external calipers	3.40
Small and large internal calipers	3.40
Small and medium spring dividers	2.75
Friction joint dividers, large	.90
Internal micrometer and extensions	10.60
Micrometer, 3″	16.90
Micrometer, 2″	15.25
Micrometer, 1″	10.40

Shears	
Tinner's snips	$ 1.40
Heavy shears	2.10
Bolt cutters	2.00

Hammers	Price
Rawhide mallet	$ 1.65
Lead hammer mold	2.10
Straight pein, 4 oz.	.65
Ball pein, ½ lb.	.80
Ball pein, 1 lb.	1.00
Ball pein, 2 lb.	$ 1.40
Blacksmith's sledge, 12 lb.	3.60
Blacksmith's, 4 lb.	1.20

Screwdrivers	
Small jeweler's	$ 0.40
6″ blade	.85
10″ blade	1.20
12″ blade	1.75
Offset	.80
T-handle, large	2.30

Bench Equipment	
Small bench anvil	$ 3.60
Swivel vise	17.00
Medium pipe vise	3.70
Surface plate	5.40
Machinist's clamps	7.00
C-clamps	8.00
Surface gage	2.50
Straightedge	4.20
Scriber	3.65

Chisels	
Cape, large	$ 0.35
Cape, medium	.25
Cape, small	.20
Chipping, large	.40
Chipping, medium	.35
Chipping, small	.20
Round nose, large	.40
Round nose, medium	.35
Round nose, small	.25
Cotter pin puller	.15
Diamond point, large	.40
Diamond point, medium	.30
Diamond point, small	.20
Center punch, large	.45
Center punch, medium	.30
Center punch, small	.20
Drift pins, 1/16″ to ¾″ by 16ths	2.40

Pliers	
Combination 8″	$ 1.50
Combination 6″	1.30
Piston ring expanding	1.15
Side-cutting, parallel jaws	1.40
Cotter pin	1.10

Miscellaneous Tools	
Wheel and gear pullers	$18.00
Valve spring lifter	2.00
Breast drill, two-speed	11.50
Valve seat reamer set	70.00
Soldering copper, large	2.75
Soldering copper, small	1.00
Gasoline blow torch	6.00
Hand drill, small	2.50
Belt punch	.60
Hacksaw frame and blades	2.50
Small hand vise	3.50
Oil stone	2.50
Three bearing scrapers	1.85
Three carbon scrapers	1.10
Pickup pliers	.85
Gasket cutter	13.50
Portable electric drill and valve grinding attachment	110.00
Piston ring compressor	.45
Total	$487.89

Open-End Flat Wrenches

Probably the most abused, the least considered, and yet the most indispensable tool in the kit of the mechanic is the wrench, the solid open-ended wrench, known to the British mechanician as the "fixed spanner," and known in the United States as the "machinist's" wrench.

Of the many kinds of wrenches, the cheapest, strongest, most efficient, and most durable is the open-end wrench. This style of wrench varies in quality and price in the following order: gray iron castings, malleable iron castings, sheet steel stamped, and steel drop forgings. The drop-forged wrench is superior. See illustrations for proper name of the popular type of open-end wrenches.

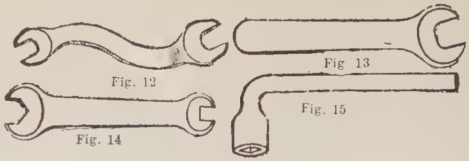


Fig. 12. The popular "S"-wrench.
Fig. 13. Engineer's single-end wrench.
Fig. 14. Double-head engineer's wrench, machinist's type.
Fig. 15. Socket-type wrench, with bent handle.

Open-end wrenches are used on cap screws, bolt heads, and nuts.

They may be divided into two general classes: **the U. S. S., and S. A. E.** The only difference between them is the width of opening between the jaws.

A standard wrench for a ½″ U. S. S. bolt will not fit a ½″ S. A. E. cap screw, and vice versa.

The S. A. E. wrenches are usually of the **"cap-screw size"** and the U. S. S. wrenches are of the **"U. S. S. bolt and nut size."** The Tables 1 and 2 explain this, and also give the various sizes for automobile work. The head is always larger on a U. S. S. bolt than on a cap screw.

Markings: Wrenches are usually marked with the size on each end. They are also marked with the manufacturer's number; this number is an indication of its size (see Tables 1 and 2).

Explanation of Tables 1 and 2

The first columns in each table give the trade number of Williams wrenches, and those sizes marked (*) are those most used for auto work. See Tables 1 and 2.

The second columns in each table give the actual diameters of the body of the bolts and cap screws.

The third columns in each table give the milled (or actual) opening size of the wrench at each end, and are the sizes suitable for the heads and nuts, with allowance for an easy fit.

Table 1

Number	For U. S. Standard Nuts Size Bolts	Openings Milled
21	1/8 & 3/16	5/16 & 13/32
22	1/8 & 1/4	5/16 & 1/2
•23	3/16 & 1/4	13/32 & 1/2
24	3/16 & 5/16	13/32 & 19/32
25	1/4 & 5/16	1/2 & 19/32
26	1/4 & 3/8	1/2 & 11/16
•27	5/16 & 3/8	19/32 & 11/16
28	5/16 & 7/16	19/32 & 25/32
•29	3/8 & 7/16	11/16 & 25/32
30	3/8 & 1/2	11/16 & 7/8
31	7/16 & 1/2	25/32 & 7/8
•32	7/16 & 9/16	25/32 & 31/32
•33	1/2 & 9/16	7/8 & 31/32
34	1/2 & 5/8	7/8 & 1 1/16
35	9/16 & 5/8	31/32 & 1 1/16
36	9/16 & 3/4	31/32 & 1 1/4
37	5/8 & 3/4	1 1/16 & 1 1/4
•38	5/8 & 7/8	1 1/16 & 1 7/16
39	3/4 & 7/8	1 1/4 & 1 7/16
40	3/4 & 1	1 1/4 & 1 5/8
41	7/8 & 1	1 7/16 & 1 5/8
42	7/8 & 1 1/8	1 7/16 & 1 13/16
43	1 & 1 1/8	1 5/8 & 1 13/16
44	1 & 1 1/4	1 5/8 & 2
45	1 1/8 & 1 1/4	1 13/16 & 2

Probably the most universally used wrench is the Williams wrench. See notes at foot of Table 2.

To find the size of wrench to fit an S. A. E. cap-screw head, consult Tables 3 and 2.

To find the size of wrench to fit a standard bolt and nut, see Table 4, and refer to Tables 1 and 2 for additional information.

Table 2

	Number	For Hexagon Head Cap Screws; Diameter Screws	Openings, Milled
*	721	1/8 & 3/16	5/16 & 3/8
	722	1/8 & 1/4	5/16 & 7/16
	723	3/16 & 1/4	3/8 & 7/16
	723A	3/16 & 5/16	3/8 & 1/2
	725	1/4 & 5/16	7/16 & 1/2
*	725A	1/4 & 3/8	7/16 & 9/16
*	725B	5/16 & 3/8	1/2 & 9/16
	726	5/16 & 7/16	1/2 & 5/8
	727	3/8 & 7/16	9/16 & 5/8
	728	3/8 & 1/2	9/16 & 3/4
*	729	7/16 & 1/2	5/8 & 3/4
	730	7/16 & 9/16	5/8 & 13/16
	731	1/2 & 9/16	3/4 & 13/16
	731A	1/2 & 5/8	3/4 & 7/8
*	731B	9/16 & 5/8	13/16 & 7/8
	732	9/16 & 3/4	13/16 & 1
	733	5/8 & 3/4	7/8 & 1
	734	5/8 & 7/8	7/8 & 1 1/8
	735	3/4 & 7/8	1 & 1 1/8
	736	3/4 & 1	1 & 1 1/4
*	737	7/8 & 1	1 1/8 & 1 1/4
	738	7/8 & 1 1/8	1 1/8 & 1 3/8
	739	1 & 1 1/8	1 1/4 & 1 3/8
	739A	1 & 1 1/4	1 1/4 & 1 1/2
	739B	1 1/8 & 1 1/4	1 3/8 & 1 1/2

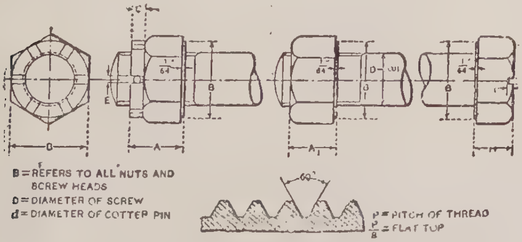
The foregoing list is Williams double-head open-end wrench.

Nos. 21 to 45 will fit U. S. standard nuts and bolt heads.

Nos. 721 to 739B will fit cap-screw heads (U. S. or S. A. E.).

S. A. E. Cap-Screw and Bolt Sizes

Table 3 gives the diameter of cap screw (D); threads per inch (P); thickness of head (A1); diameter across flats of nut or head—where wrench fits (B); size of drilled hole for cotter pin for castellated nut (E); depth of slot in head (I); width of slot (K); diameter of cotter pin (d). The diameter of bolts and cap screws is one one-thousandth of an inch less than the nominal diameter.



D	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$
P	28	24	24	20	20	18	18	16	16	14	14	12	12	12	12
A	$\frac{9}{32}$	$\frac{21}{64}$	$\frac{13}{32}$	$\frac{29}{64}$	$\frac{9}{16}$	$\frac{39}{64}$	$\frac{23}{32}$	$\frac{49}{64}$	$\frac{13}{16}$	$\frac{29}{32}$	1	$1\frac{5}{32}$	$1\frac{1}{4}$	$1\frac{13}{32}$	$1\frac{1}{2}$
A_1	$\frac{7}{32}$	$\frac{17}{64}$	$\frac{21}{64}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{31}{64}$	$\frac{35}{64}$	$\frac{19}{32}$	$\frac{21}{32}$	$\frac{49}{64}$	$\frac{7}{8}$	$\frac{63}{64}$	$1\frac{3}{32}$	$1\frac{13}{64}$	$1\frac{5}{16}$
B	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	$\frac{15}{16}$	1	$1\frac{1}{16}$	$1\frac{1}{4}$	$1\frac{7}{16}$	$1\frac{5}{8}$	$1\frac{13}{16}$	2	$2\frac{3}{16}$
C	$\frac{3}{32}$	$\frac{3}{32}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{3}{8}$
E	$\frac{5}{64}$	$\frac{5}{64}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{5}{32}$	$\frac{5}{32}$	$\frac{5}{32}$	$\frac{5}{32}$	$\frac{5}{32}$	$\frac{5}{32}$	$\frac{7}{32}$	$\frac{7}{32}$	$\frac{1}{4}$	$\frac{1}{4}$
H	$\frac{3}{16}$	$\frac{15}{64}$	$\frac{9}{32}$	$\frac{21}{64}$	$\frac{3}{8}$	$\frac{27}{64}$	$\frac{15}{32}$	$\frac{33}{64}$	$\frac{9}{16}$	$\frac{21}{32}$	$\frac{3}{4}$	$\frac{27}{32}$	$\frac{15}{16}$	$1\frac{1}{32}$	$1\frac{1}{8}$
I	$\frac{3}{32}$	$\frac{7}{64}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{7}{32}$	$\frac{7}{32}$	$\frac{1}{4}$	$\frac{1}{4}$
K	$\frac{1}{16}$	$\frac{1}{16}$	$\frac{3}{32}$	$\frac{3}{32}$	$\frac{3}{32}$	$\frac{3}{32}$	$\frac{3}{32}$	$\frac{3}{32}$	$\frac{3}{32}$	$\frac{3}{32}$	$\frac{3}{32}$	$\frac{5}{32}$	$\frac{5}{32}$	$\frac{3}{16}$	$\frac{3}{16}$
d	$\frac{1}{16}$	$\frac{1}{16}$	$\frac{3}{32}$	$\frac{3}{32}$	$\frac{3}{32}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{11}{64}$	$\frac{11}{64}$	$\frac{13}{64}$	$\frac{13}{64}$

All dimensions in inches.

Table 3

U.S. Standard Bolt Size: Head and Nut

Table 4 gives (first column) diameter of bolt or screw; (second column) threads per inch; (third column) diameter across head; (fourth column) size of hole in thousandths of an inch; (fifth column) size drill to use for tapping hole (see page 708).

Mill means the "milled size" of head of screw or bolt or the opening in an open-end wrench.

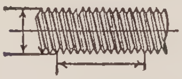
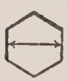
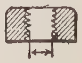
				
Diameter of Tap.	**Threads per Inch.**	**Mill**	**Exact Size of Hole.**	**Tap Drill Used.**
¼	20	½	.1910	13/64
5/16	18	19/32	.2403	15/64
⅜	16	11/16	.2938	19/64
7/16	14	25/32	.3447	23/64
½	13	⅞	.4001	13/32
9/16	12	31/32	.4542	15/32
⅝	11	1 1/16	.5069	17/32
¾	10	1¼	.6201	⅝
⅞	9	1 7/16	.7307	47/64
1	8	1⅝	.8376	27/32
1⅛	7	1 13/16	.9394	61/64
1¼	7	2	1.0644	1 5/64
1⅜	6	2 3/16	1.1585	1 11/64
1½	6	2⅜	1.2835	1 19/64
1¾	5	2¾	1.4902	1 33/64
2	4½	3⅛	1.7113	1 23/32
2¼	4½	3½	1.9613	1 31/32
2½	4	3⅞	2.1752	2 3/16
2¾	4	4¼	2.4252	2 7/16
3	3½	4⅝	2.6288	2 41/64

Table 4

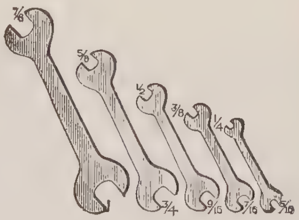


Fig. 16

Fig. 16. Walden's No. 100 thin wrench set for close places, check nuts, etc. Sizes are: 1"; ⅞"; ¾"; ⅝"; 9/16"; ½"; 7/16"; ⅜"; 3/16"; and ⅛" (actual width of opening; Walden Co., Worcester, Mass., or automobile supply jobbers).

Fig. 17

Fig. 17. Williams spark-plug wrench: No. 993, socket end fits ⅞" and ½" spark plug with ⅞" hex. and ½" U. S. standard nut. The open end fits a ⅜" S. A. E. nut or screw and a ⅜" U. S. S. cap screw (9/16" actual opening). No. 994 size, socket end, fits spark plugs with 1" hex. Open end is ⅞" actual opening. (J. H. Williams Co., Brooklyn, N.Y.

S. A. E. spark-plug shell dimensions are given elsewhere; see Index.

S. A. E. spark plugs are all ⅞-18, meaning that the outside diameter is ⅞", and there are 18 threads to the inch. See page 235 for difference in spark-plug threads and explanation of spark-plug sizes. **Gaskets must be used with the S. A. E. spark plugs.**

A ⅞" **S. A. E. spark plug requires a special tap** cutting 18 threads, whereas the standard S. A. E. ⅞" thread is 14 threads to the inch.

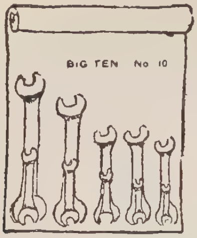


Fig. 18. Williams "Big 10" wrench assortment for general automobile work. Note the sizes in the table (Table 5). This is a recommended assortment taken from the list in Tables 1 and 2. The St. Louis Machinist's Supply Co., St. Louis, Mo., carries a full line of these wrenches, as do other supply houses.

"EXTRA CAPACITY" GARAGE, ETC. (See Table) SET, "BIG TEN," No. 10

No.	U. S. Nuts Dia. Bolts		U.S. Cap Scs Dia. Screws		S. A. E. Standard Nuts and Cap Screws	A. L. A. M. Standard Nuts and Cap Screws	Openings Milled	PRICE		
	Small Head	Large Head	Small Head	Large Head				Un-finished	Semi-finished	Finished
721	1/8		1/8	3/16		1/4	5/16&3/8	$.12	$ 17	$ 26
23	3/16	1/4		5/16	5/16	5/16	13/32&1/2	.14	21	.32
725A			1/4	3/8	1/4&3/8	3/8	7/16&9/16	.17	.25	.38
27	5/16	3/8				7/16	19/32&11/16	21	.31	.46
729			7/16	1/2	7/16&1/2	1/2	5/8&3/4	.25	.37	.56
731B		1/2	9/16	5/8	9/16	9/16	13/16&7/8	.30	.45	.68
32	7/16	9/16					25/32&31/32	.37	.55	.85
33C				3/4	5/8&11/16	5/8&11/16	15/16&1	.37	55	.85
737		3/4	7/8	1	7/8	3/4&7/8	1 1/8&1 1/4	.66	96	1.40
38	5/8	7/8			3/4&1	1	1 1/16&1 7/16	1.00	1 40	1.90
No. 10	Set	List Price of Roll, $.60 extra						3 59	5 22	7.66

Table 5

Socket Wrenches

Probably the handiest wrench to use for all nut and bolt work about a car is the socket wrench.

Socket wrenches are made with handles attached (Fig. 19), and in sets or singly, to which a ratchet lever is fitted (Fig. 20).

Socket Wrenches with Handles Attached

There are a number of different makes of wrenches of this type. The Walden Co., Worcester, Mass., manufactures a very extensive line. The wrenches can be purchased in sets or singly.

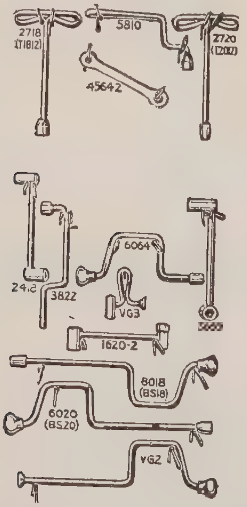


Fig. 19. **The Walden socket-wrench set showing some of** the different shaped handles which are designed for reaching nuts on certain parts of an engine or car. For example, the **set shown is for a Ford.** No. 2178 wrench is designed to reach the clutch release; No. 5810 is for the connecting rod; No. 2720 is for the brake shoe; No. 2418 is for the clutch lever, and so on. Sets such as the one shown are made for all parts of Ford, Chevrolet, Overland 4, Maxwell, and other cars. Can be secured of automobile supply houses, or the manufacturers, the Walden Co., Worcester, Mass.

Ford Socket Wrenches with Handles

The list below gives the Walden number of the socket wrench designed for each different part of a Ford, as itemized. The wrenches are designed to fit the nuts on the parts mentioned.

Front Axle

Ball socket	6018–2418
Front radius rod	5660
Front spring clip	2418
Front spring hanger	5660
Front spring perch	5660
Spindle bolt	5660
Spindle bolt nut	2418
Spindle connecting rod	5660
Steering yoke clamp	2418

Rear Axle

Axle housing	6064–1620
Brake-shoe support	1620–2418
Differential case	2418
Differential drive gear	1620–6064
Drive-shaft roller bearing	2720–1620
Hub nut	5660
Radius rod	5660
Rear-spring clip	5660
Rear-spring hanger	5660
Rear wheel to brake drum	5660

Engine

Carburetor flange (on cars without self-starter)	1018
Commutator-case support	6018–2718
Commutator-case support (on cars with self-starter)	6020–2720
Connecting rod	1020–5810
Crank case	6018–2718
Crank-case arm	2418
Crank-case lower cover	1620–6064
Crank-shaft bearing	1881–2418
Cylinder cover	6018–2718
Cylinder cover (on cars with self-starter)	6020–2720
Cylinder head	6020–1020–1620
Cylinder-valve cover	1018
Fan adjustment	6018–2718
Fan bracket	2418
Fly wheel	3822
Inlet and exhaust clamp	1018–2418
Magnet	6018–2718
Motor support, front	6020–1621
Piston-pin locking screw	1880
Radiator support	2718–2418
Valves	VG–2 VG–3
Water cyl. inlet conn.	1020–1620
Water cyl. outlet conn.	1620

Steering Assembly

Steering-post bracket	2418
Steering-tube flange	6064

Transmission

Brake adjustment	4564
Brake and reverse support	2418
Clutch-pedal support	2418
Controller shaft, bracket	2418
Hub brake-rod support	1620
Reverse adjustment	4564
Transmission cover	6018
Universal ball cap	1018–2718–2418

Miscellaneous

Body bracket	5660
Dash bracket to dash	1620–6064
Front fender iron	2418
Muffler	1620–6064
Running board	1881
Running board to fender	1881

Walden No. 23 Garage Service Set

The No. 23 garage service set is especially adapted for general use on different cars. It will take care of the parts on the front axle, rear axle, and motor unit of the following cars: Dodge, Buick, Chevrolet Model "490," Cadillac, Nash, Hudson, Oakland Model "34-C," Essex, Marmon, Dort, Chevrolet Model "BH."

This set makes thirty-eight combinations and sells for $22.00. The manufacturers are the Walden Co., Worcester, Mass., or it can be secured of the supply houses.

Socket Wrenches and Ratchet Levers

Socket wrenches are often purchased in sets, that is, the sockets (S) (Fig. 20) which fit the nuts or cap screws are made in a variety of sizes, thus giving a very large assortment in a small case.

The socket is operated on the nut by the ratchet lever (R) and if the nut or cap screw is in an inaccessible place, such as a cylinder stud nut, an extension bar, which is included in the set, can be placed between the socket and ratchet lever.

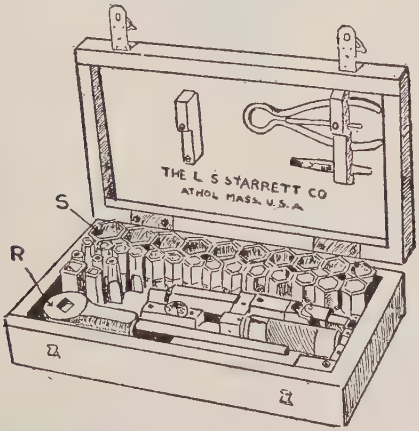

THE L S STARRETT CO
ATHOL MASS. U.S.A
S
R

Fig. 20. **Starrett socket ratchet wrench set.** With this set one can reach nuts in inaccessible places and at an angle; has 28 hexagon steel sockets from 1/16" to 1", also 1 1/32", 1 5/32" and 1 9/32". Drill attachment for drills ⅛" and ½" included, $15.

How to Find Socket-Wrench Sizes

When selecting a socket wrench for a certain size cap screw or nut, the first point to determine is if the size wanted is an S. A. E. nut or cap screw, or a U. S. S. cap screw or a U. S. S. nut. **For an example,** refer to the table of sizes below (Table 6) and find a ⅜" S. A. E. or U. S. S. cap screw; note that this size nut will take a 9/16" socket (which is the wrench size); a ⅜" U. S. S. nut takes a 11/16" socket.

SOCKET STOCK NUMBERS		SOCKET SIZES	SIZES SCREW-BOLT-NUTS			
SQUARE	HEXAGONAL		S.A.E. NUTS CAP SCREWS	U.S. STAN. NUTS	U.S. STAN. CAP SCREWS	U.S. STAN. BOLT HEADS UNFINISHED
112		3/8				
114	214	7/16	1/4		1/4	
116	216	1/2	5/16	1/4	5/16	1/4
118	218	9/16	3/8		3/8	
	219	19/32		5/16		5/16
120	220	5/8	7/16		7/16	
122	222	11/16		3/8		3/8
124	224	3/4	1/2		1/2	
	225	25/32		7/16		7/16
	226	13/16			9/16	
128	228	7/8	9/16	1/2	5/8	1/2
	230	15/16	5/8			
	231	31/32		9/16		9/16
132	232	1	11/16		3/4	
	234	1 1/16	3/4	5/8		5/8
136	236	1 1/8			7/8	
140	240	1 1/4	7/8	3/4	1	3/4

Table 6. From the Walden catalogue.

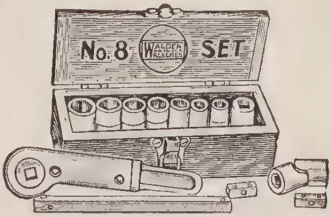


Fig. 21. Walden No. 8 socket wrenches and ratchet lever set. Assortment particularly selected to fit Ford cars: No. 516, 9" ratchet wrench; No. 1139, 9" extension bar; No. 1102, universal joint; No. 1109, plug connections (two); 7 sockets, hexagonal ½", 9/16", ⅝", 11/16", ¾", ⅞", 15/16"; 1 socket, square 9/16". Price complete, $9.90.

For socket wrenches for spark plugs, and also for spark-plug wrench sizes, see page 236.

Auto Machinists' Tap and Die Sets for Automobile Work

Among the essential and necessary tools for the repair shop is a set of taps and dies for cutting threads (see Index under "Threads"; "How to use taps and dies," etc.).

If the work is chiefly on Ford cars, the set shown below (Fig. 23) is designed for this purpose.

For all general automobile work the set shown in Fig. 22 is an excellent assortment.

Reamers (see Index) are also necessary. Tools of this description can be secured of the automobile supply houses.

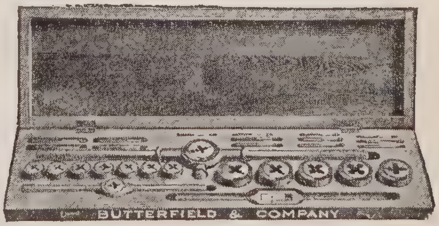


Fig. 22. **Butterfield screw plate set** No. 202, consisting of 7 sizes (14 different threads) 1-4 x 20—28, 5-16 x 18—24, 3-8 x 16—24, 7-16 x 14—20, 1-2 x 13—20, 5-8 x 11—18, 3-4 x 10—16, 14" and 26" Derby stocks, and adjustable tap wrench No. 10, as shown. Dies and taps to cut S. A. E. and U. S. S. threads as enumerated on the lid of box. (Butterfield Co., Derby Line, Vt.)

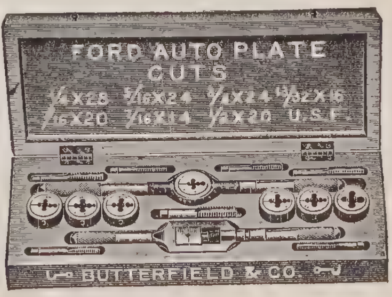


Fig. 23. The Butterfield screw plate is designed for Ford work, and contains taps and dies, cutting all the threads for bolts and screws on the Ford. (Butterfield Co., Derby Line, Vt.)

Pipe Dies and Taps

Taps and dies for cutting threads on small pipes, such as ⅛″, ¼″, ⅜″ and ½″, are shown in Fig. 24. See also page 709 for the "Briggs Standard" pipe-thread table. These can be secured of automobile supply houses.

Fig. 24. The Greenfield "Little Giant" set of taps and dies for cutting threads on pipes. (Greenfield Tap and Die Corpn., Greenfield, Mass.)

Pipe Specifications

Size	Outside Diameter	Inside Diameter	Length of Thread	Distance Pipe Screws into Fitting
1/8	13/32	9/32	27/64	13/64
1/4	35/64	3/8	4/8	19/64
3/8	11/16	1/2	41/64	5/16
3/4	1 1/16	53/64	53/64	33/64
1 1/4	1 21/64	1 3/64	1 1/32	9/16
1 1/2	1 29/32	1 5/8	1 5/64	57/64
2	1 3/8	2 5/64	1 7/64	61/64
2 1/2	2 7/8	2 15/32	1 41/64	1

Table 7

Electric Portable Drills

One of the handiest tools the automobile mechanic could possess is an electric portable drill. The electric drills shown below are the Black & Decker make, which can be secured of auto supply houses or direct from the manufacturers.

The drills are complete with interchangeable spade handle and breast plate and Almond chuck for straight shank drills and 15 feet of duplex electric cable and separable attachment plug.

This is the drill "with the pistol grip and trigger switch." Without removing or changing position of hands, current is switched on by pulling the trigger. The next pull on the trigger switches the current off.

This patented control prevents breakage of drill bits when operating the switch. It increases speed and accuracy of work.

The spindle on these drills is offset for close corner drilling.

The motors are built specially, and operate on direct current or 25, 40, or 60-cycle alternating current. They are cooled by forced circulation of air, and will not overheat under the most severe conditions of operation.

Reduction gears are packed in grease in grease-tight housing; extremely light and easily handled.

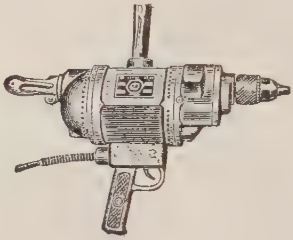


Fig. 25. Electric portable drill.

The Black & Decker portable electric drill is made in the following sizes:

Size 0 to ⅜″ for drilling steel; in hardwood, 0 to 9/16″; speed, no load, r.p.m. 900; weight 26 lbs.; volts, 110, 220, or 32; fuse ampere, 6, 3, 15.

Size 0 to ½″ for drilling steel; in hardwood, 0 to ¾″; speed, no load, r. p. m. 600; weight 34 lbs.; volts, 110, 220, or 32; fuse ampere, 6, 3, 20.

Size 0 to ⅝″ for drilling steel; in hardwood, 0 to ⅞″; speed, no load, r.p.m. 600; weight 34 lbs.; volts, 110, 220 or 32; fuse ampere, 6, 3, 20.

Electric Bench Grinders

For grinding tools or general grinding work.

These grinders should be connected to the electric power line, not the lamp socket. They are designed for alternating current of 110 or 220 volts, 3-phase current of 60 cycles.

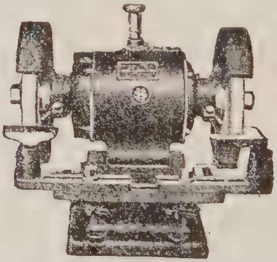


Fig. 26. U.S. ball-bearing bench grinder.

They are made in three sizes of ½, 1, and 2 h.p., and the speed is 3,000, 2,400 and 2,050 r.p.m. Wheels used are 8″ x 1″, 10″ x 1″ and 12″ x 1¼″ respectively. Can be secured of auto supply houses.

INSTRUCTION No. 64

PRECISION TOOLS FOR THE AUTOMOBILE MECHANIC: How to Use Them; How to Read Micrometer Calipers; How to "Mike" up Cylinders, Pistons, etc.; Miscellaneous Small Tools and Gauges; Types of Bolts, Screws, and Nuts; Standards of Threads; Sizes of Taps and Drills to Use for Cutting Threads; How to Select Dies and Taps and How to Use Them; How Drill Sizes Are Designated; How to Sharpen Drills; How to Select Reamers and How to Use Them; Types of Keys; Tightening and Removing Studs and Nuts; How to Select Files and How to Use Them.

Precision tools are those designed for accurate **measurements,** such as calipers, micrometer calipers, thickness gauges, etc. They measure in fractions of an inch, such as one one-hundredth and one one-thousandth part of an inch.

One feature of automobile repairing which has been sadly neglected by the average repairman is the use of electrical testing instruments for testing generators, starting motors, the wiring system, the ignition system, and storage batteries; as well as **the use of the micrometer caliper** for measuring and testing piston clearances, to see if the cylinders are out of round, etc.

The reason for this neglect is possibly the fact that the repairman has not realized the importance of making adjustments to a thousandth part of an inch, or else he thinks the subjects are too complicated for him to understand.

The writer would, however, advise every repairman who wishes to be skilled in making small measurements and in doing accurate work, not only to study the use of the instruments which will now be mentioned, but to become the proud possessor of the instruments. You will not only place yourself in a position where you can diagnose and remedy troubles, test cylinders, pistons, valve clearances, etc., with a degree of accuracy you have not been accustomed to, but you will be in a position to do work "over the head "of your competitor, and your work will be accurate, which of course will build a profitable business for you.

List of Precision Tools and Instruments Suitable for the Automobile Mechanic

1—**Model 280 Weston volt-ammeter,** for making tests as shown under electric tests and storage-battery tests. Price	$ 42.50
1—**Cadmium voltmeter** with cadmium stick, for testing storage-battery plates. Price	$ 26.50
1—**Hydrometer,** for testing electrolyte of storage batteries. Price	$ 1.50
1—**Wiring manual** to aid one in tracing electrical wiring circuits. Price	$ 15.00
1—**No. 203 micrometer caliper,** for measuring spaces from .001″ to 1″. This instrument can be used for measuring ball bearings, drills, screws, rods, sheet metal, etc. Price	$ 8.50
1—**No. 226 3-inch micrometer caliper,** for measuring the diameter of pistons, etc. Will measure from 2 to 3 inches in thousandths part of an inch. Price	$ 10.00
1—**No. 226 4-inch micrometer caliper,** for measuring the diameter of pistons, etc. Will measure from 3 to 4 inches in thousandths part of an inch. Price	$ 10.75
1—**No. 226 5-inch micrometer caliper,** for measuring the diameter of pistons, etc. Will measure from 4 to 5 inches in thousandths part of an inch. Price	$ 12.00
1—**No. 124A inside micrometer caliper,** for measuring the inside diameter of cylinders. Will measure spaces from 2 to 8 inches. Price	$ 7.25
1—**No. 72 thickness gauge,** for measuring spark-plug gap clearance; interrupter-gap clearance; piston-ring gap clearance, etc. Has 22 leaves varying in thickness from .004″ to .025″. Price	$ 2.50
1—**No. 172A thickness gauge;** has 9 leaves and measures smaller clearance than No. 72, as follows: .001½″ or .0015″; .002″; .003″ also .004″; .006″; .008″; .010″; .012″; .015″. These smaller measurements are necessary for measuring ring-groove clearance and valve clearances where under .004″. Price	$ 1.50
1—**Machinist's steel rule or scale,** 6″. Price	$ 1.00
1—**Inside caliper,** 5″, as shown in Fig. 7, page 704. Price	$ 1.00
1—**Outside caliper,** 5″, as shown in Fig. 8, page 704. Price	$ 1.00
1—**Compression tester,** for testing the comparative pressure of cylinders. Price	$ 6.50
Total	$147.50

You will note that all of the foregoing list is required, in order that one may make all tests. One micrometer caliper cannot be obtained that will measure all sizes of pistons, as, for instance, from 2 to 5 inches in diameter. Instead, a set is required as listed above.

Other suggested tools are: 4″ machinist's vise, $12.75; blow pipe torch for soldering, $8.50; set of drills 1/16″ to ½″ in thirty-seconds, $7.00; Townsend grease gun, $5.50. All material listed on this page can be secured of A. L. Dyke, Elect. Dept., St. Louis, Mo.

THOUSANDTH PART OF AN INCH

A thousandth part of an inch is infinitesimally small, but must be used to measure correctly the clearance of a spark-plug gap, the interrupter-point gap in ignition systems, and also for valve clearances, piston clearances, and for many other purposes.

What Is a Thousandth Part of an Inch

If 1″ is divided in 2 parts, each part is $\frac{1}{2}$″
If 1″ is divided in 32 parts, each part is $\frac{1}{32}$″
If 1″ is divided in 64 parts, each part is $\frac{1}{64}$″
If 1″ is divided in 100 parts, each part is $\frac{1}{100}$″
If 1″ is divided in 1,000 parts, each part is $\frac{1}{1000}$″

A hundredth part of an inch could be expressed in fractions as $\frac{1}{100}$ part of an inch, but is usually expressed in decimals as .01″.

A thousandth part of an inch could be expressed in fractions as $\frac{1}{1000}$ part of an inch, but is usually expressed in decimals as .001″.

To read decimals, start with the decimal point (the period); call it decimal or point; the next figure to the right of it, call tenths; the next figure, hundredths; the next figure, thousandths; the next figure, ten-thousandths; the next, hundred-thousandths, and so on.

Thus, the figure 3, standing alone, would represent three units, but if it had a decimal point in front of it, as .3, this would represent three-tenths; if expressed thus, .03, it would represent three-hundredths; if expressed thus, .003, it would represent three-thousandths; if expressed thus, .0003 it would represent three-ten-thousandths, and so on.

If an inch was measured off into one thousand equal parts, each part would represent one one-thousandth part of an inch or .001″.

Twenty-five of these parts would represent twenty-five one-thousandths of an inch (.025″), which is equal to 1/40 of an inch.

One hundred of these parts would represent one hundred one-thousandths of an inch (.100″), which is exactly equal to 1/10 of an inch.

Five hundred of these parts would represent five hundred one-thousandths of an inch (.500″), which is exactly equal to ½ an inch.

One thousand, or all of these parts would represent one thousand one-thousandths of an inch (1.000″), which is exactly 1 inch.

In order to gain an idea as to the thickness of a one-thousandth part of an inch, we will compare the thickness of this paper, which is only approximate.

.001 (one one-thousandth) = 1/3 thickness of this sheet of paper, or about the thickness of fine tissue paper.

.003 (three one-thousandths) = the thickness of this page you are reading (approximately). If it were 3½ one-thousandths, it would be expressed as .0035″ (thirty-five ten-thousandths of an inch).

.006 (six one-thousandths) = the thickness of two sheets of this paper.

.015 (fifteen one-thousandths) = the thickness of five sheets of this paper.

.020 (twenty one-thousandths) = the thickness of seven sheets of this paper.

.025 (twenty-five one-thousandths) = the thickness of eight and one-third sheets.

.030 (thirty one-thousandths = the thickness of ten sheets.

Decimal Equivalent of Fractional Parts of an Inch

In using Table 1, it is not necessary to carry out all of the fraction. As a rule, three figures to the right of the decimal point is close enough for all practical purposes—which would be, of course, read in thousandths, as .015 (fifteen one-thousandths). Note that ⅛ of an inch is equal to .125 (one hundred and twenty-five one-thousandths of an inch).

Table 1

8ths

1/8 = .125
1/4 = .250
3/8 = .375
1/2 = .500
5/8 = .625
3/4 = .750
7/8 = .875

16ths

1/16 = .0625
3/16 = .1875
5/16 = .3125
7/16 = .4375
9/16 = .5625
11/16 = .6875
13/16 = .8125
15/16 = .9375

32ds

1/32 = .03125
3/32 = .09375
5/32 = .15625
7/32 = .21875
9/32 = .28125
11/32 = .34375
13/32 = .40625
15/32 = .46875
17/32 = .53125
19/32 = .59375
21/32 = .65625
23/32 = .71875
25/32 = .78125
27/32 = .84375
29/32 = .90625
31/32 = .96875

64ths

1/64 = .015625
3/64 = .046875
5/64 = .078125
7/64 = .109375
9/64 = .140625
11/64 = .171875
13/64 = .203125
15/64 = .234375
17/64 = .265625
19/64 = .296875
21/64 = .328125
23/64 = .359375
25/64 = .390625
27/64 = .421875
29/64 = .453125
31/64 = .484375
33/64 = .515625
35/64 = .546875
37/64 = .578125
39/64 = .609375
41/64 = .640625
43/64 = .671875
45/64 = .703125
47/64 = .734375
49/64 = .765625
51/64 = .796875
53/64 = .828125
55/64 = .859375
57/64 = .890625
59/64 = .921875
61/64 = .953125
63/64 = .984375

See also page 68, "Converting decimals of hundredths of an inch into fractions of an inch."

Another table of decimal equivalents is given below (Table 2):

Table 2

1/64	.015625	33/64	.515625
1/32	.03125	17/32	.53125
3/64	.046875	35/64	.546875
1/16	.0625	9/16	.5625
5/64	.078125	37/64	.578125
3/32	.09375	19/32	.59375
7/64	.109375	39/64	.609375
1/8	.125	5/8	.625
9/64	.140625	41/64	.640625
5/32	.15625	21/32	.65625
11/64	.171875	43/64	.671875
3/16	.1875	11/16	.6875
13/64	.203125	45/64	.703125
7/32	.21875	23/32	.71875
15/64	.234375	47/64	.734375
1/4	.25	3/4	.75
17/64	.265625	49/64	.765625
9/32	.28125	25/32	.78125
19/64	.296875	51/64	.796875
5/16	.3125	13/16	.8125
21/64	.328125	53/64	.828125
11/32	.34375	27/32	.84375
23/64	.359375	55/64	.859375
3/8	.375	7/8	.875
25/64	.390625	57/64	.890625
13/32	.40625	29/32	.90625
27/64	.421875	59/64	.921875
7/16	.4375	15/16	.9375
29/64	.453125	61/64	.953125
15/32	.46875	31/32	.96875
31/64	.484375	63/64	.984375
1/2	.5	1	1.

MICROMETER CALIPERS

It would be a difficult matter to divide an inch into one thousand divisions or graduations on a rule or scale, therefore an instrument known as **a micrometer caliper with a double scale is employed** for measuring spaces as small as .001″. In fact, by adding a third scale (called a Vernier, Fig. 4, page 703), and computing the ratio of one figure to another, a space as small as one ten-thousandth (.0001″) of an inch can be measured.

The automobile repairman seldom finds it necessary to measure spaces less than .001″; therefore this subject will be devoted to micrometer calipers reading .001″ and more.

The three kinds of micrometer calipers the automobile repairman will need most are shown in Figs. 1, 2, and 3.

The "outside micrometer caliper" (Fig. 2) is used for measuring the outside of pistons, etc. The "inside micrometer caliper" (Fig. 3) is used for measuring the inside of cylinders, etc.

The outside micrometer caliper shown in Fig. 1, this page, is a smaller one, it measures spaces only from .001″ to 1″. The one shown in Fig. 2 will take larger measurements, but also reads .001″ to 1″.

Micrometer Caliper Reading One-Thousandth Part of an Inch

How to read: Frame A (Fig. 1) and sleeve D are stationary. The thimble E and spindle C are connected together. On the inside of A and D there are threads (40 to the inch).

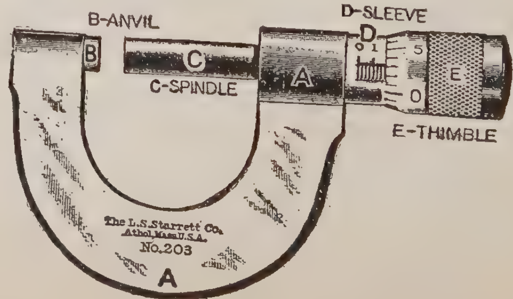


Fig. 1. Micrometer caliper which reads spaces as small as .001″, up to 1″. Lines on (D), .025″; lines on (E), .001″.

When the micrometer caliper is closed, the end of (C) is against (B) and the bevel edge of thimble (E) is on the vertical line (O) on (D), and the (O) line on the bevel edge of (E) is in line with the horizontal line on (D).

When caliper is opened (we will assume that it is closed), turn thimble (E) to the left. If it is turned one complete revolution, then the (O) line on (E) would have revolved from the horizontal line on (D) back again, and one vertical line will then be visible on (D) which represents a space of twenty-five one-thousandths (.025″) of an inch from (B) to the end of (C) (where all measurements are made).

The reason for this is the fact that the spindle (C) and thimble (E) are revolved on threads which are cut 40 to the inch, and a complete turn represents a movement of (C), of 1/40 of an inch, which, expressed in decimals, equals .025″ (twenty-five one-thousandths) 25/1000 = 1/40.

Each line, therefore, on (D) which is exposed by the bevel edge of thimble (E) as the caliper is opened, represents .025″ or 1/40 of an inch. Every fourth line is longer, and is numbered, 1, 2, 3, 4, etc. Therefore, if the fourth line with the number 1 on (D) is visible at the edge of (E), then we should have an opening at (B) to (C) of 4 x .025″, or .100″, or 4/40, or 1/10 inch. If eight lines on (D) were visible, the **eighth line** would be numbered 2, and we should have an opening of 8 x .025″, or .200″, or 8/40 of an inch, which is also equal to 1/5″.

Any fractional part of a complete revolution of (E) will be read on the edge of thimble (E). For instance, suppose thimble (E) is not revolved a complete revolution, but only a portion of a revolution. We know that a complete revolution of (E) represents .025″; therefore there are 25 divisions or lines on the bevel edge of (E), an equal distance apart, and every fifth line is numbered, from 0 to 25. Rotating the thimble (E) from one of these marks to the next, moves spindle (C) longitudinally 1/25 of twenty-five one-thousandths, or one one-thousandth (.001) of an inch, and this is where we get the reading in one-thousandths (.001).

For example, see Fig. 1: There are seven vertical lines (do not count the O line) visible on (D). Multiply this by .025 (7 x .025 = .175), then add the number of divisions or lines from (O) (do not count the O line) on thimble (E) to the horizontal line on (D), and we have 3 divisions or lines (each line represents .001). Therefore, we have a space from (B) to the end of (C) of (.178″) one-hundred and seventy-eight one-thousandths of an inch (7 x .025 = .175 + .003 = .178″).

The outside micrometer caliper (Fig. 2) is used for measuring the outside diameter of pistons, etc. Note that the frame is much deeper, which is necessary, so that there may be room to place the caliper over the piston.

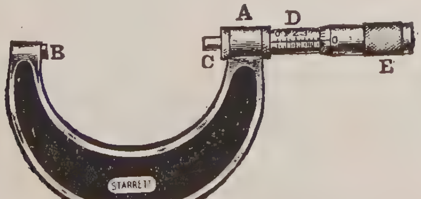


Fig. 2. Outside micrometer caliper.

The usual diameter of pistons for automobile engines varies from 2″ to 5″ diameter. In order to measure pistons from 2″ to 5″ diameter, it is necessary to have three micrometer calipers (see list, page 701), as each caliper reads only for 1″ measurement. In other words, the movement of (C) (Fig. 2) is only 1 inch. This 1″ movement can be read in thousandths of an inch, as explained in connection with Fig. 1.

For instance, on a caliper designed **for 2″ to 3″**, the permanent open space between end of (C) and (B) would be 2″ when the caliper was closed. Thus the micrometer reading in thousandths of an inch would be between 2 to 3 inches. This also applies to the 3″ to 4″ and 4″ to 5″ micrometer caliper. See reference to No. 226, 3″, 4″, and 5″ calipers, page 701.

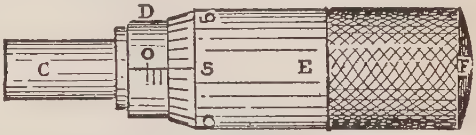


Fig. 3. Inside micrometer caliper.

To read the inside micrometer caliper (Fig. 3), the same method is used. However, bear in mind that in order to read the measurement of a cylinder, which, say, is 4.080″ (four and eighty one-thousandths of an inch in diameter), we should place an extension bar in the end of (C) (bars of different lengths are supplied with inside micrometer calipers). Then open the caliper slightly more than the required amount. Then close the caliper gradually until it will go into the cylinder freely. Then gradually open it until the edge of (F) touches the cylinder wall on one side and the end of the bar on the other side. Remove and note the reading (note that (F) is pointed, as is also the end of the extension rod which fits into (C), in order that they conform with the curvature of the cylinder).

The reading on **Fig. 3** shows three lines exposed on (D). The third line is hardly visible, but the bevel edge of (E) is just exposing the third line on (D). In fact, the spaces between lines is more often counted than the lines themselves. Do not count line (O). Therefore as each line on (D) represents .025″, we have 3 x .025 = .075 on (D). Then count the number of lines from the (O) line on (E) (at bottom), to the horizontal line on (D), counting each line as .001″, and we have 5 lines, or .005; therefore we have a reading of .080″ (3 x .025 = .075 + .005 = .080″).

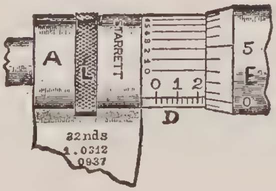


Fig. 4

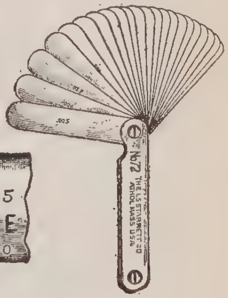


Fig. 5

Fig. 4. **The Vernier micrometer caliper** has a third scale and reads one ten-thousandth. To read, note the thousandths as in the ordinary caliper (Fig. 1); then observe the numbered line on (D) which coincides with the line on (E). If it is the line marked (1), add one ten-thousandth; if it is the line marked (2), add two ten-thousandths, etc.

Fig. 5. **A thickness gauge:** This tool is used for measuring the clearance of valve stems, spark-plug and interrupter points, etc. as mentioned on page 701 (No. 72 and 172A thickness gauge). This is the No. 72, and has 22 leaves which vary in thickness from .004″ (four one-thousandths) to .025″ (twenty-five one-thousandths) of an inch. See page 701 for description of the No. 172A gauge.

SYMBOLS OF DEGREES, MINUTES, SECONDS, INCHES, AND FEET

It will be observed that the same designations which stand for inches are also used for seconds, and those for feet are also used for minutes.

Degrees

A degree is a unit employed in measuring angles, and is the ninetieth part of a right angle or one three-hundred and sixtieth part of a circle.

The explanation of degrees is given on page 60. See also pages 68 and 69 for "Converting degrees into inches."

A circle is 360° around its circumference. If divided into 360 equal parts, each part would represent 1 degree, designated as 1°.

We can divide each degree into 60 parts called **"minutes,"** and each minute can be divided into 60 parts called **"seconds."** One minute would be designated thus (1′) and one second thus (1″).

Signs or Symbols of Inches, Feet, Minutes, and Seconds

The sign for inches or seconds is (″) as 6″.

The sign for feet or minutes is (′) as 6′.

MISCELLANEOUS SMALL MEASURING TOOLS AND GAUGES

Dividers Calipers.

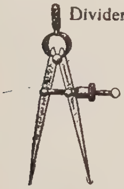


Fig. 6

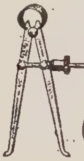


Fig. 7

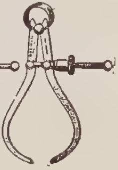


Fig. 8

Fig. 6. **Dividers** are used to lay off circles and distances on metal, for drilling, etc.

Fig. 7. **Inside calipers** are used for measuring inside diameters, such as cylinders, bearings, etc. The points of a caliper are then placed on a machinist's rule and the measurement is noted.

Fig. 8. **Outside calipers** are used for measuring exterior diameters, such as drill taps, etc. The caliper is adjustable, and after the measurement is taken the points of the caliper are placed on a rule or scale to find the measurement in inches or the fraction thereof.

Caliper dividers are made with and without springs. The spring is an advantage, however, inasmuch as when once set, they retain their setting.

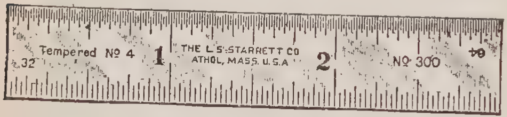


Fig. 9. **A machinist's steel rule or scale** is of thin tempered steel and comes in lengths from 2″ to 24″. The popular size is 6″, with graduations reading sixty-fourths and thirty-seconds of an inch on one side and sixteenths and eighths of an inch on the other side. They can also be obtained graduated in tenths and hundredths of an inch, as well as in millimeters.

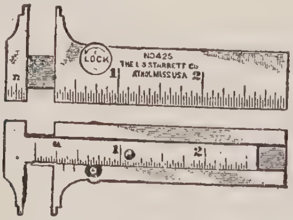


Fig. 10

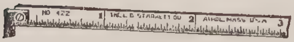


Fig. 11

Fig. 10. **A pocket sliding rule,** also called a caliper rule, usually made in 3″ lengths; graduated in thirty-seconds on one side, and in sixty-fourths on the other. Handy for measuring sheet or bar stock, wire, tubing, etc.

Fig. 11. **A hook rule** for measuring the diameter of flanges or circular pieces, through the hubs of pulleys, setting calipers or dividers, etc.

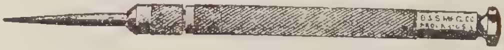


Fig. 12. **A scriber,** used for scribing fine lines on planed surfaces of iron or steel, such as timing marks on fly wheels, etc. The points are of tempered tool steel.

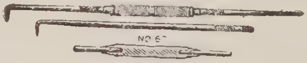


Fig. 13. **Double-point scribers,** threaded to screw into the holders and knurled for finger grip.

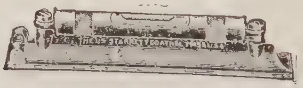


Fig. 14. **Spirit level,** used for lining up pistons, connecting rods, etc., when used in conjunction with a steel square. Also used for finding grades.

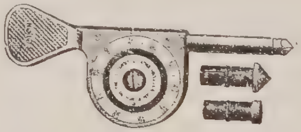


Fig. 15. **A speed indicator,** or revolution counter, as it is sometimes called, is a necessity in high-speed work. The dial can be set at the 0 mark, and when timed with a watch for a minute or fraction thereof, will indicate the total number of revolutions made by the crank shaft, line shaft, motor, or generator.

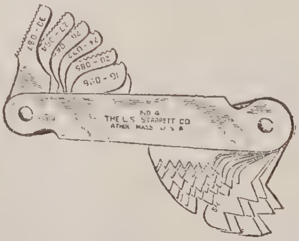


Fig. 16. **Screw pitch gauge** for determining the number of threads to the inch on bolts, taps, etc. The shape of the blades makes it applicable also for inserting in nuts and bolt holes. Sizes and decimal equivalents are stamped on each blade. This particular tool is made in pocket-knife form.

Wire and Sheet-Metal Gauges

Standard gauges for wire and sheet metal: The standards were originated by the various plate and wire manufacturers, thus causing several standards to be recognized.

To avoid confusion it would be well, when ordering wire or sheet metal, to specify the diameter or thickness in dimensions of an inch. If this is not possible, and a wire or sheet-metal gauge can be used, gauge the stock, and when ordering, specify the gauge number and the name of the gauge.

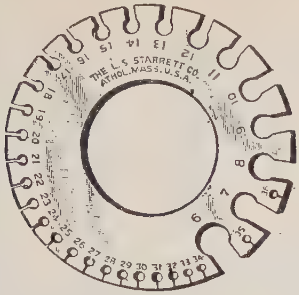


Fig. 17

There are three standards in general use, and they all look very much like that shown in Fig. 17.

The "United States Standard Gauge" for sheet and plate iron and steel was legalized by Act of Congress, March 3, 1893, as a standard gauge to be used by the custom-house department for sheet iron and steel. This gauge is now the adopted standard of the tin-plate manufacturers, there being about forty-five manufacturers using it for their steel. The number of this gauge is No. 283.

The steel-wire gauge is known as the "American Steel and Wire Gauge," as well as the "W and M Standard" (Washburn and Moen Standard). This gauge is applied to all steel wire upon the recommendation of the Bureau of Standards at Washington (No. 287).

The American Standard Wire Gauge is the gauge usually recognized in the United States as the standard for copper wires and wires of metals other than steel (No. 281).

No confusion should be encountered between these two gauges; that is, the "Steel Wire Gauge" is used only to gauge steel wire, and the "American Wire Gauge" is used on copper wire and wires of metals other than steel.

Before using these gauges the material to be gauged should be cleaned thoroughly of all rust and grit. A gauge is then applied, and tests of the different gauge slots are made until one is found that fits the material snugly. Never force the gauge on the material. By doing this the gauge may be sprung, which will cause it to be inaccurate. When gauging a sheet or plate, file off the edges smooth to eliminate danger of error in engaging.

Tap and Drill Gauge

By the use of this gauge one is enabled to select at once the right-sized drill, to suit the machine screw taps most commonly used, leaving just stock enough for the tap to cut as near a full thread as is practical without breaking it, thus saving much time and uncertainty of result attending the former crude ways of selection.

Explanation of illustration (Fig. 18): The first row of figures, for instance, reads thus, 14 x 20 10 ¼. The number 14 (in the first row of figures) means the number or size of the tap; 20, the pitch or number of threads per inch; 10, the size of drill to use which will leave the right stock for proper thread; and ¼, the size of drill to use to let this tap or screw through outside of the thread.

The figures—1, etc., up to 60—designate the number of drill (the size agreeing with the holes). Other figures, 228, 221, etc., designate the size of the hole in thousandths of an inch.

Example: Suppose you had a cap screw of a certain size and you found that it required a 10 x 32 tap. First find the tap size 10 x 32 in the first column to the left (on the drill gauge). Referring to the second column (tap-drill size), you will find that a drill is required of such size as will be a snug fit in the No. 20 hole. Referring to the No. 20 hole you will note that it has the decimal .161 under it. This is the diameter in thousandths of an inch of the drill to use, and is the proper size for tapping, to insure a full thread.

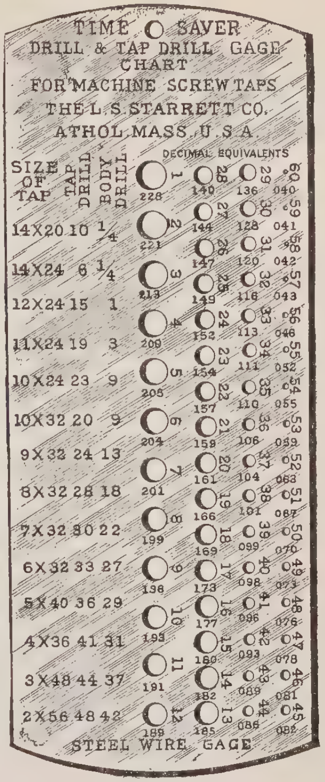


Fig. 18

Suppose, however, that in this particular job you were fastening a bracket or brace to the frame of the chassis. It would then be necessary to drill a hole large enough through the bracket so that the screw would pass through it (as there would be no threads required in this piece). Referring to the third column (body size of cap screw), you will find after the figures 10 x 32 20, the figure 9, thus the proper size drill to use is the one that is a snug fit in the No. 9 hole, and under hole 9, the decimal size is .196 (196 one-thousandths). By referring to the table on page 702 of Decimal Equivalents, the nearest size of the drill to use can be found.

In selecting a drill to drill a hole (whose diameter is expressed in thousandths), always select the nearest size to it, preferably a size or two larger. As an example, take the decimals above: the first one was 161 thousandths. Referring to the table on page 702, you will find that the nearest decimal to this is 171 thousandths. Thus this is equivalent to a 11/64 drill.

The second decimal was 196 thousandths, and we find that the nearest size to this is 203 thousandths, equivalent to a 13/64 drill.

If you select a size smaller instead of larger, you run chances of breaking the tap when trying to cut the threads, especially in hard or very thick metals. As long as there is 75 per cent of the thread available, the thread will be stronger than the bolt itself, and so there is no harm done by having the hole a trifle larger.

BOLTS, SCREWS, AND NUTS

Nuts are not usually used on capscrews, as the capscrew is generally screwed right into the metal part. However, nuts can be put on to them, and they can be used in place of bolts.

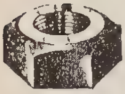


Fig. 19

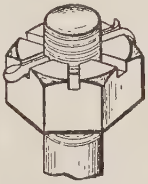


Fig. 20

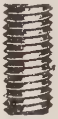


Fig. 21

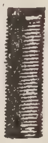


Fig. 22

Fig. 19. A hexagon nut.

Fig. 20. A "castellated" nut. The castellated nut is slotted to take a cotter pin to prevent it coming loose.

Fig. 21. U. S. S. (United States Standard) capscrew and bolt thread.

Fig. 22. S. A. E. Standard cap screw and bolt thread. These exaggerated illustrations are intended to show the only difference between a U. S. S. capscrew and an S. A. E. capscrew —which is in the thread. Note that in this illustration (S.A.E.) the thread is much finer. Therefore there are more threads per inch.

By referring to Table 4 (page 697) it will be seen that a ¼″ U. S. S. capscrew has 20 threads per inch; whereas a S. A. E. capscrew (Table 3, page 697) has 28 threads per inch.

Bolts always have nuts on them, either square or hexagon, and in most cases the nuts are larger than the head and consequently take a different size wrench. For instance, a ⅜ machine bolt has a 11/16″ head and a ⅝ nut; whereas an S. A. E. ⅜ capscrew has a 9/16″ head (see page 697, Table 3).

The measurement for the diameter of a bolt or screw is taken just below the head, where the metal is full diameter. If measured across the threaded part, they will be found to be of slightly less diameter, owing to the "flat" (see Fig. 27, page 707).

U. S. S. and S. A. E. Bolt and Cap Screws

The U. S. S. and S. A. E. capscrews are alike in all respects, with the exception of the pitch diameter and the number of threads per inch. By referring to table No. 5, page 709, you will notice the number of threads to the inch on the S. A. E. is more than on the U. S. S. (table 4).

On the automobile we find bolts are used on the springs and various parts. In fact there is hardly a part of the entire mechanism that does not have its quota of bolts, capscrews, machine screws, or carriage bolts (the latter used for holding the body to the frame). Stove bolts are used frequently for fender and drip pans.

Difference between Bolts and Cap Screws

The difference between a capscrew and a machine bolt lies mostly in the method of manufacture.

In making **a capscrew,** the usual method is to cut off a piece of the required length, from a piece of steel of hexagon shape and of the size required for the head. The piece is then turned down to the size required for the body, and a thread is cut on it (or it is milled).

In making **a machine bolt,** the stock is cut from a bar of round steel of the required diameter of the body, and the head is then formed by a process called "upsetting." The machine bolt has a slightly larger diameter head than the capscrew, but the threads are identical in both.

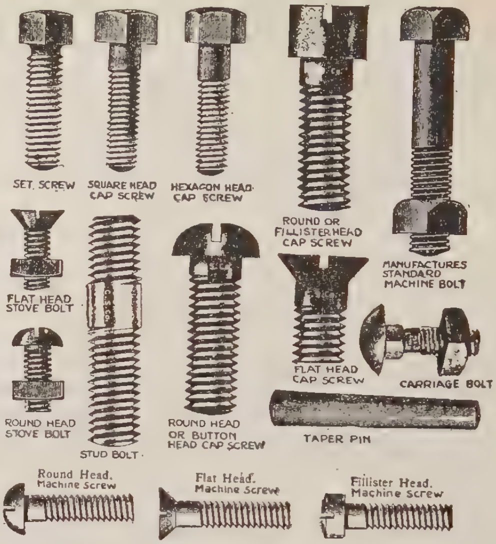


Fig. 23. Illustrations showing the different kinds of bolts and screws. The square-head capscrew is seldom used for automobile work.

The only difference between an S. A. E. bolt and an S. A. E. capscrew is in the amount of thread cut on it. The size and shape of the head are the same and the number of threads per inch is the same.

The difference between a U. S. S. bolt and a U. S. S. capscrew is also in the length of thread and the size of head. The thread on a capscrew is run down nearly to the head, while on a bolt it is run down only about one-third of its length. The heads differ in that the bolt head is larger than the capscrew head, and in the former is usually square instead of hexagon.

The difference between a machine screw and a machine bolt is mostly in the shape of the head. The screw has either a round or a flat head, but never a hexagon head, and differs in the further respect that the head is slotted for the reception of a screwdriver.

A wrench that fits a U. S. S. capscrew will fit an S. A. E. capscrew, because the heads are of the same size.

A wrench that fits a U. S. S. machine bolt will not fit an S. A. E. capscrew, because the U. S. S. bolt head is larger.

A wrench that fits a U. S. S. capscrew will fit an S. A. E. machine bolt, because the S. A. E. bolts have the same heads as capscrews.

A wrench suitable to fit any and all of those mentioned above is the adjustable S-wrench, and open wrenches in sets.

Studs, Taper Pins, and Set Screws

Studs are usually placed in the top of cylinders with detachable heads. The cylinder head is slipped over the studs and fastened down with hexagon nuts. They are also used on top of the crank case.

Taper pins require taper pin reamers—a reamer must always match the pin (see Index for a taper pin reamer). Taper pins are used for locking collars to shafts (where keys cannot be conveniently used), and for various other purposes.

Set screws are usually cut full, so as to fit tight in the part to be held. They are either pointed or cupped at their lower ends, and are either square headed or slotted. In using, set up tight and tap them directly on top with a light hammer, then tighten again. This will set the point or cup in the shaft. The threads are always U. S. Standard.

When driving out bolts that are to be used again, strike the hardest blow you can, and use a heavy hammer. Light blows and the use of a small hammer will upset or rivet the bolt.

THREADS

The two principal threads with which the repairman or mechanic should familiarize himself are the **bolt thread** and the **pipe thread.** A little study and use of the various sizes will enable him to know the particular kind and size by merely looking at it. A comparative difference in size between a bolt tap and a pipe tap is shown in Figs. 38 and 39, page 710.

Note how much larger a ⅜″ pipe tap is than a ⅜ bolt tap. This is due to the fact that a ⅜″ pipe is measured on the inside and twice the thickness of the metal (of which the pipe is made) must be added to the ⅜″ to get the diameter required. In the bolt tap the measurement is taken on the outside, consequently the tap is of practically the same diameter as the bolt. See also, Fig. 24, page 700, for pipe dies and outside and inside dimensions of pipes.

Explanation of the Meaning of Threads

Note the original size of stock on which the thread was cut in Fig. 24. Then note the meaning of "angle," "pitch," and "V-thread." The "root diameter" is measured from the base of threads and the **"basic diameter"** is measured from the top of flats (used in this illustration merely to explain its meaning).

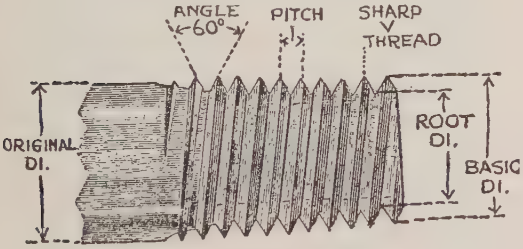


Fig. 24

Root Diameter Determines Drill Size

Root diameter means the diameter of the bolt measured from the **bottom** of one thread to the bottom of the thread diametrically across from it, and is the measurement that must be taken into account when figuring the working strength of the bolt, and is the diameter that gives you the drill size.

In practice the drill size is a little larger, so that after a thread is cut, it will be found that it is not really a full thread, but is full enough for all practical purposes if the drill is not unnecessarily large.

The sharp V-thread (Fig. 25) with its razor-like edge, is a thread the manufacturers do not favor. The flat thread (Fig. 27) is the one favored.

The length of a thread on a capscrew is more than on a bolt.

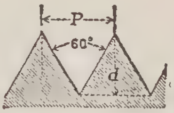


Fig. 25

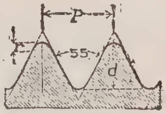


Fig. 26

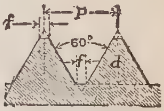


Fig. 27

Fig. 25. The sharp V-thread (U. S. S.).

Fig. 26. Whitworth's standard (oval). Note that the thread does not come to a point at either top or bottom.

Fig. 27. The U. S. S. (United States Standard) and S. A. E. thread. Note the flat at top of thread. This is also called the A. S. M. E. thread.

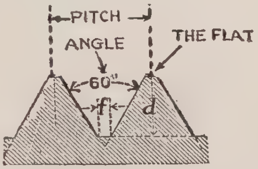


Fig. 28

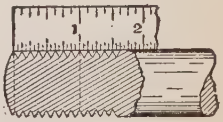


Fig. 29

Fig. 28. Explains the meaning of "pitch," "angle," and "flat." The "pitch" is the distance from one thread to another. The "angle" is the degree of slope, and is usually 60°, except Whitworth, which is 55°. The "flat" is the top of the thread coming to a flat instead of to a point.

Brigg's standard thread which is only for pipe, is oval like the Whitworth.

Fig. 29. The number of threads to an inch can be measured as here shown, or with a screw-pitch gauge as in Fig. 16, page 704. The pitch is the number of threads per inch. A screw-pitch gauge is a quicker and more accurate method for finding the number of threads per inch.

U. S. S. and S. A. E. Threads Used Most

The threads most commonly used in this country are the United States Standard and the S. A. E., formerly A. L. A. M. This latter is the standard adopted by the Society of Automotive Engineers for automobile work.

The diameter and angle of the S. A. E. thread is the same as the U. S. Standard, the only difference being that the S. A. E. thread is of finer pitch (see Fig. 22, page 706), or more threads to the inch.

Take, for instance, a U. S. Standard ¼″ screw. It has 20 threads per inch, while a ¼″ S. A. E. screw has 28 threads per inch (see Tables 4 and 5, page 709).

This **finer thread** has been found by experience and tests to have several **advantages over the coarse** U. S. S. **thread** in auto construction, one of which is in meeting the incessant vibration to which a fast-moving automobile is subjected. A nut with fine threads takes more revolutions or turns to remove it than one with coarse threads, and the chances are that were the threads coarse, the nut would be far more likely to be lost, whereas the fine-thread nut with the same number of turns would be only loose. There are various other reasons, of as much or more importance, which led the manufacturers to adopt this finer thread.

The fine thread is nearly always used where hardened material is employed (such as case hardened), and the coarser thread where soft material is used, such as aluminum, brass, bronze, etc.

Other thread standards used somewhat in this country (although they are made principally for foreign business) are the Whitworth Standard (Fig. 26) and the metric or French standard (not illustrated).

Pipe Threads

The Briggs Standard (Table 6) **is for pipe work** only, and has no connection with capscrews or bolts.

Pitch of thread: By this is meant the number of threads per inch, or the distance from the top of one thread to the top of the next. This pitch is always the same for the same size bolt, nut, tap, or die of the same standard.

To Find the Pitch or Threads per Inch

To find the pitch of a screw when a thread gauge is not convenient, place a scale on the screw (Fig. 29), so that the end of the scale is opposite the top point of any thread; count the number of spaces under the scale between the threads, for a distance of one inch, viz.: there are eight spaces underneath the scale in one inch, therefore the screw is ⅛″ pitch or eight threads per inch.

Another method is to place the scale as shown in Fig. 29, and count the top of the threads for a distance of one inch, omitting one thread. The reason for omitting one thread may be seen by following the two dotted lines drawn from the top point of the first and ninth threads; count the number of complete threads between the dotted lines at the bottom of the screw, and you will find it to be eight.

Pitch angle: By this is meant the angle or degree of slope that the sides of the individual threads have, and is always 60° in the various standards, with the exception of the Whitworth which has 55°. This angle is clearly shown in Fig. 26.

Flats: See Fig. 27; note that U. S. S. and S. A. E. use this thread, but while the angle and flat are the same, the S. A. E. is of finer pitch, or more threads per inch.

In Tables 4 and 5, page 709, a tabulation is given **of sizes and threads per inch,** from ¼″ to 1″ for U. S. and the S. A. E. standards, and **also the drill size** to use for drilling a hole preparatory to tapping or cutting the threads.

Size of Tap and Drill to Use for U. S. S. Threads Expressed in Decimals

The sizes of tap and drill to use for U. S. S. (United States Standard) **or A. S. M. E.** (American Society of Mechanical Engineers) screw thread, are given in Table 3 this page.

The first and sixth columns give the size of tap designated in numbers; the second and seventh columns, the outside diameter of tap; the third and eighth columns, the number of threads per inch; the fourth and ninth columns, the size of drill expressed in decimal parts of an inch; the fifth and tenth columns, the number, or size, of drill which is necessary to drill the hole for the tap. Those sizes marked (+) are most commonly used.

Example: Suppose that on the tap the numbers 14–20 appeared. This would mean that the tap number was 14, and 20 is the number of threads per inch. Therefore by referring to the sixth and tenth columns, the size of tap to use would be No. 14 and the size of drill to use for this tap would be No. 10 drill which is .1932″ in diameter. See page 712, explaining drill numbers and page 711, explaining tap numbers.

Note. A ¼″ S. A. E. tap is larger in diameter than a U.S.S. ¼″ tap, due to the difference in the root diameter of the bolt or screw. See page 707, explaining root and basic diameter.

How drills are designated: Refer to Table 7 page 712, which explains how certain sizes of drills are lettered instead of numbered, etc.

Table 3

Size of Tap	Outside Diam	Threads per Inch	Nearest Commercial Size Drill producing 75% depth of thread		Size of Tap	Outside Diam	Threads per Inch	Nearest Commercial Size Drill producing 75% depth of thread	
			Inch Decimals	Commercial Designation				Inch Decimals	Commercial Designation
0	.060	80	0478	3/64	9	177	24	1364	29
1	.073	72	0595	53	+10	.190	32	.1610	21
1	.073	64	0577	54	10	190	30	1575	21
2	.086	64	0707	50	+10	190	24	.1496	25
+2	.086	56	0686	53	12	216	28	.1812	14
3	.099	56	.0816	45	+12	.216	24	.1754	16
+3	.099	48	.0786	47	14	.242	24	.2014	7
4	.112	48	.0916	42	+14	.242	20	1932	10
4	.112	40	.0876	43	16	268	22	.2237	I
+4	.122	36	0849	44	16	.268	20	2192	7/32″
5	.125	44	.1028	37	18	.294	20	.2452	D
5	125	40	1006	38	18	.294	18	.2398	C
5	125	36	.0979	40	20	.320	20	.2712	I
6	.138	40	.1136	33	+20	.320	18	.2658	H
6	.138	36	1109	34	22	.346	18	.2918	M
+6	.138	32	.1075	36	22	.346	16	.2851	K
7	.151	36	.1239	⅛″	24	.372	18	.3178	O
7	.151	32	.1205	31	+24	.372	16	.3111	5/16″
7	.151	30	.1185	31	26	.398	16	.3331	R
8	.164	36	.1369	28	26	.398	14	.3284	21/64″
+8	.164	32	.1335	29	28	.424	16	.3631	U
8	164	30	.1315	30	28	.424	14	.3544	T
9	.177	32	1465	26	30	.450	16	.3891	25/64″
9	.177	30	.1445	27	30	.450	14	.3804	V

Note. A common nut, drilled out so that it contains only 50 per cent of a full-depth thread will break the bolt before it will strip.

A 75 per cent depth of thread yields an ample margin of safety (2 to 1), and is economical in tapping.

A full depth of thread in a common nut is only about 5 per cent stronger than a 75 per cent depth of thread; yet it requires three times the power to tap.

Size of Tap and Drill to Use for U. S. S. Threads Expressed in Fractions of an Inch

Tap and drill sizes for U. S. S. threads: Table 4 gives the diameter of the tap, the threads per inch, and the size drill to use (expressed in common fractions) for the tap. The diameter of the tap expresses the screw size. For instance, a ¼″ tap is for a ¼″ screw with 20 threads; therefore the size of drill to use would be 3/16″, etc.

To find what size and number tap to use for a ¼″ U. S. S. bolt with 20 threads to the inch: First find the decimal equivalent of ¼ inch (see page 702); ¼ inch is equal to 2/8 inch, so by looking in the column under heading of "8ths" Table 1 (page 702), you will find that ¼ (or 2/8) is equal to 250 one-thousandths, or decimal point 250. Referring back to Table 3, this page, find the nearest decimal. This will be found in column No. 7, and can be either .242 or .268; so you could use either a No. 14 or a No. 16 tap.

To find what would be the number of the drill for a ¼″ U. S. S. tap, 20 threads to the inch: Proceed as in the previous instance. First find the decimal equivalent of ¼ inch. This you have found to be

U.S.S. Threads

Diam. Tap in Ins.	Thds. per inch	Size of Drill Ins.	Diam. Tap in Ins.	Thds. per inch	Size of Drill Ins.	Diam. Tap in Ins.	Thds. per Inch	Size of Drill Ins.
¼	20	3/16 in.	9/16	12	29/64	1¼	7	1 5/64
5/16	18	¼ in.	⅝	11	33/64	1⅜	6	1 11/64
⅜	16	5/16 in.	11/16	11	37/64	1½	6	1 19/64
7/16	14	⅜ in.	¾	10	⅝			
½	13	11/32 in.	13/16	10	11/16			
½	12	13/32 in.	⅞	9	47/64			
			15/16	9	51/64			
			1	8	27/32			
			1⅛	7	61/64			

Table 4

250 one-thousandths. The nearest decimal to this is in column No. 7, Table 3 (page 708), and can be, as before, either .242 or .268; and the proper drill corresponding thereto is found in column No. 10 and can be either a No. 10 drill or a 7/32 inch drill. You will notice by referring to Table 4 that a 3/16-inch drill will also answer.

Note. The only difference in using one or the other of the various drills would be in the fullness of the thread. The larger the drill, the less depth of thread. You can readily see that by using a drill **too large**, you would cut away the metal that should go to make the thread, and, on the other hand, if you use a drill **too small**, you would not be able to enter the tap. See note at bottom of Table 3.

Tap and Drill Size for S. A. E. Threads

Tap and drill size for S. A. E.: Table 5 gives practically the same information as Table 4—but for S. A. E. capscrews. The first column gives the size of tap to use; the second column, the number of threads to the inch (pitch); the third column, the size of drill to use.

To find what number of **tap** would be required, or the number **of drill**, the procedure would be the same as in the case of Table 4. The diameter of drill and tap would be the same as for the U. S. S., but the number of threads per inch would be greater, as would also be the root diameter. A comparison of the two drills for the 5/16″ taps, for instance, will make this clear.

Stove Bolt Threads

Diameter	Threads per Inch
3/16″	24
¼″	18
5/16″	18
⅜″	16

Tap and Drill Size for Pipe Threads

Tap and drill size for pipe threads: Table 6 gives the size of drill to use for a certain size of pipe tap. The Briggs standard is the one used in this country.

Note that the threads on a ¼″ pipe tap are 18 to the inch, whereas on the S. A. E. (Table 5) there are 28 threads to the inch, and on the U. S. S. (Table 4) there are 20 threads per inch. See also, page 700 for "Pipe specifications."

The diameter of a pipe tap is larger than a stated size of any other tap (see page 710).

S. A. E. Threads

Diam. in.	Pitch	Tap Drill
¼	28	No. 4
5/16	24	17/64 in.
⅜	24	21/64
7/16	20	⅜
½	20	7/16 in.
9/16	18	½
⅝	18	9/16
11/16	16	39/64
¾	16	43/64
⅞	14,18	51/64, 13/16
1	14	59/64

Table 5

Pipe Threads

Size Tap Inches	BRIGGS STANDARD	
	Thread	Drill
⅓	27	21/64
¼	18	27/64
⅜	18	9/16
½	14	11/16
⅝		
¾	14	29/32
⅞		
1	11½	1⅛

Table 6

The size of a No. 4 drill, as shown in the third column of S. A. E. threads above (Table 5) can be found by referring to Table 8 (page 712). It is .207. The nearest decimal to this on page 702 is .203, or 13/64″.

Note that the ⅞″ S.A.E. thread with 18 threads per inch is for the S.A.E. spark plug.

DIES AND TAPS

Tap and die sets are shown on page 699, under Figs. 22, 23, and 24. An explanation as to how to select and use dies and taps is given below.

Dies

The subject of dies is really a part of the tap subject, inasmuch as where the one is used, the other must be used also. The tap cuts a thread on the **inside** and the die cuts the companion thread on the outside. Thus you would **"tap a hole"** or nut, and **"run a die over"** a bolt or pipe.

Dies, as in the case of taps, are divided into two classes: **pipe dies** and **bolt dies.**

The better grade of dies are adjustable as to size, that is, you can make them cut a little larger or a little smaller than "standard." This will be found to be of special value in repair work.

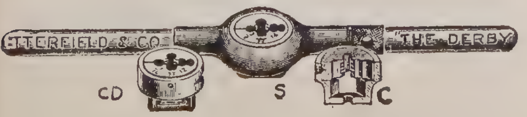


Fig. 30. **Cutting male threads** is accomplished with a die and stock, or on a lathe. When a die and stock is used, it is placed in a collet (C), and the collet and die (CD) are then placed in a stock (S). This is worked over the part to be threaded. The illustration shows a die and stock for cutting threads on machine screws.

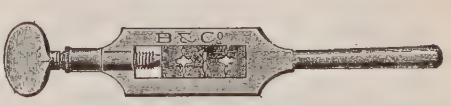


Fig. 31. **A screw plate or gunsmith's die.** It cuts threads in the same manner as the one shown in Fig. 30, but there is no collet. Bicycle dies are often made in this form.

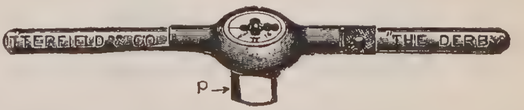


Fig. 32. **A stock and die for cutting threads on pipe.** The pipe is held stationary and the tool revolved. Note projection (P) at bottom, to hold the die to the pipe.

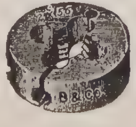


Fig. 33

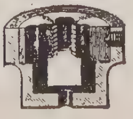


Fig. 34

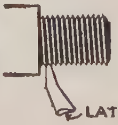


Fig. 35

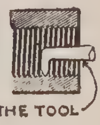


Fig. 36

Fig. 33. Die without collet. Fig. 34. Sectional view collet and die. Fig. 35. Threads may also be cut on a lathe. Note the lathe tool cutting an outside, or **male thread.** Fig. 36. Note the lathe tool cutting an inside or **female thread.** The tool is held stationary—just the reverse of hand-cutting.

The solid die is non-adjustable, and, when worn, will not cut deep enough. As a consequence, the nut or fitting is nearly ruined by forcing it on. It sometimes happens that a cutting lip is broken off; this necessitates the purchase of an entire new die, whereas in the adjustable die one can renew—just the broken lip—at slight expense.

How marked: Dies are marked as to **size, number of threads per inch,** and whether **right or left hand** thread, designated by the letter R or L. In a great many instances it is both necessary and convenient to cut a left-hand thread, and it is advisable to have a few of the most used sizes on hand. (A brake rod, for instance, where it screws into the turnbuckle, has a left-hand thread.)

Dies and their corresponding taps are so made relative to the diameters at the top and bottom of thread, that when the nut is screwed on the bolt, the extreme tops do not touch one another. In other words, there is a small space allowed, called the **"clearance"** (about .002″). The real bearing surfaces are the angular sides of the thread. This clearance space is accountable for the rust that is found in the threads of old bolts and nuts, and it is in this space that the kerosene soaks, when applied to loosen up a rusty nut.

See page 699 for illustration of a set of dies of various sizes and also the stocks in which they are used, as well as tap wrenches.

The stock is the holder for the die while cutting, and usually has removable handles.

"Screw plate set" is a term used to express the entire outfit, as shown on page 699. Although we have shown Fig. 30 as a die and Fig. 31 as a screw plate, the term is used as stated above.

Screw Taps

Taps may be divided into two distinct groups: bolt and pipe taps.

Machinists' hand taps are used for cutting internal threads in metal, and are usually bought in sets of three, viz., taper, following, and bottoming, as shown in Fig. 37.

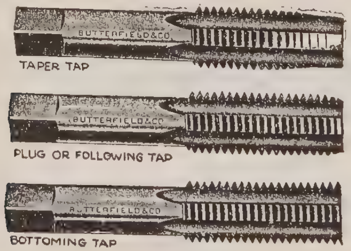


Fig. 37

Pipe taps are used for cutting threads in pipe fittings and cutting threads for the insertion of pipes, pet cocks, drain plugs, etc. (see Fig. 39, also Table 6, Briggs standard, page 709).

The taper tap (Fig. 37), so called owing to its sides being tapered, is the one first used after the hole is drilled. This is in reality a roughing tool, and does not give a full thread unless run all the way through. It is used for open work, such as the truing up of the threads in a nut, and also for tapping various parts of the chassis.

The "following" tap (Fig. 37) is next used, and, in the majority of cases, is all that will be required to finish the tapping process. Where tapping is done in solid metal, this is the one generally used. If threads are desired clear to the bottom of the solid work, then the "bottoming" tap is used.

The "bottoming" tap (Fig. 37): In many instances, the thickness of the metal is such that a tap cannot be run in far enough to cut a complete thread all the way to the bottom of the hole. It is therefore necessary to use the bottoming tap. There is no taper to this tool, consequently it cuts full size from start to finish, and the thread must be started with one of the other taps first.

Flutes: This term applies to the grooves cut in the sides of taps for the reception of iron cuttings or chips and any foreign matter that might be present while cutting. It is the almost universal practice to make taps with four flutes, as shown in the end view of Fig. 45 (page 711). This makes it convenient to caliper the diameter, which otherwise could not be so easily done if there were five or any other odd number of flutes.

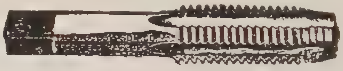


Fig. 38. A ⅜″ machinist's tap.

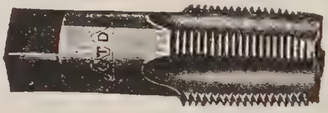


Fig. 39. A ⅜″ pipe tap.

Figs. 38 and 39 are intended to show the comparative difference in size between a ⅜″ machinist's hand tap and a ⅜″ pipe tap, as explained in the text.

U. S. S. and S. A. E. Taps

Sizes of tap: After the proper size of hole is drilled, it will then be in order to get the proper size and standard of tap necessary to cut the thread.

Suppose, for example, you wished to tap a hole to fit a ⅜″ S. A. E. screw. If you drilled the hole of such a size as called for in Table 5, page 709, you would have used a 21/64″ drill. Therefore you would call for a ⅜″ S. A. E. tap.

If the bolt or stud was the U. S. Standard ⅜″ size, use a 5/16″ drill, as in Table 4. Note that the S. A. E. tap is 1/64″ larger than the U. S. S. (page 709) and use a ⅜″ Standard tap.

If, on the other hand, you are working on a ⅜″ pipe job instead of a bolt job, you would have used a 9/16″ drill (see Table 6, page 709). Therefore use a ⅜″ pipe tap. Notice that the drill used for a ⅜″ pipe tap is nearly twice as large as that used for a standard bolt of the same size (see Figs. 38 and 39, above, for relative size).

How Taps are Marked

You will find on all taps at least two marks: They refer to the diameter and to the threads per inch. Thus, a tap marked ¼-20 or ¼-28 will denote that the tap is for ¼″ size nut or hole, and has 20 or 28 threads per inch. The ¼-20 is a U. S. S. tap, and the ¼-28 is an S. A. E. tap.

A great many taps are marked with a number instead of a fraction, thus: 14-20, means that the number of the tap is 14 and the threads are 20 to the inch.

In Table 3 (page 708) is shown a complete list of tap numbers from 0 to 30. Those marked with a + mark are the sizes most used for ordinary work. The table also gives the proper size of drill to use with the various taps. The dimensions are given in thousandths of an inch. By referring to Table 1 of "Decimal Equivalents" (page 702), you can get the proper size in fractions of an inch.

Tap Sizes

Sizes of numbered taps: Taps from No. 1 to No. 30 run from 1/16″ to 7/16″ outside diameter, varying approximately by thirty-seconds.

Numbers above 30 are marked according to the size and thread; for instance, a ½″ tap (U. S. S.) would be marked ½-13, meaning ½″ size and 13 threads to the inch. When taps are marked in this manner, they run from ½″ to 1″, varying in 1/16″ sizes, or fractional parts of an inch.

Size of taps most used: A set for small work would be from No. 1 to No. 30 (page 708, Table 3), which runs from 1/16″ to 7/16″ with variations by sixteenths, then from ½″ to 1″, varying in eighths of an inch. Taps are seldom used over 1″ for general auto work.

Special Taps for Spark Plugs

For regular ½″ size (Fig. 13, page 235), with 14 threads per inch, use the regular standard ½″ pipe tap and a drill 11/16″ (see Table 6, page 709).

For S. A. E. ⅞″ size, with 18 threads per inch, use the S. A. E. ⅞″ "special spark-plug tap." Note, by referring to Table 5, page 709, that the standard ⅞″ S. A. E. screw tap has 14 threads, and the S. A. E. spark plug has 18 threads. It is for this reason that a special tap is required. A 13/16″ drill is the proper size to use.

The metric 18 m.m. size uses the metric 18 m.m. spark-plug tap (French standard).

See page 235 for S. A. E. spark-plug dimensions, and page 236 for spark-plug gaskets.

How to Use Taps[1]

Before using a tap, the hole must be drilled to the proper size. Never use a monkey wrench or an S-wrench unless in a tight corner, as there is a liability of breaking the tap.

Get the work perfectly level and rigid before starting the tapping, and start the tap true.

When the tap is caught, sight or use a square (Fig. 40) to see if it is true; if not, turn the tap backward, and then forward, pressing in the direction required to straighten on the forward stroke only.

Start the taping with a No. 1 tap, or "taper tap," followed by the No. 2 or "following" tap, and if threads are desired a little large, or particularly clean, and to the bottom of a hole, then use the "bottoming," or No. 3 tap. (See page 710 for the meaning of "taper," "following," and "bottoming" taps.) Fig. 41 above also shows the three taps.

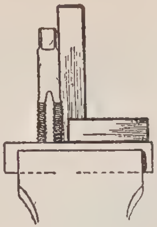


Fig. 40

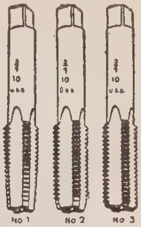


Fig. 41

Lard oil should always be used on taps, or dies, never a mineral oil.

Brass or cast iron requires little oil; **steel,** a continued application, and the tap should not be forced during the cutting. If the tap sticks, backing off and starting over will usually permit the tapping to be done with little exertion.

Several methods are employed to make a tap cut oversize. One is to pack the groove with cotton waste; another, to place a thin strip of copper or brass over one cutting lip, and another, to place the tap in boiling water, and cut the thread while the tap is still hot. Of the three, the first is perhaps the best method.

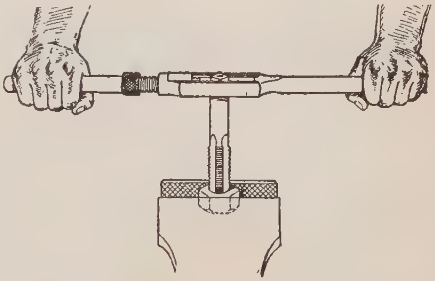


Fig. 42. The tap should be started square, and with even pressure on each arm of the "tap wrench."

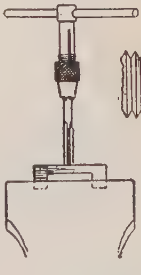


Fig. 43

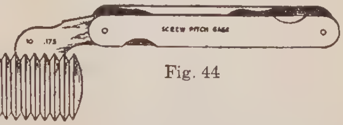


Fig. 44

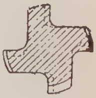


Fig. 45

Fig. 43. A large tap and reamer wrench (Fig. 42) should never be used for small taps. Use the small "hand-tap-wrench" illustrated in Fig. 43.

Fig. 44. Illustrates a screw-pitch gauge, similar to that shown in Fig. 16, page 704.

Fig. 45. End view of a regular type (4-flute) tap. See page 710 for meaning of "flute."

DRILLS

Twist drills are the kind always used for boring in metals. They are generally made with two flutes or spiral grooves, for the reception of the cuttings or chips of the metal being drilled.

Flute drills are those having flutes or grooves arranged longitudinally along their length. They are mostly used for soft metal, and are the kind which usually come with hand drills in small sizes.

Shanks: The part that goes into the chuck is called the shank. The shanks most generally used for a power-drill press are either straight or taper.

Straight shank drills are used in lathes or in drill chucks. For instance, where a straight shank drill is desired to be used in a power drill press which takes a taper shank only, then a taper arbor (B), Fig. 46, can be fitted in the end of **drill chuck**[1] (C), and the tapered end of the taper arbor (A) can be inserted in the drill press. This method is usually employed where the drills are ½″ or less.

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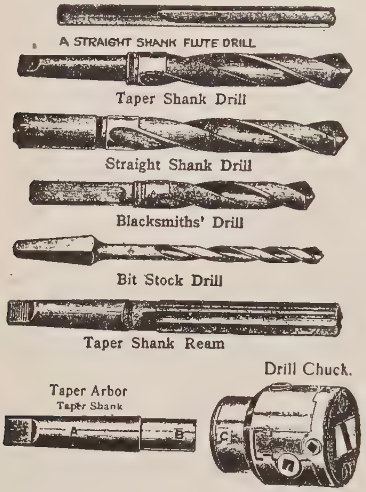
[1] From *Motor World.*

Taper shank drills fit into the drill press without the use of drill chucks.



A STRAIGHT SHANK FLUTE DRILL

Taper Shank Drill

Straight Shank Drill

Blacksmiths' Drill

Bit Stock Drill

Taper Shank Ream

Drill Chuck.

Taper Arbor

Fig. 46

Taper Shanks on Drills

Taper shanks on drills vary. For this reason, drill presses are usually fitted with four sizes of taper shanks as follows:

For drills 1/16″ to 9/16″ with No. 1 taper shank
For drills 37/64″ to 29/32″ with No. 2 taper shank
For drills 59/64″ to 1¼″ with No. 3 taper shank
For drills 1 17/64″ to 2″ with No· 4 taper shank

How Drills Are Designated in Sizes[2]

You will observe in Tables 7 and 8 that in the sizes from 1½″ to No. 80 (0.013″ or 13/1,000 of an inch) the drills are numbered and lettered. The No. 80 is the smallest size. In other words, the larger the number, the smaller the drill (see also "Drill Gauge," on page 705).

Drills from No. 80 to No. 1 (1/64″ to 7/32″) do not bear size numbers or letters on them, but are measured on drill gauges (see page 705).

Drills from No. A to Z (15/64″ to 13/32″) have their size designated by letters stamped on their shank.

Drills from Z to 1½″ have the actual size stamped on them (as 27/64″ to 1½″).

Comparison of Tables 7 and 8 with Table 3: The exact size of a No. 30 drill, for instance, as given in Table 8, is 127 one-thousandths of an inch. In Table 3 (4th column) it is given as 131 one-thousandths. This difference is only slight, and does not affect the strength of the thread. This difference is due to using a table of actual drill size (Table 3), and a table of drill rods (Tables 7 and 8).

Table 7

Size drill	D. E.	Size drill	D. E.	Size drill	D. E.
1½	1.500	15/32	0.4687	O	0.316
1¼	1.250	29/64	0.4531	5/16	0.3125
1	1.000	7/16	0.4375	N	0.302
31/32	0.969	27/64	0.4218	19/64	0.2968
15/16	0.937	Z	0.413	M	0.2950
29/32	0.906	13/32	0.4062	L	0.290
⅞	0.875	Y	0.404	9/32	0.2812
27/32	0.844	X	0.397	K	0.281
13/16	0.812	25/64	0.3906	J	0.277
25/32	0.781	W	0.386	I	0.272
¾	0.750	V	0.377	H	0.266
23/32	0.719	⅜	0.375	17/64	0.2656
11/16	0.687	U	0.368	G	0.261
21/32	0.656	23-24	0.3593	F	0.257
⅝	0.625	T	0.358	E	0.250
19/32	0.594	S	0.348	¼	0.250
9/16	0.562	11/32	0.3437	D	0.246
17/32	0.531	R	0.339	C	0.242
½	0.500.	Q	0.332	B	0.238
31/64	0.4843	21/64	0.3281	15/64	0.2343
		P	0.323	A	0.234

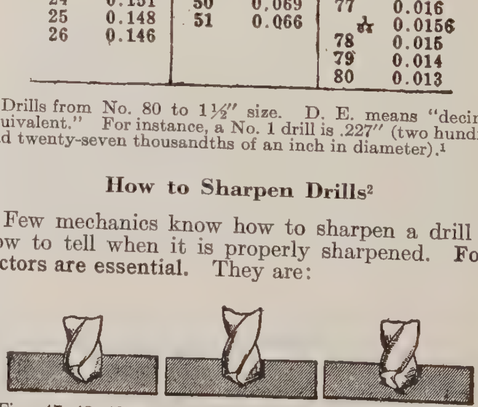
Table 8

Size drill	D. E.	Size drill	D. E.	Size drill	D. E.
1	0.227	27	0.143	52	0.063
2	0.219	9/64	0.1406	1/16	0.0625
7/32	0.2187	28	0.139	53	0.058
3	0.212	29	0.134	54	0.055
4	0.207	30	0.127	55	0.050
5	0.204	⅛	0.125	3/64	0.0468
13/64	0.2031	31	0.120	56	0.045
6	0.201	32	0.115	57	0.042
7	0.199	33	0.112	58	0.041
8	0.197	34	0.110	59	0.040
9	0.194	7/64	0.1093	60	0.039
10	0.191	35	0.108	61	0.038
11	0.188	36	0.106	62	0.037
3/16	0.1875	37	0.103	63	0.036
12	0.185	38	0.101	64	0.035
13	0.182	39	0.099	65	0.033
14	0.180	40	0.097	66	0.032
15	0.178	41	0.095	1/32	0.0312
16	0.175	3/32	0.0937	67	0.031
17	0.172	42	0.092	68	0.030
11/64	0.1718	43	0.088	69	0.029
18	0.168	44	0.085	70	0.027
19	0.164	45	0.081	71	0.026
20	0.161	46	0.079	72	0.024
21	0.157	5/64	0.0781	73	0.023
5/32	0.1562	47	0.077	74	0.022
22	0.155	48	0.075	75	0.020
23	0.153	49	0.072	76	0.018
24	0.151	50	0.069	77	0.016
25	0.148	51	0.066	1/64	0.0156
26	0.146			78	0.015
				79	0.014
				80	0.013

Drills from No. 80 to 1½″ size. D. E. means "decimal equivalent." For instance, a No. 1 drill is .227″ (two hundred and twenty-seven thousandths of an inch in diameter).[1]

How to Sharpen Drills[2]

Few mechanics know how to sharpen a drill or how to tell when it is properly sharpened. Four factors are essential. They are:



Figs. 47, 48, 49. Results of improperly ground drills: Fig. 47 has an unequal lip angle; Fig. 48 shows an unequal lip length; in Fig. 49, both lip angle and length are unequal.

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[1] See page 693 for a drill and lathe chuck.

[2] See page 709 for the size of drills to use for U. S. S. and S. A. E. taps.

[1] From Shield's "Mechanic's Guide Hand Book."

[2] From *Motor World*. Figs. 47, 48, and 49 are from *Electrical Experimenter*.

1. Both cutting lips should have the same angle to the axis; otherwise the cutting will all be done by one lip, and the drill will drill oversize (see (Fig. 47).
2. Both cutting lips should be exactly the same length; otherwise it will throw the point of the drill off-center, causing the drill to cut oversize (see Fig. 48).
3. Proper clearance back of the cutting edge is necessary. Insufficient clearance causes the drill to drag, cut hard, and get dull quickly.
4. The angle of the lips should be about 60° each, as shown in Fig. 51.

To Sharpen

5. Hold the drill lightly against the wheel, as shown in Fig. 54, with the cutting lip on the wheel.

   Wheels for drill grinding should be fairly soft and open so that they will not clog or burn. The drill should be pressed lightly against the the wheel and carefully watched to see that it is not burned and the temper drawn. Watch the surface from which the grinding wheel leaves, as the heat is concentrated there (see Index for "Tempering drills and small tools").

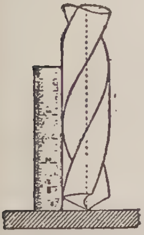


Fig. 50

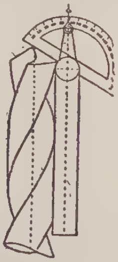


Fig. 51

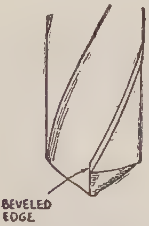


Fig. 52

Fig. 50. Method of measuring cutting-lip length.

Fig. 51. Measuring the angle.

Fig. 52. Method of beveling cutting lip to cut thin or hard material.

6. Twist the drill and at the same time throw the right hand down in order to grind the proper clearance.

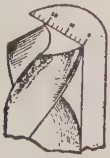


Fig. 53

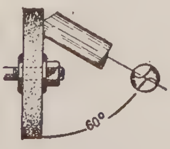


Fig. 54

7. Check the length of the cutting lip, as shown in Fig. 50.
8. Check the angles of the cutting lips, as shown in Figs. 51 and 53, when sharpening it. The best cutting angle is 60°.

Drilling

9. Brass or thin sheet metal may be more readily drilled if the cutting lips are beveled, as shown in Fig. 52. This prevents the drill from digging in and catching.
10. Always clamp or hold the work being drilled to prevent the drill catching and breaking, and place a block of wood under the work.
11. In starting to drill use moderate speed, gradually increasing until the best cutting speed is obtained.
12. When drilling small holes, speed the drill up and go carefully when the drill is breaking through the work. This is the point where the drill usually catches and breaks.
13. When drilling large holes, say 3/8" to 3/4" in diameter, it is better to drill a small hole first.
14. It is advisable to always make a center punch mark in metal to be drilled.
15. Case-hardened steel must first be softened until an even red heat is reached, and re-hardened again.
16. The following are the cutting compounds for the various metals:

    Hard steel—turpentine, kerosene; **soft steel**—lard oil, machine oil; **brass**—soda water, if anything; **aluminum**—kerosene; **cast iron**—none. An air blast is a very good cooling medium for cast-iron drilling.
17. If the drill chips out at the cutting edge there is too much feed, or the drill has been ground with too much clearance. A split up the web is caused by the same improper grinding.

Laying Out Work for Drilling

The easiest way to lay off work for drilling, etc., on iron or steel is to cover it with a coating of chalk, which permits the lines to be scribed on the surface with a steel-pointed instrument so as to be readily seen.

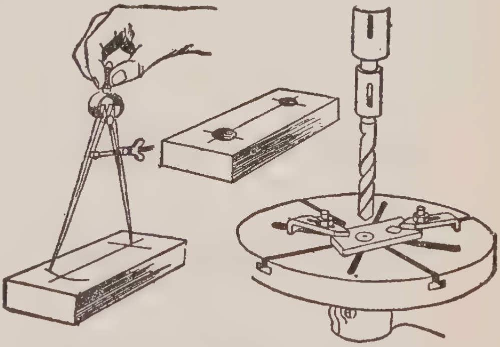


Fig. 55 Fig. 56 Fig. 57

Fig. 55. Accurately mark off the center distances with a pair of steel dividers, after first lightly prickpunching one center.

Fig. 56. Shows the part to be drilled after having scribed it and prick-punched the centers.

Fig. 57. The piece must be clamped to the drill table by steel clamps; otherwise the drill will wander, destroying the accuracy of the hole.

All lines showing the size, location of holes, etc., are scribed out on the metal, previously chalked over, as mentioned, or, if on wood, simply by a hard pencil, and all centers of holes to be drilled should then be center punched by a hard-steel punch.

The finished piece, with the center lines scribed, is shown in Fig. 56.

When drilling a piece of thick metal, if the drill has a tendency to bore crooked or off the center, it can be re-centered again by cutting a groove with a diamond-point chisel on the side towards which you wish to draw drill, as shown in Fig. 58, next page.

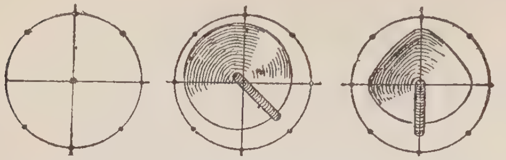


Fig. 58. Left—The piece prepared and ready for drilling; the prick punch marks should be made carefully and lightly. Center—The groove should be made the depth to which it is desired to draw the drill, and on the side that the drill is to be drawn. Right—A triangular hole may be corrected in the manner illustrated.

A diamond-point chisel, shown in Fig. 58A, should be used in "drawing" the drill.

One method for finding the size drill to use for tapping is to select one that will be a sliding fit in the die which goes with the tap. If the drill is to large to go into the die (a nut will do just as well the threads will not be full, and if it is smaller tha the die or nut, the tap will turn so hard that it wi probably break (see Fig. 58B).

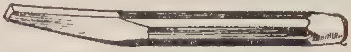


Fig. 58A. A diamond-point chisel.

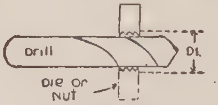


Fig. 58B

REAMERS

Reamers are used a great deal in automobile work, as they enable one **to enlarge a hole** to any desired size without having to resort to any particular size of drill. Simply drill a small hole and ream it out to size.

Reamers are also used for reaming crank-shaft bearings, connecting-rod bushings, piston-pin bushings, etc.

Each flute has a cutting edge which actually cuts the metal with a shearing action.

Reamers are of two general types: straight flute (Fig. 60) and spiral flute (Fig. 59). The object in cutting the **flutes spiral** on a reamer is to prevent chattering, which is very likely to happen if the work is carelessly done. **Straight-flute** reamers always have an odd number of flutes, so that no two flutes can ever be exactly opposite each other, and this also helps to stop chattering.

Fig. 59. Spiral flute reamer.

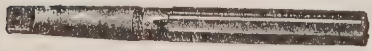


Fig. 60. Straight flute reamer.

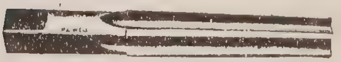


Fig. 61. Taper reamer for finishing.

Fig. 62. Taper reamer designed with a head or stock to use in an ordinary brace.

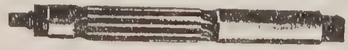


Fig. 63. An expanding type of reamer.

Reamers are made in stock sizes from 1/8" to 1 3/8" by thirty-seconds and by sixty-fourths, and also in metric sizes. Most **taper** reamers are special, although there are a few stock sizes.

Expanding reamers are ground .005" undersize, and can be brought up to .005" oversize.

Use of Reamers

Reamers are used for reaming out such parts a piston-pin bushings, steering-spindle bushings transmission-gear bushings, cam-shaft front and rea bushings, crank-shaft bearings, etc. In fact, they are indispensable to the repairman.

A reamer for piston-pin bushing is shown in Fig. 73. It is used for reaming through both the piston-pin bushings for perfect alignment of the piston pins.

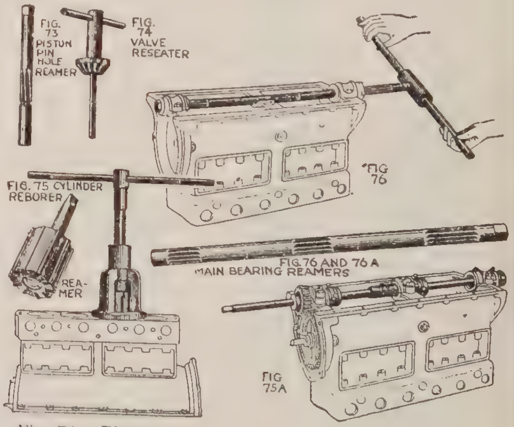


FIG. 73 PISTON PIN HOLE REAMER
FIG. 74 VALVE RESEATER
FIG 76
FIG. 75 CYLINDER REBORER
REAMER
FIG. 76 AND 76 A MAIN BEARING REAMERS
FIG 75A

Fig. 73. Piston-pin hole reamer.
Fig. 74. Valve reseater.
Fig. 75. Cylinder reamer.
Fig. 75A. Main bearing boring tool.
Fig. 76. Main bearing reamers. (*Motor World.*)

Aligning Reamer

A reamer, as shown in Figs. 76 and 76A, is designed **to ream all three main bearings simultaneously,** and saves much time in scraping and refitting bearings.

The unequal distribution of weight and of driving strain on the crank shaft of an engine naturally causes unequal wear in the main bearing. It can be seen that tightening up on the bearing caps only will spring the shaft out of line and throw additional strain on the bearings, causing them to wear loose again very rapidly. This reamer will bring all bearings to proper size and perfect alignment. An allowance of .0025" is made for wear of the crank shaft.

This reamer can also be used for **reaming the connecting-rod lower bearings,** as they are of the same diameter as the main bearings. (Can be secured of K. R. Wilson, 16 Lock St., Buffalo, N.Y., and also of automobile supply houses.

CUTTING A KEY-WAY; TYPES OF KEYS

Key-way cutting with a chisel is an art that requires skill. There are many men who can cut a key-way nearly as well as can be done by a machine; not so the amateur. The first thing to do is to mark out on the shaft the key-way required, with a line to show the center. It is best to drill a series of holes in the shaft to the depth of the bottom of the proposed key-way with a flat-bottom drill. The holes should not be in actual contact; if they were so, the drill would not bore straight. Then, with a narrow cape chisel, chip away the intervening spaces and file with a small, blunt, square file. Allow the file to work up to the ends of the key-way. The key must be of steel, fitted to the bed on the bottom of the key-way and tight at the sides. Keys of different sizes (in the rough) can be bought at tool shops. The key and key-way must be slightly tapered. The key-way will be found shallowest in the middle; this must be worked down, using the edge of a flat file.

Note. **Key-ways on automobile work are seldom cut by hand, but are milled on a milling machine,** or by a special key-way cutting machine. This explanation is given as a matter of information.

Keys

There are three kinds of keys used on shafts: the square key, the round, and the half-disk type, called the Woodruff.

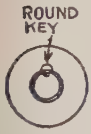


Fig. 77

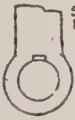


Fig. 78

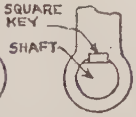


Fig. 79

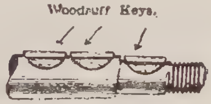


Fig. 80

The Woodruff key is used more on automobile work. It is the easiest to remove and to apply, but when fitted, the shaft must be milled on a milling machine to take this key (see Figs. 80, 81).

The round key (Fig. 77) is seldom used because it is difficult to remove. If, however, a quick job is desired, the round key is the most speedy, as a hole can be drilled and the round key hammered in (not advised except on temporary work).

The square key (Figs. 78, 79), if applied properly, can easily be removed.

Woodruff Key-Ways

The key-way for a Woodruff key must be **milled.**

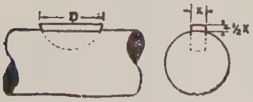


Fig. 81

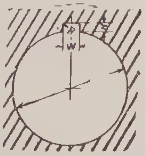


Fig. 82

A shaft that has been milled for a Woodruff key is shown in Figs. 80 and 81, with keys inserted. (X) (Fig. 81) equals the thickness of the key. The key should project above the shaft one-half its thickness.

Standard key-ways for pulleys and shafts: Table 9 shows the recognized standard for the depth and width of a key-way in pulleys. The same formula of course may be used for the depth and width of a key-way in a shaft. A list of the standard sizes of key-ways, both for pulleys and shaft, is given. The radius (**R**) refers to the round corners on the key.

Diameter (D) of Hole	Width (W) of Keyway	Depth (H) of Keyway	Radius (R)
3/8″ to 9/16″	3/32″	3/64″	
5/8 to 7/8	1/8	1/16	030
15/16 to 1 1/8	5/32	5/64	035
1 3/16 to 1 3/8	3/16	3/32	040
1 7/16 to 1 3/4	1/4	1/8	050
1 13/16 to 2	5/16	5/32	060
2 1/16 to 2 1/2	3/8	3/16	060
2 9/16 to 3	7/16	3/16	060

Table 9

A Drift

A drift (Fig. 83) is used for many purposes. In this instance it is used with square keys.

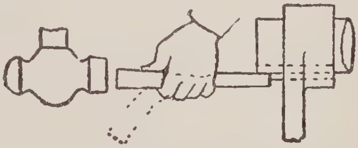


Fig. 83

If the shaft projects from the boss, a drift should be used to prevent damaging the key-way by the blows of the hammer. The drift (Fig. 83) is a steel tool with a hardened nose. They are sometimes curved (note the dotted lines), as in many cases it is impossible to get a straight blow at a key. Care should be taken not to burr up the end of the key. A piece of heavy copper held over the end of the key by an assistant will prevent this.

Tightening Nuts on Cylinder Heads

Attention is called to the method of tightening the nuts on a detachable cylinder head, as well as to the importance of locking nuts to prevent them from coming loose.

Detachable cylinder heads are now quite generally used, and it is very important that they be kept tight against leakage at the joint with the main cylinder casting. A striking loss of power in a certain engine was puzzling until a thorough inspection revealed that some of the head bolts were loose, allowing some of the compression pressure to escape.

There also are many instances of careless tightening of heads and cylinder blocks which has resulted in cracking the casting. This is due to drawing down one bolt or series of bolts too tightly before equalizing the strain by tightening others in another part of the casting. The object is to pull the casting down uniformly without any tendency to bend or distort the piece.

In the diagram (Fig. 84A) (the Dort cylinder head), the cylinder head has fifteen bolts, and the numbers on the diagram indicate the order in which they should be tightened. It will be seen that the center bolts are adjusted first; then the rest are tightened alternately.

REMOVING TIGHT NUTS AND STUDS; LOCKING NUTS, ETC.

To Remove a Tight Stud

A method of removing a tight stud is to use two nuts and lock them, keeping the wrench on the lower nut (Fig. 84).

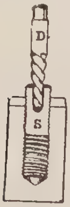


Fig. 85

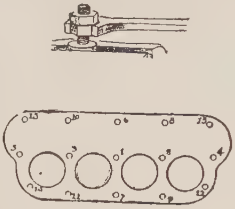


Fig. 84 (upper)
Fig. 84A (lower)

Removing a Broken Stud

A broken stud or screw (S) (Fig. 85) can best be removed by a special left-hand drill (D), called the "Ezy-out," manufactured by Cleveland Twist Drill Co., Cleveland, Ohio.

Other methods are: Pour kerosene around the stud to soak into the threads. If a piece of the broken stud stands above, the broken part may be removed with a chisel and hammer—not a sharp chisel, however. A diamond-point chisel is best. If it will not move, then drill it out, using a drill well under the size of the thread. The hole should then be cleaned out with a tap, the same size as the thread. In the case of a hardened set screw which is broken, use a blow torch and heat. **Another method:** If the broken part projects, saw a slot and use a screwdriver.

Over-Size Stud in Worn Bolt Hole

Use an over-size stud which will make a tight fit in the top of the cylinder-stud bolt holes; then either file, bore, or ream a hole out in the cylinder head so that it will take the over-size stud you are to use. For instance, if a 5/16″, use a ⅜″ tap and stud bolt. If a ⅜″, use a 7/16″ tap and stud bolt. If a ⅝″, use a ¾″ tap and stud bolt. The holes could be drilled out if you have no reamer. A straight reamer would be best.

To Remove a Tight Nut

Try heating it, if it cannot be budged with a wrench. Try pouring kerosene on the nut and bolt and let it stand for an hour or so. Drill holes in the nut and split it with a chisel if it will not come otherwise. This will save the threads of the bolt.

A Stripped Nut Will Not Grip

Usually the fine-thread nut is the one which causes this trouble. A method that may be adopted is to reline the nut uniformly with soft solder and then give it a start on the bolt, and, by working it down the thread, a little at a time, to cut a new thread inside the nut.

The soldering part of the operation is simple enough, the nut being fastened to a piece of iron wire, dipped in the killed spirits, and then held in the blow-lamp till hot enough to melt the solder. The same process reversed would apply equally well to a stripped bolt and nut used to cut a new thread on it.

Fig. 85A (next column). A simple method for inserting screws in inaccessible places.

Fig. 85B. Cut a slot in a cap-screw head with a hack saw and use a screwdriver to start capscrews in inaccessible places.

Fig. 85C. Showing the method for tightening a loose throttle-control lever. Remove the lever from the car, place it on the anvil portion of the vise, strike it a few sharp blow with a hammer, as indicated in the illustration.

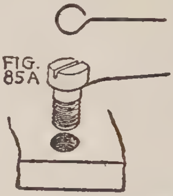


FIG. 85A

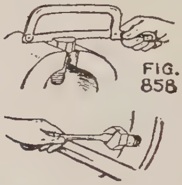


FIG. 85B

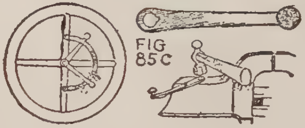
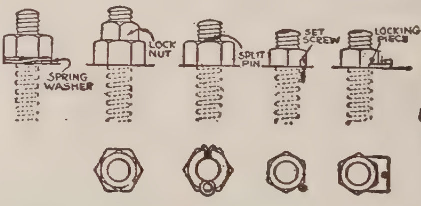


FIG 85C

Methods of Locking Nuts and Studs

To prevent nuts from coming off, various locking devices are employed. The first one shown in Fig. 86 to the left is the well-known and most used lock washer. The next one is used a great deal also, and is operated by using two nuts. By holding the top one and backing off the lower one slightly, the nuts are securely locked. The next one is also used a great deal in connection with castellated nuts. The two other methods are used extensively by the Navy Department (absolutely sure, but expensive). The lower cuts show a plan view of the various locking devices directly above.

FIG. 86



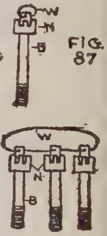
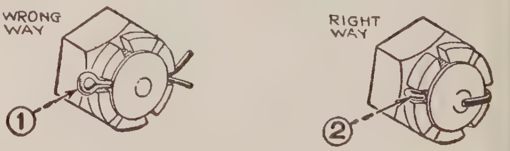


FIG. 87

A stud locking method is shown in Fig. 87. It sometimes happens that after securely locking the nut on a stud, the stud unscrews itself at the other end, and is lost. When wired as shown in the lower cut, this is prevented.



Wrong and right way to secure a cotter pin: (1) Head of cotter not in slot of nut—turned wrong. Ends not split right—turned wrong. This combination will soon work loose and come out. (2) Head of cotter in right—pounded down firm—a snug fit in hole. End of cotter pounded back over end of bolt—other end pounded down. Cotter should be tight.

FILES

Kinds: There are many different kinds of files, but we will deal principally with those used for metal work and suitable for automobile repair shops.

Shapes of the files in general use are shown in Fig. 88.

Cutting surfaces are shown in the upper row of Fig. 89. The coarsest metal cutting file is the "**bastard-cut**"; the next is the "**second-cut**"; the next, "**smooth-cut**"; then, "**dead-smooth.**" Note that the finer the cut, the closer the teeth are together. **Coarse-cutting** files are used for **soft metal** or for removing a quantity of metal, and **finer** cut files are used for **finishing** or for **harder metals.**

Method of cutting teeth on a file: The teeth can be "double-cut" or "single-cut," but this does not interest the purchaser, as the manufacturer makes some of the files "single" and some "double" cut. But whichever way they are made, the point that determines the cutting surface of a file is as given in the paragraph above.

The flat file (1) (Fig. 88) tapers, but not to a fine point. Used for filing flat surfaces. A very popular file. Can be had in any of the grades of cutting surfaces as shown in the upper row of Fig. 89. Teeth are usually a "double-cut." This file comes in lengths from 3″ to 18″.

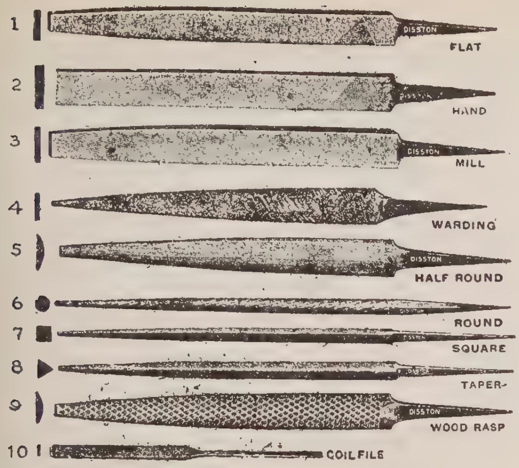


Fig. 88. Shapes of files in general use.

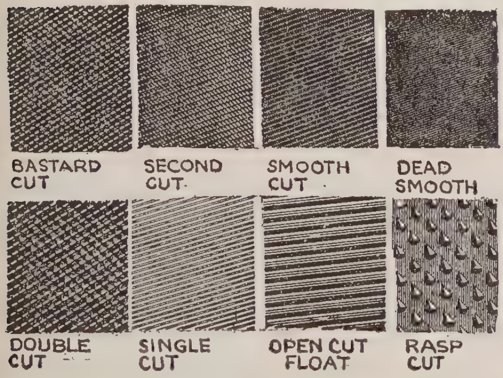


Fig. 89. The top row illustrates the different cutting grades of files that can be obtained; the closer the teeth are together, the finer the cut. The lower row illustrates different methods of cutting teeth on files.

The hand file (2) (Fig. 88) is also a flat file. Used very much for the same purposes as the "flat" file (1). Does not taper towards its end, but does taper in thickness. This file can also be had in different grades of cutting surfaces. The teeth are usually "double-cut." There is one point, however, where it differs. It has one or both edges plain (not cut at all), called "safe-edge." It would be suitable for beveling piston-ring grooves as shown in Fig. 90. Comes in lengths of 3″ to 16″.

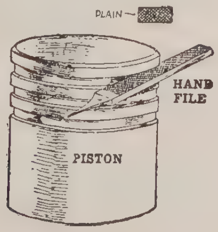


Fig. 90

Mill file (3): Is also a flat file. Used very much for the same purposes as the "flat" and "hand" file, but is of a cheaper make. Teeth are usually a "single-cut." Can be had in the different grades of cutting surfaces, but one point to remember about a "mill" file is that it is one grade finer cut than a "flat" or "hand" file. That is, if you call for a "mill" file with a "bastard-cut," it will be equal to a "hand" or "flat" file of a "second-cut." Lengths, 3″ to 18″.

Warding file (4): Is a flat file, but very thin, about half the thickness of other flat files of the same length. It tapers sharply to a point towards its end. Used for work where space is limited. Can be had in different grades of cut. Teeth are usually "double-cut." Lengths, 3″ to 10″.

Half-round file (5): Tapers. Can be had in different grades of cutting surfaces. Teeth usually "double-cut" on one side and "single-cut" on the convex or round side. Used for work curved in shape; the flat side is used for flat work. Lengths, 3″ to 18″.

Round file (6): Tapers. Used for enlarging round holes, etc. Is usually a "bastard-cut." A small round file is known as a "rat-tail" file. Lengths, 4″ to 18″.

Square file (7): Tapers. Usually a "bastard-cut." Teeth "double-cut." Used principally for enlarging apertures square in shape or rectangular. Lengths, 3″ to 18″.

A square "blunt" file is a square file which does not taper, but preserves its sectional shape from point to tang. It is used for finishing and enlarging mortises, key-ways, or splines. Usually "bastard-cut"; "double-cut." Lengths, 10″ to 20″.

Triangular files (8): Come in many different names as "three-square," "handsaw taper single-cut," "handsaw taper double-cut," "slim taper," and "extra slim taper."

The three-square file tapers and its teeth are usually "double-cut," with cutting surfaces mostly "bastard." Used for filing out square corners, filing taps, cutters, cutting steel tubing, notching round bars, etc. Lengths, 3″ to 18″.

The handsaw taper single-cut file tapers to a small point. Teeth "single-cut." Usually a "second-cut." Used for sharpening handsaws. The three-square file is not suitable for sharpening handsaws. Lengths, 3″ to 10″.

The handsaw taper double-cut file is another triangular file with teeth "double-cut," and a "second-cut" surface. Used for filing fine-tooth hand and metal workers' hack saws, which are harder than wood saws. Lengths, 3″ to 6″.

The slim taper: Teeth are "single-cut" with "second-cut" surface. It tapers and is triangular in shape but very light; in other respects like the "handsaw file." It has superseded the regular handsaw file as it has a greater sweep or stroke. Lengths, 3″ to 10″.

Extra slim taper: Lighter stock than the slim taper. Teeth usually "single-cut" with "second-cut" surface. Generally tapers, but occasionally is blunt. Lengths, 4″ to 8″.

Other triangular files are the "bandsaw file" for filing the teeth of a bandsaw; the "cantsaw file" for filing cross-cut saw teeth, and the "ginsaw file," which is a 4″, three-square, single-cut.

Wood rasp file (9): Is a very coarse-cut file. Note the "rasp-cut" in Fig. 89. Rasp files can be had with teeth shaped as shown, but in the different grades of fineness of cuts, as "coarse," "bastard," "second-cut," and "smooth." Can also be had in flat and half-round shapes. They are used for various purposes, as for wood cabinet work, wheelwright, carriage, and, to some extent, by plumbers and marbleworkers.

Coil file (10): A very fine, flat file, made especially for dressing down vibrator and screw points on ignition coils and platinum interrupter points on magnetos and timers.

Files to Use for Different Work

The larger the work, the larger the file. For flat surfaces, use the "hand," "flat," or "mill" file.

If the work is in a thin narrow space, use the warding file. If for interior work, curved or square, use the round, half-round, and square file.

For cast iron, use the "bastard-cut" to begin the work, and finish with a "second-cut." Cast iron is softer than steel.

For soft steel, use a "second-cut" to begin the work, and finish with a "smooth-cut." If a "mill" file is used, see "Mill file (3)."

For hard steel, use a "smooth-cut," finish with a "dead-smooth."

For brass or bronze, use a "bastard-cut," and finish with a "second" or "smooth-cut."

For babbitt, aluminum, lead and soft metals, use a "bastard-cut." A popular file used for soft metals is a "float" or "open-cut" file, which has wide, deep, open-cut teeth, which do not fill up as readily as those of a finer cut.

How to File

First, select the file suited for the work.

Second, the vise jaws should be about 42″ from the floor.

There are three general methods of using a file: "cross-filing," "draw-filing," and "revolving-filing."

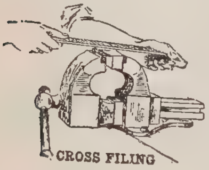


Fig. 90

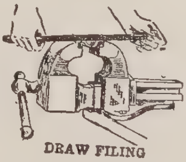


Fig. 91

Fig. 90. Cross-filing.
Fig. 91. Draw-filing.

Cross-filing: Fig. 90 represents the position of the file when used for filing flat surfaces. The file is grasped firmly but not tightly. The far end of the file may be grasped with the left hand, but not in such a way as to assist the left hand in drawing the file forward. The right hand will push it forward, and the left hand will regulate the pressure desired

If the pressure of the hand be equal through the stroke, it will be greatest on the corner nearest the workman at the commencement, and on the other corner at the end of the stroke—due to the leverage —and will tend to form a curved surface by imparting a slight rocking action to the file.

Therefore the pressure must be greatest on the left hand at the beginning of the stroke, and as the file crosses the work, must be gradually diminished on the left hand and at the same time increased on the right hand.

Notwithstanding this, it is impossible to file truly flat. If the work be examined with a straight edge, it will be found higher in the middle.

Draw-filing: To reduce this high part, recourse must be had to draw-filing (Fig. 91), which is the method used for filing bearing caps, which must be filed even or they will not fit up snug against the opposite member. The file is held at both ends and is operated over the work at right angles to the length of the file. In this position the cutting stroke can occur on the forward or the return stroke or both. An even pressure on each end of the file is necessary, and if this is effected, there will be little danger of filing one side more than the other, and the oscillation, which is certain in cross-filing, is mostly done away with in this method.

Revolving-filing: Is filing done on work in a lathe, chuck, or in some cases while in a drill press. Because of the work revolving at a greater rate of speed than the file moves in bench filing, the strokes are less frequent, but should continue through the length of the file, thereby bringing all the cutting edges into service. Hold the file in the same manner as in cross-filing in the vise. Do not exert as great a pressure as in cross-filing or draw-filing. Special "machine files" should be used where considerable of this work is done.

INSTRUCTION No. 65

MISCELLANEOUS REPAIRING: How to Solder; How to Braze; How to Case-Harden and Temper Steel, etc.; How to Straighten Metal Parts; Repairing and Adjusting Silent Chains; Gaskets; Radiator Repairing

EQUIPMENT FOR SOLDERING

The equipment required for soldering consists of a blow-pipe torch, soldering irons or coppers, and solder, acid or flux.

Blow-Pipe Torches[1]

There are many different methods of heating a soldering iron, the usual method being with the use of blow-pipe torches as illustrated below.

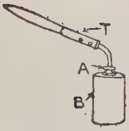


Fig. 1

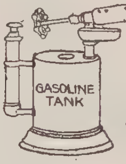


Fig. 2

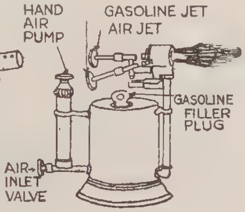


Fig. 3

Fig. 1. The "baby" blow-pipe torch does not require air to be pumped into the gasoline tank (B). It is intended for very light work.

Fig. 2. A single-jet blow-pipe torch.

Fig. 3. A double-jet blow-pipe torch.

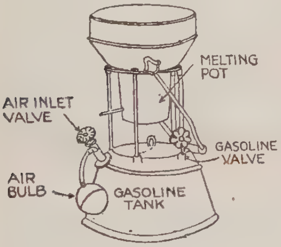


Fig. 4

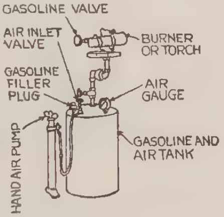


Fig. 5

Fig. 4. A gasoline torch or "fire pot," designed for melting solder and lead; used extensively by plumbers for wiping lead joints.

Fig. 5. A large-size gasoline blow-pipe torch designed for brazing, pre-heating, and general work. The principle of operation is similar to that explained in Fig. 12. With the torch shown in Fig. 5, about 75 lbs. of air is pumped into the gasoline and air tank by the hand air pump. The tank is usually of a 10-gallon capacity.

A Home-Made Gas Blow-Torch

Small soldering jobs, especially in cramped quarters, may be most readily done by means of a blow-torch. Such a torch may be made from pipe fittings in the manner illustrated (Fig 6). In brief, it comprises a piece of pipe, attached to the gas main by a length of rubber hose, with another piece of pipe, attached to the air line and welded to the gas nozzle, as shown. A spacer cross-brace is welded between the two pipes at the rear, making a torch a unit. A valve on the gas pipe renders regulation of the flame easy. Though this torch is somewhat small for brazing jobs, a heavier torch could readily be made for that purpose.

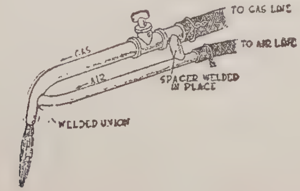


Fig. 6

Gas Torch and Soldering Iron

(A) copper soldering iron; (B) gas-burner tube; (C) gas burner; (D) gas tube to connect hose.

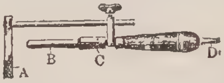


Fig. 7

The gas-heated soldering iron (Fig. 7) can be used with illuminating or acetylene gas by attaching it to a gas burner or to a Prest-O-Lite tank with a rubber tube. By removing the soldering iron, the burner can be used as a blow-pipe for brazing, and also for soldering aluminum. (For sale by automobile supply houses.)

Starretts Gas Heater

The heater (Fig. 8) will be found very useful in the machine shop, as it is convenient for tempering small tools, heating soldering irons, melting lead, babbitt, etc.; and as a forge for light work it will be found very valuable.

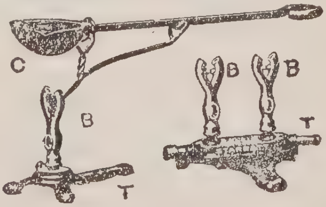
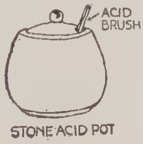


Fig. 8

It consists of one, two, or three burners (B), with or without a tool holder, and is connected to the ordinary gas jet at (T). A ladle (C) 14″ long, holding 12 oz., can be had of the same company, L. E. Starrett, Athol, Mass.

Soldering Copper or Iron

A soldering copper or iron (Fig. 10) is a wedge-shaped block of copper, fitted in an iron fork with a wooden handle. Preparatory to its use, it is placed in a clear fire, or gas or blow-pipe torch burner until it is hot enough. The usual size used is No. 1 or No. 2 (1 lb. and 1½ lb. in weight, respectively).



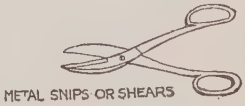


Fig. 9

Fig. 10 (above)

Fig. 11 (below)

If the copper is a new one, it must be tinned. When hot, file off the scale on both sides and ends for a quarter of an inch from the tip, so that the metal will be clean and bright. Dip the nose in the soldering fluid for a second, and then apply it to the stick of solder. A globule will melt off on to a piece of dry brick or tinplate which must be ready to receive it. Rub the nose of the copper in this solder, which will adhere to it as quicksilver does to zinc. The copper can then be used. Copper is used because copper readily absorbs heat and will retain it longer and give it off again rapidly.

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[1] Imperial Brass Mfg. Co., Chicago, Ill., and Clayton & Lambert, Detroit, Mich., manufacture blow-pipe torches.

The soldering copper must not be allowed to get red hot, as the tin will be burned off and the tinning process must then be repeated. The reader should practice soldering at leisure.

How to Solder

In soldering two parts together, it is necessary that the contact surfaces be perfectly clean. A clean file, scraper, emery cloth, or a little acid is generally used in cleaning the surfaces. Sometimes, especially in old work, the emery cloth will not get a clean surface. A dark spot may be a depression; the file must then be used.

If the work to be cleaned is greasy, clean it first with hot water and soda.

After cleaning, the surface to be soldered should be warmed, and swabbed with prepared acid—that is, muriatic acid which has been prepared by dissolving in it as much zinc as it will hold.

The flux or acid generally used may be prepared in the following manner: To ¼ pint of muriatic acid add scraps of zinc in a pot (Fig. 9) until the acid ceases to bubble and a few small pieces of the metal remain. Let this stand for a day; then carefully pour off the clear liquid, or filter it through a piece of blotting paper. Add to this a teaspoonful of salammoniac, and when dissolved the solution is ready for use.

A solution of salammoniac and borax also makes a good flux for soldering copper and brass.

Wire solder, containing a flux, is generally used, thus saving the necessity of a separate flux or acid (obtainable from the Chicago Solder Co., 4203 Wrightwood Ave., Chicago, Ill.).

Soldering Pointers

The melting point of the soldering material must be lower than that of the article being soldered (see Index for melting points of different metals).

Hard soldering or brazing is a term used when the soldering mixture is composed largely of copper, brass, or silver. Use borax for flux. Hard soldering is best where the material will stand intense heat.

Soft soldering is the ordinary half-and-half (one-half lead and one-half tin). Plumbers' solder has 2 parts of lead to 1 of tin, and is therefore still softer than half-and-half, in order to fit it for working on lead pipe. See pages 738, 736 for solder for radiator repairing, known as "50-50" solder.

Sweating is a term used where the solder is applied to a surface to be soldered and the hot iron is then held on it until it "sweats" or runs in.

For electrical work use resin or a soldering paste, as acid sets up a resistance in the joint.

After an iron has been cleaned and heated and is then rubbed on a piece of "fluorite," the tin or solder will spread readily thereon.

How to Operate a Gasoline Torch—Single-Jet Type

Fill about two-thirds full of gasoline; the filler plug on this type of torch is at the bottom of the tank. The torch is turned up-side-down, the gasoline is poured in, and the plug is screwed up tight, making sure that it does not leak.

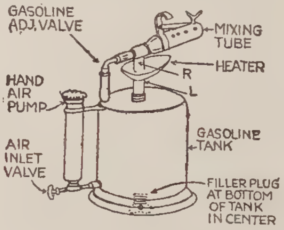

Fig. 12

Air is then pumped into the tank by the hand air-pump plunger, after first opening the air inlet valve (Fig. 12), and after making sure that the gasoline adjusting valve is closed.

Next hold the hand over the mixer tube, and slowly open the gasoline valve at which point gasoline will drip into the heater. Light this gasoline with both valves closed. This heats the pipe (**R**).

After the gasoline in the heater has burned up, the heat should be sufficient to vaporize the gasoline, causing air and gasoline to flow through the pipe (**L**) and (**R**) from the tank to the burner or mixer, when the gasoline valve is opened. A match is applied to this mixture, and the resulting flame should be blue in color; if it is yellow, the heating is not sufficient, and the operation must be repeated. It is advisable to protect the flame from wind while heating.

All torches work on the same principle. Some, however, have two valves (as shown in Fig. 3, page 719); this type is termed a "double-jet." They are also constructed with pots over the flame in which to melt lead; these are termed "fire pots" (Fig. 4).

For brazing, a similar principle is resorted to, except that a larger tank and burner and a separate air pump are used, as shown in Fig. 5.

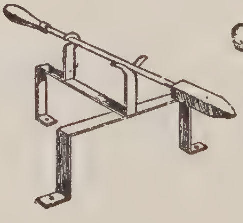

Fig. 13

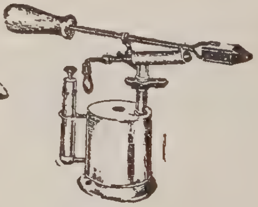

Fig. 14

Fig. 13. A soldering-iron stand which can easily be made, and is well worth the necessary time and labor.

Fig. 14. The usual method of placing a soldering iron on a blow-pipe torch to be heated.

Soldering Aluminum

There are various compounds on the market for soldering aluminum, but this operation depends more on the workman than on the solder, and unless considerable experience has been had, it is probably better to purchase solder than to attempt making it.

The chief difficulty in soldering aluminum is that the heat is dissipated so rapidly that it cools the soldering iron. Furthermore, aluminum oxidizes instantly upon exposure to the air. This extremely thin film effectually prevents a perfect union being made. If the parts are well heated and melted solder is kept melted by allowing the iron to stand on it, the surface can be scraped beneath the melted solder by the point of the soldering iron, thus preventing oxidation to a certain extent. In this way the metal can be tinned. When both parts to be brought together are well tinned, the parts can be united with some chance of success, nitrate of silver, resin, or zinc chloride being used as a flux.

A nickel soldering tool gives more satisfactory results than a copper one, as the latter alloys with the tin and soon becomes rough.

The parts to be united must be thoroughly cleaned. If the surface is of such a shape that it cannot be readily cleaned by scraping, it can be cleaned by dipping it into a solution of nitric acid in three times its bulk of hot water containing about 5 per cent of commercial hydro-fluoric acid. This causes a slight action on the surface of the metal, as shown by bubbles. Rinse the metal after removing from the acid bath and dry in hot sawdust; or thoroughly clean and allow it to stand two or three hours in a strong solution of hyposulphate of soda before being operated upon or cleaned in the acid bath described above.

Aluminum solder: The following formula, in the hands of a competent man, can be used to unite aluminum or aluminoid parts: tin, 10 parts; cadmium, 10 parts; zinc, 10 parts; lead, 1 part. It is best however, to purchase the solder ready made. Concerns making a specialty of aluminum and brazing solder are: Aluminum Brazing Solder Co., Widener Bldg., Philadelphia, Pa.; this concern claims that with the use of Peters aluminum and brazing solder crank cases, etc., can be successfully repaired. The Victory Aluminum Solder Co., 3334 Kedzie Ave., Chicago, Ill., is another manufacturer of this class of solder.

Soldering Cast Iron

To solder and tin cast iron, dissolve as much zinc as possible in one quart of common muriatic acid. Take a half-pint of warm water and dissolve in it 2 oz. of sal ammoniac. In a half-pint of warm water dissolve 2 oz. of chloride of tin. Then mix all thoroughly.

Where cracked cylinders, etc., are to be repaired, half-and-half solder is melted with some copper added. If this is used with the acid just described, excellent results will be obtained. A mixture of about 5 parts tin and 1 part copper is also recommended.

Another method of soldering cast iron: Clean the parts with a file until bright; also use muriatic acid. Wash the acid off with water. Then use a hot soldering iron and soldering acid (muriatic acid cut with zinc), so as to clean the pores of the iron where it is to be soldered. The work must be brought up to the heating point required to melt solder. When the work is thoroughly cleaned and heated in this manner, cool it with a solution of copper sulphate (copper sulphate dissolved in water). This will give a coppered surface. After coating, wash the surplus off; then use soldering acid, the solder and a hot soldering iron, and sweat or run the solder in. (*Sheet Metal.*)

Flux for Soldering Different Metals

Iron and steel: sal ammoniac or chloride of zinc.

Tinned iron: borax, sal ammoniac.

Zinc: chloride of zinc.

Copper and brass: rosin or chloride of zinc.

Lead: tallow or rosin.

Lead and tin: rosin and sweet oil.

Gasoline Feed-Line Repair

A broken gasoline feed line (taken as an example of soldering) may be quickly repaired by scraping the tube near the break, and winding it for 1 in. on each side with clean copper wire. The wire should then be heated, covered with soldering flux, and sweated together with solder. A solid sleeve is thus formed that makes the pipe stronger than originally.

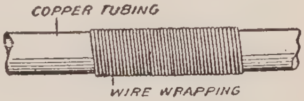

Fig. 15

Gasoline pipes sometimes get loose in the sockets of the unions. This is due to bad fitting, and shows that there is not sufficient elasticity in the pipe; it is too rigidly held. The screwing up of the union strains the pipe, and the vibration on the road causes the pipe to give way at its weakest point, namely, the soldered joint. If the pipe gets loose more than once, it shows that there is something wrong. A longer pipe should be put in, having a U-bend in it, or a complete circle, to give elasticity. The U-bend, or circle, should lie horizontally, with a drop towards the carburetor, otherwise there may be what is called an air-lock in the pipe, and the gasoline will not pass through.

If the carburetor float leaks (if of metal), it can be repaired with solder. Sometimes it is difficult to find the leak. For one method of locating it see Index under "Carburetor float repair."

Brazing

Brazing is infinitely stronger than soldering. It is by brazing that bicycle frames are built up. Bicycle makers use a gas blow-flame. This consists of two parallel pipes—one for gas and one for air. The air, which issues under pressure, causes a strong and very hot flame. The air pressure is produced by a small bellows worked by the foot. The work may be done with the torch shown in Fig. 5 (page 719).

The hard solder, as it is sometimes called, is a brass that melts at a low, red heat. It is generally bought in packets, and is in grains about the size of a pin's head. Brass wire is also used. After being wound around the part to be brazed, it melts and runs into the joint. The **flux** used for brazing is powdered borax.

Brazing a flange: If, for example, it is desired to braze a flange on to a pipe, the flange is placed on the pipe and the pipe is expanded by hammering till it is a tight fit. This is necessary, as it may shift its position in the act of brazing.

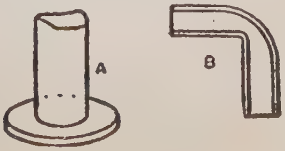

Fig. 16

The flange and pipe (A) (Fig. 16) are put in a clear fire in the forge. Then as it gets hot the spelter, with borax, is sprinkled round the joint, which melts and finds its way into the space between the pipe and the flange. If the reader has a gas or gasoline blowpipe, it will make the work easier, as the heat can be directed where required from above. When cool, the superfluous brass is filed off. In many cases it is impossible to keep the two pieces of metal in the correct places in the forge; therefore a pin or rivet must be put in, so that they cannot shift.

Wiping a Joint

Joining two pieces of lead pipe is termed "wiping a joint." The pipe is first cleaned and prepared, by spreading one pipe with an expander, as at (1) (Fig. 17), and pointing the other ends, which are slipped together, shown at (2). The solder is then melted in a ladle, as shown in (3), and poured around the joint. A pad about 3″ or 4″ square and about ¼″ thick, of canvas or velvet, is held in the hand under the pipe as shown (3), the surface being greased with tallow. The bottom layer may be an asbestos sheet, so that the molten metal will not burn through.

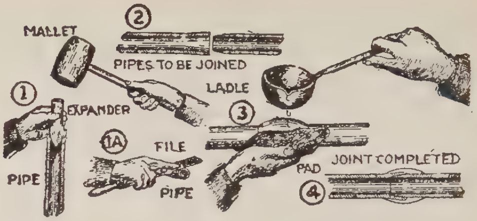

Fig. 17

As the melted solder is poured on the pad, it is wiped around the joint until it is heaped up all around it. The amount of metal used depends upon the size of the pipe. Rub the pipe on each side of the joint with a tallow candle to prevent the metal adhering to where it is not wanted.

Although copper or brass pipe may be joined without difficulty by the ordinary methods of soldering or brazing, the "wiping" method is about the only practical way to couple **lead pipe.**

MISCELLANEOUS[1]

How to anneal, to bend tubing, to use a metal saw, to make small springs and to repair a cracked cylinder, are explained in the pages following.

Annealing Tubing

The copper or brass tubing used for gasoline pipes, carburetors, etc., can be purchased either annealed or not annealed. When not annealed, it is stiff and hard. It is difficult to bend it when hard. The tubing can be softened by heating, as shown in Fig. 18 (called annealing). Iron rods and other metals of like nature can also be softened by annealing.

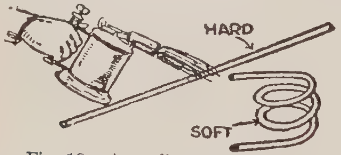

Fig. 18. Annealing copper tubing.

Bending Metal Tubing and Small Rods

The problem of bending metal tubing is one that comes up quite often in the motor vehicle repair and construction shop. Frequently when you undertake to bend some of the new kinds of metal tubing you are surprised to have it break, even though the usual precautions may have been taken to prevent a fracture of this nature. Fill the tube with fine sand packed tight, otherwise the walls are very liable to break, or they are liable to collapse.

First of all, it is best to **determine** the character of the **composition of the tubes.** Many tubes are made by different manufacturers and are finished nearly alike, and you cannot very well determine what procedure to follow when desiring bends or scrolls in them. But the file test will quickly make this clear; or even the point of a cold chisel will do to determine the nature of the metal. Then you can work accordingly.

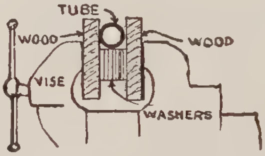

Fig. 19

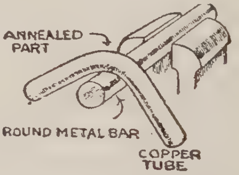

Fig. 20

Fig. 19. **Bending small tubing:** It is well to anneal the tubing first. Then procure several washers, and place side by side until the diameter of the tubing is obtained. Two wood blocks are placed one on each side of the washers and are clamped in the vise. The blocks serve as guides. The tubing is then bent by hand over this form.

Fig. 20. **Another plan** to secure a uniform bend of smaller tubing is to employ an outside mandril on the tube. This consists of a closely and tightly wound spiral of iron wire of about 14 gauge over the tube. This distributes the stresses in the operation of bending, and it can be unwound afterwards. Small-bore tubing can be bent by placing a piece of copper wire (a fairly good fit) inside, and withdrawing it afterwards. A piece of string solder well greased can be used and then melted out.

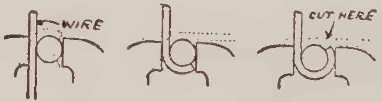

Fig. 21. To bend an "eye" in a small rod.

To bend wire or a small rod and yet leave it circular in form: Drill a hole in a flat piece of iron; fix this in a vise; heat the end of the rod, having previously marked the place where the bend is to be; insert the hot rod in the hole and bend down, using the hammer to insure a right-angle turn, not a curve. The hole must be larger than the rod or the hot end will not enter.

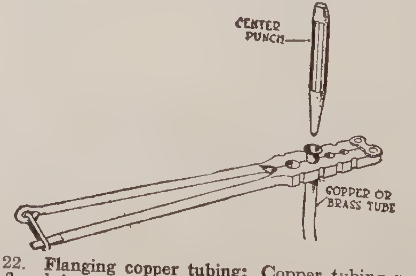

Fig. 22. **Flanging copper tubing:** Copper tubing may be readily flared for the attachment of unions by the use of a pair of lineman's splicing pliers. The end of the tube to be flanged is caught in the jaw of the pliers and a punch is used to press the end out to the extent required. Ordinarily some one of the grooves in the pliers will be found to fit almost any of the copper tubing commonly used. When this is not the case, the grooves may be readily enlarged by an emery wheel.

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[1] *Automobile Repairshop Short Cuts:* A book containing over 1,500 time and labor-saving kinks, methods and devices, from more than 1,000 of the best garages, service stations, and repairshops in the U.S. Ideas that have been developed to save a good man's time, covering engine, clutch, gearset, running gear, and body repairs, managing and equipping the shop, etc. Collected and edited by *Motor World's* corps of experts. 256 pp., 9 x 12 Ins., 1,500 figs., cloth; price $3.50.

How to Use the Metal Saw

The fine-toothed blades should be used for iron and steel, and the **coarser** ones for brass and soft metals. For **cutting through a brass or steel tube** use a fine-toothed blade, as the teeth rip off the coarse ones. Before sawing, make a true circumferential line round the tube where the cut is desired; then, by turning the tube round a little between each cut, the latter will be true and square. The broken blades are useful at times for small repairs, as they are readily softened.

Another method for sawing tubing is shown in Fig. 23.

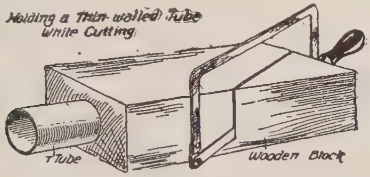

Fig. 23. Method of sawing through tubing. Consists of a wooden block with a drilled hole to receive the tube.

How to Make Small Springs

Spiral springs are now so readily obtained in a large variety that it is not often one is at a loss for a particular size of spring. The occasion may arise where a certain unusual size of spring is required. Figs. 24 and 25 illustrate two methods of winding small spiral springs.

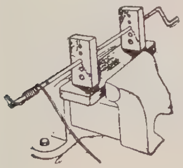

Fig. 24

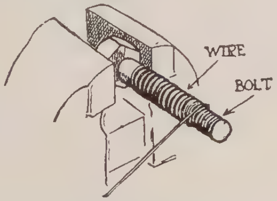

Fig. 25

Fig. 24. Springs of various sizes may be wound on the **spring winding outfit** illustrated. A cast-iron frame supports two uprights that act as bearings for the spring-winding spindle. These spindles are tool steel rod, having a diameter somewhat smaller than the inside diameter of the spring to be wound. One end is bent to form a crank and handle, the other being notched to receive the spring wire.

Fig. 25. How a spring is made by winding wire around a bolt.

Repairing a Cracked Cylinder[1]

Repairing a cracked cylinder: Welding is best, but if this is not convenient, repair with copper as directed below:

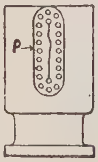

Fig. 26

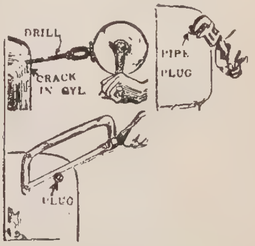

Fig. 27

A small hole should be drilled at each end of the crack, or a little beyond it (Fig. 26), for the crack may go farther than is visible to the eye. A quarter-inch hole should be drilled and tapped, and a screw inserted and screwed home, and the end filed off flush with the metal. Then a piece of stout sheet copper (**P**) (not less than 1/12″ thick) should be cut out, covering the crack extending about ¾″ all around. This must be bent to fit the cylinder and fixed down with a number of 3/16″ or ¼″ screws. Put a piece of canvas smeared with red lead, putty, or thick oil paint under the copper. The patch may leak a little at first, but will probably "take up" in a few days.

Plugging is another plan. A very small crack in a cylinder, probably caused by freezing of contained water, may be mended as follows. Drill a small hole in each end of the crack, and tap it for a small copper plug (Fig. 27). Scrape the surfaces near the crack until the metal is bright. Cover the crack with soft copper filings and melt them in with the blow-torch. Use a flux of rosin dissolved in alcohol, or simply drill and thread the hole, if not too large, and screw in a pipe-plug tap, and saw it off.

Rusting up a small leak in a cylinder: ¼ lb. of sal ammoniac to 1 quart of water, poured into the cylinder and left to stand for 48 hours has caused rust enough to form to close a small hole entirely. Be sure to wash out thoroughly. Another remedy is an "iron cement," secured at supply houses.

Cider or vinegar will cut rust out of cast-iron cylinder water jackets, if left standing for two or three days.

HEAT TREATMENT OF STEEL[2]

In ordinary shop practice this consists of the following: (1) the process of **annealing**; (2) the process of **hardening**; and, (3) the process of **tempering**.

Annealing Metal

Annealing or softening renders a metal in such a condition that it can be easily cut, machined, or bent. See Fig. 18, page 722, showing how tubing is annealed.

To anneal steel: Heat to a dull-red heat and then remove the metal from the heat and permit it to cool in the air.

Where the work is of great importance, an oven or crucible is used. A simple oven is shown in Fig. 28 and in Fig. 30, page 724.

A piece of gas pipe is used, large enough to admit the tool or metal to be heated. One end is closed and placed in the coals until the inside of the pipe has been heated to a bright red. Then the part to be heated is placed in the pipe and brought to the desired heat. Then, instead of cooling in the open air, the work is placed in a bed of non-heat-conducting material, such as charred bone, asbestos fiber, ashes, lime, fire clay, or sand. The metal should be left for a long period of time, well covered, until cool.

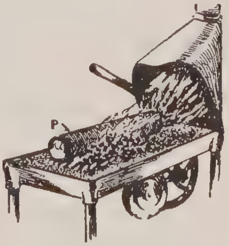

Fig. 28

Brass or copper is heated to a low red heat and quickly dropped into cold water.

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[1] There is a spelter, called Peters Metallic Filler, which can be used in connection with an ordinary gasoline blow-pipe torch (or any heat up to 300° F.) for filling up cracked water jackets, cracked cast iron, steel, brass or bronze. This can be used instead of brazing and welding on cracks. Write Aluminum Solder Co., Widener Bldg., Philadelphia, Pa.

[2] A book dealing with the subjects of annealing, hardening, tempering, brazing, etc., can be secured of A. L. Dyke, Granite Bldg., St. Louis, Mo. Price $3.50.

Hardening

The process of hardening is accomplished by bringing the metal to the proper temperature, slowly and evenly, the same as for annealing, and then cooling more or less rapidly, depending on the grade of the steel being worked upon.

The degree of hardening is determined by the grade of steel, the temperature from which it is cooled, and the temperature and kind of cooling bath into which it is plunged for cooling.

Steel to be hardened is placed in the oven and permitted to come to a heat of about 650° or 700°. It then is placed in a heating bath of molten lead, fused cyanide of potassium, heated mercury, or some other preparation designed for the purpose. The degree of heat to which a piece of steel must be brought depends on the percentage of carbon contained within the steel. The more carbon, the lower the heat required to harden it.

It is essential that the cooling bath be of the same temperature during each process of cooling.

Ordinarily, steel is cooled in water, but many other liquids are used. If cooled in strong brine, the heat will be extracted very rapidly and the degree of hardness will be much greater. If cooled in mercury, a still greater degree of hardness is obtained.

If toughness is wanted without extreme hardness, the metal may be cooled in lard oil, fish-oil, or neats foot oil.

In hardening carbon steel, bring to a cherry-red heat, plunge into cold water (brine is best), and hold until hissing ceases; then remove and place in oil for complete cooling.

For hardening high-speed tool steel, see page 726.

When hardening brass, bronze, or copper, the work is accomplished by hammering or working while cold.

Tempering

Tempering differs from hardening, in that tempering is the process of making steel tough so that it will hold a cutting edge and not crack or check. Tempering makes the metal stronger and the grain finer. Tempering may be considered as a continuation of the hardening operation.

To temper, the metal or tool is heated slowly, to a cherry-red heat, then dipped into water (Fig. 29), to a depth of about ½″ or ¾″ above the point. When the piece has cooled to the point where the portion above the water has not lost its redness, remove it from the water and quickly rub the end with fine emery cloth.

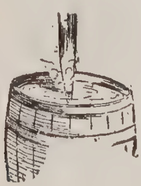

Fig. 29

While the heat from the uncooled portion of the metal gradually heats the point again, a change of color occurs at the polished point. When a **certain color** has been reached, the entire tool should be completely immersed in water and permitted to remain there until cold.

Colors for different work are as follows: Wood saws and springs: **dark blue, 600°**; cold chisels and screwdrivers: **dark blue or light purple, 600° or 520°**; punches, drills, and wood-working tools: **brown, 510°**; taps and reamers: ordinary **straw color, 450°**; lathe tools, planers, shapers, and slotter tools: **light straw color, 430°.** Colors darker than the dark blue, ranging through green and gray, signify that the piece has reached its ordinary temper, which means it is partially annealed.

After a **spring** has been properly hardened by dipping in fish-oil or lard, it may be held over the fire while still wet with the oil and permitted to catch fire. After the oil burns off the spring, it has been properly tempered. Self-hardening steel should never be placed in water.

Drills and small tools can be tempered quite well in a flame. Larger parts are better tempered on an iron plate on which has been placed a thick layer of fine sand and the flame allowed to play underneath. This insures the part being uniformly tempered.

Difficulty is often experienced in lathe work on **nickel-steel stock** through the failure of the tool to retain its cutting edge. To overcome this, heat the tool nearly to white heat and plunge it into kerosene oil. See also, page 725.

Case-Hardening

The process of hardening the surface of the steel, leaving the inside strong and tough, is termed "case-hardening." More carbon is added to the surface of the steel, which offers good wear-resisting qualities and has the effect of forming a very hard coat on the outside while leaving the inside practically unaffected. In other words, the outer surface only is hardened, as for instance, gear teeth or nuts which are hardened to only about 1/50″ deep (see page 725). (*Motor Age.*)

Example of Case-Hardening Steel

The outer surface of any piece of soft steel may be made hard by case-hardening. Its purpose is to increase the strength and wearing qualities of the steel. All machine work to be done on the steel should be done before the case-hardening, as grinding alone can be done afterward. (If any part of the piece must be left soft, this may be done by covering that part with asbestos paste or paper.)

The hardening compound: Mix 9½ parts of fine charcoal with 2½ parts of table salt. Place 2½ parts of kerosene oil in a dish, and put with it as much sawdust as is required to soak the kerosene up. Now mix the sawdust and oil with the charcoal and salt. This compound may be used many times.

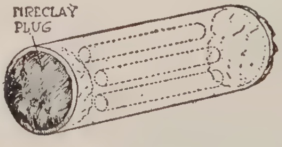

Fig. 30. Case-hardening steel. The pieces are packed in a pipe with the hardening compound—but they must not touch.

The crucible: Get a piece of iron pipe long and large enough to hold the pieces to be hardened (Fig. 30). Pack the pieces in this pipe with the hardening compound. Do not let one piece touch another, or touch the pipe side, but keep them well apart with the compound. Now close both ends of the tube with fire clay.

A large forge fire is necessary for heating the pipe, and the pipe should be heated to a bright-red heat. The length of time varies, depending on the size of the pieces and the depth of case desired.

Ordinarily two hours at bright-red heat will give 1/16″ case. This heat should be held as evenly as possible to give an even case and reduce warping effects.

To produce the maximum strength, two heat treatments are necessary after hardening. First heat each piece to a bright red and plunge in oil. Then again heat it to a dull red, and plunge. This will give a fine grain, both in the core and in the case.

Quick case-hardening: If a thin case is desired, this may be applied quickly by heating the piece to redness and sprinkling the part to be hardened with potassium cyanide. Keep the temperature constant for 4 or 5 minutes, then plunge the piece in water or oil. An exceedingly thin case will result that will increase the wearing qualities of the steel, better its appearance, and prevent rust.

To harden tools quickly: The tool should be heated to the correct temperature and then thrust into a potato, after which draw to the proper temper.

Another Method of Case-Hardening

It is possible **to case-harden small pinions** quite well by bringing them to a uniform bright-red heat and plunging them into finely-powdered yellow prussiate of potash, repeating the operation three or four times, and finally plunging into clean cold water while still at a red heat. The mild steel absorbs carbon from the potash to a depth of about 1/50″, and this surface hardens perfectly on the final cooling. Nuts so treated resist rough usage with the spanner much better than an ordinary soft-surface nut.

In treating parts of this class it is, however, important to remember that the threaded part should be filled up with clay so that it does not come in contact with the carbonizing material, otherwise it will be certain to be spoiled. Any roughness of the surface, such as on the teeth of pinions, can be smoothed off with emery cloth wrapped over a thin flat file. Parts made from tool or high-carbon steel are readily hardened by making them red-hot and plunging them into cold water. The correct heat is important, because if the parts be heated to a very bright red, they may be spoiled or decarbonized, and if heated to a white heat, they will certainly be decarbonized. On the other hand, if heated barely red, the parts will not harden.

Straightening Warped Pieces

Uneven heat and uneven cooling warps the steel. Case-hardened pieces cannot be straightened by pressure or by pounding, as this cracks the case.

To straighten a warped piece of case-hardened steel:

1. Find the high or "bowed" part. Mark this with a chalk line.
2. Heat the piece slightly—never near a red heat. (The amount of heat depends on the warp, and can be determined only by trial.)
3. Clamp the piece in a vise between the blocks, as shown in Fig. 31.
4. Direct a stream of water at the chalk line. This will contract the long side and make the piece straight.

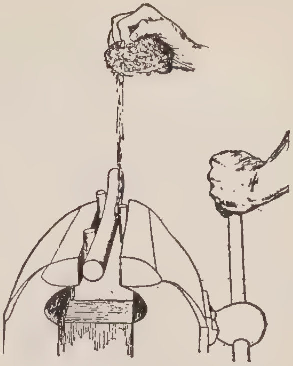

Fig. 31

How to Make Lathe Tools

High-speed steel should usually be heated until the tip of the tool starts to melt, and then plunged in oil, or buried in common salt until thoroughly cool.

High-carbon steel gives the best results when heated to dull red and plunged in oil.

Only **the tool point** proper should be heated to the plunging temperature, the heat being applied slowly at first, to be followed by the blast being turned on and the point heated to the required plunging temperature.

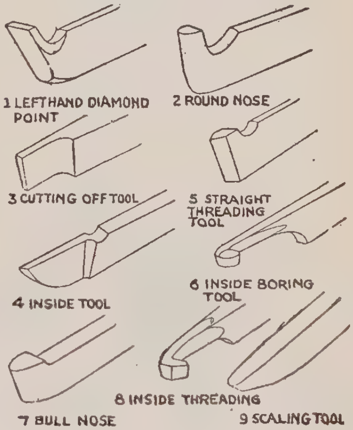

Fig. 32. There is a tool for doing each job most efficiently.

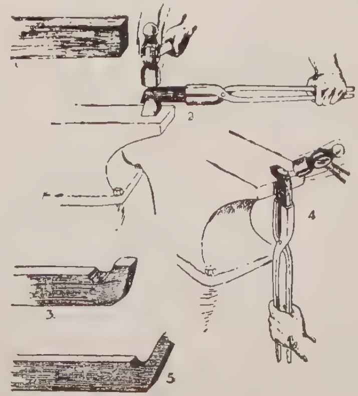

Fig. 33. Steps in making a lathe tool. The work should be done during one heat.

The tool should be plunged into the oil **when the heat is increasing,** and in the case of carbon steel at the instant the point reaches the plunging temperature—dull red, the fusing temperature in the case of high-speed steel. This is particularly necessary with high-carbon steels, as heating the steel white hot, allowing it to cool to dull red, and then plunging it in oil will make a poor tool.

High-speed steels, after hardening and grinding, are ready for use. Carbon-steel tools, however, must be tempered.

This may be done in two ways, the best being to plunge only the point of the tool in oil after heating to a dull red, thus leaving some heat in the heel of the tool.

When the point is black, remove the tool and rub the cutting edge with emery paper mounted on a stick. Watch the point closely, and as the heat is driven from the heel to the point, the color of the surface being polished will turn light straw, dark straw, and blue. When the point of the tool is straw color, plunge the whole tool in oil and cool it entirely.

The **other method of tempering** is to cool the tool after the first heating, polish the point, slowly heat it again until straw color, and then plunge it.

Almost any grinding wheel may be used for grinding the tool, but care must be taken not to draw the temper, or burn the tool. The tool should be held lightly against the wheel and frequently cooled in water. Grind the tools to the shape desired, following as closely as possible those illustrated Finish the cutting edges with an oil stone.

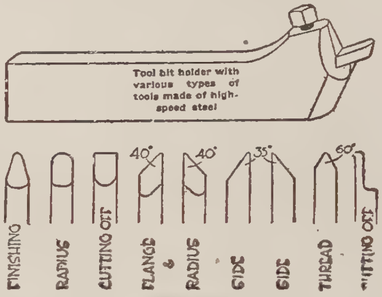

Fig. 34

Fig. 34 shows a tool bit-holder and a standard set of high-speed tools. These are excellent for repair-shop purposes, though expensive. The shapes illustrated will cover a great variety of work, and the tool should be changed to suit the work, rather than regrinding the tool each time. (*Motor World.*)

STRAIGHTENING BENT FRAMES, ETC.

Straightening a bent frame: To make the repair, the radiator is removed, a pan of charcoal is placed under the frame, and pieces of charcoal are heaped around the bend as shown; the frame is then heated up about the bent portion by playing upon the pile of charcoal with the flame of a blow-torch.

As the frame is brought to a cherry-red heat the device (**A**) (Fig. 35) is applied and used in connection with a wooden beam (**B**) which supports the jack.

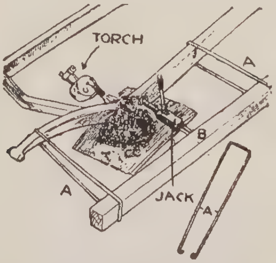

Fig. 35. Straightening a bent frame by heating.

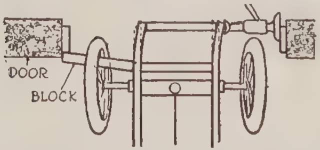

Fig. 36. Another method of straightening a bent frame.

The torch now is set aside, the charcoal removed, and while one man carefully operates the jack and slowly draws the bent member back to its proper shape, another assists the operation by tapping and shaping the heated section with a hammer.

This hammering is quite necessary and an important factor in bringing about a successful result as it assists the molecular action of the steel, and prevents the end of the frame from springing back out of line as the job cools off.

The entire straightening process must be done while the injured section is red hot, and the job must be completed before the red color is lost.

Bent frame horns may be pulled back into place by a chain, providing the force is applied in the proper place. The method of attaching the chain is shown in Fig. 37, and the force is applied by twisting the chain with a steel pinch bar. A jack placed against wooden blocks and with a chain sling over it, as shown, may be used to straighten the side members of the frame.

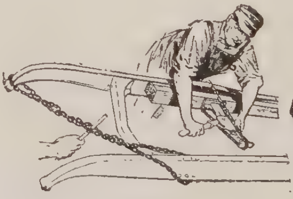

Fig. 37

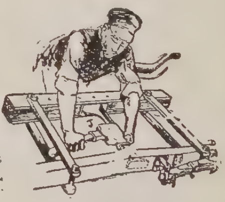

Fig. 38

Frames may be straightened without heating, and sometimes without even dismantling the car, by means of the simple device shown (Fig. 38). It consists of a wooden beam 4 in. x 6 in. x 5 ft., reinforced with iron ¼″ thick on each side. The beam forms the base of the device, to which are attached the steel arms which fasten to the frame. A powerful jack is used to apply the required pressure to bring the frame back to normal. A chain may be substituted for either of the arms.

Other methods of straightening bent frames are shown in Figs. 39 to 42. (From *Motor Age* and *Motor World.*)

Straightening dents in bumpers and similar articles can be done in minimum time with the device illustrated in Fig. 43.

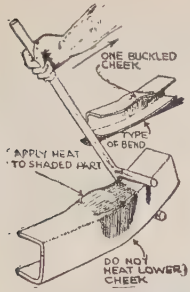

Fig. 39

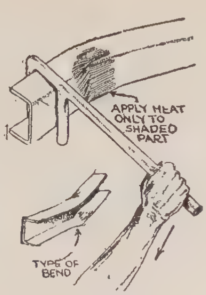

Fig. 40

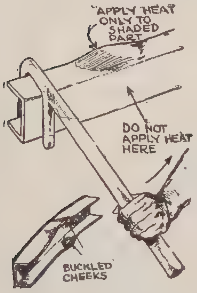

Fig. 41

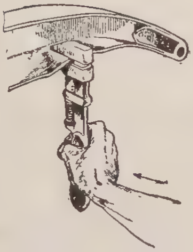

Fig. 42

Fig. 39. When one cheek and part of the face are buckled, only the bent parts should be heated.

Fig. 40. When the face is buckled very little heat should be applied to the cheeks.

Fig. 41. When both cheeks are buckled heat should not be applied to the face but to the shaded portion.

Fig. 42. Small crimps may be taken out with heat and a monkey wrench.

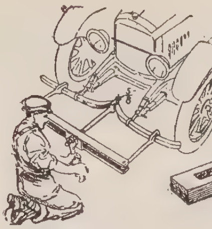

Fig. 43

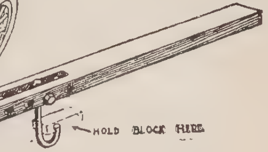

Fig. 44

It is not necessary to remove the bumper from the car. The central member, which does the pulling, may be slid from one end to the other as required, so that a dent in any part of the bumper may be removed.

A fender straightener, made of oak 3″ x 4″, is shown in Fig. 44.

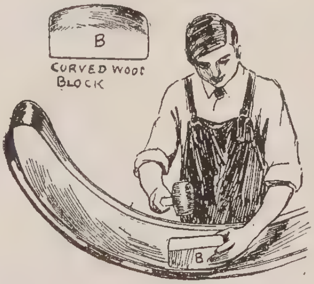

Fig. 45. Easy method of removing dents from fenders with the use of a shaped wood block.

TOOLS AND POINTERS ON STRAIGHTENING FENDERS, ETC.

With a small investment in tools, a little practice, and care in their use, a new department may be developed that will show a profit, and that will also feed other departments.

There is but one secret to sheet-metal straightening: to support all parts except that which is to be straightened, and to go slow, working the metal back to its original form by light blows.

To do this requires many special tools, some of them taken directly from the tinsmith trade; others can be developed on the job.

The Tools

1. **The blacksmith's fuller:** This is used as a hand anvil, either in conjunction with the light mallet, or the light hammer, particularly to remove small dents. The combination of flat surfaces with the rounded edge will cover a wide variety of work.
2. **Half-round file:** After all dents or indentations have been removed by use of the mallets, hammers, and hand anvils, this file is used to remove any small pits or hammer marks.
3. **Heavy wooden mallet:** Used in the preliminary straightening in order roughly to form the metal back to shape. The flat wooden surface does not dent the metal on flat or crowned surfaces.
4. **Light wooden mallet:** The most useful tool of all. After the metal has been pounded back to its original shape, the light mallet, in conjunction with some one of the hand anvils, is used to smooth up the work.

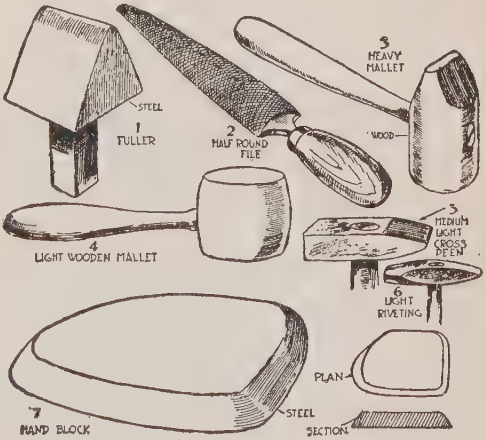

Fig. 46. Mallets, hammers, files, and special tools for straightening fenders, etc.

5. **Medium cross-peen hammer:** A tinsmith's hammer, used to smooth up the surface still further. Wooden mallets will not remove all of the smaller indentations. Hence this hammer must be used as it strikes the required concentrated blow over a limited area.
6. **Light riveting hammer:** Any minor indentation, not smoothed by No. 5 hammer, is taken out by the light riveting hammer. The cross-peen is used to finish corners, prior to filing.

7. **Hand block:** A steel block, roughly about 4″ square, and 1″ thick, with the corners rounded and beveled. The curves and beveled edges vary, so that some part of the block may be fitted to almost any part of the work. This and the light wooden mallet are the most used combination.

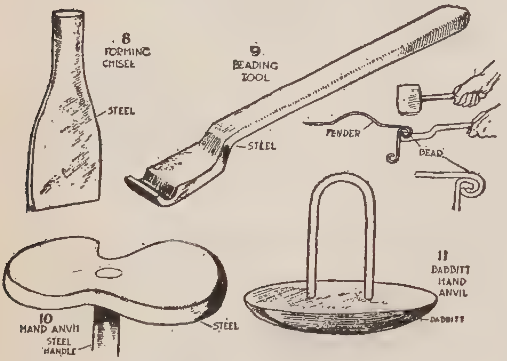

Fig. 47. Some unusual-shaped tools used in straightening fenders, etc.

8. **Forming chisel:** Made in an infinite variety of widths, shapes, and sizes. The one shown is used to form sharp corners, or edges. One with a half-round edge is used to reshape a groove. By grinding the edge to the desired form, the metal may be readily driven to that form.
9. **Beading tool:** The side strips on most fenders are held in place by rolled-in edges. When bent, these edges open. After straightening to the original form, the bead may be again closed by the aid of this tool, and a mallet or hammer.
10. **Hand anvil:** An irregular-shaped steel plate or block, mounted on a steel handle. The edges are beveled, and will fit almost any curved surface.
11. **Babbitt hand anvil:** Made in an infinite variety of forms by pouring melted babbitt into an unbent portion of the part to be straightened. When hard, the shape is that to which it is desired to form the bent portion. Make the handle as shown.

Reshaping Bent Metal

It is not usually advisable to attempt to straighten mudguards and lamps having broken surfaces.

The first step is to work it roughly back to its original shape with a heavy wooden mallet. Care must be taken not to break the surface or to draw it beyond the original shape.

A hand anvil of some sort should always be used in conjunction with the hammer or mallet, to support the edges of the bent surface. Many light blows, rather than few heavy blows, should be applied, and the blows should be drawn, rather than applied dead on. The main thing is to go slow, to feel the dents with the hand anvil, and to direct the straightening blow to the point of the bend.

After the surface has been malleted to approximately the original shape, the smaller dents should be removed, using first the small mallet and then one of the metal hammers. This is slow work.

Filing

By passing the hand over the surface, many of the smaller dents may be felt and removed. Some, however, will still remain. These may be located by filing the surface down. The file will hit the high spots and pass over the low spots. Then the low spots may be pounded up to shape.

Finally it will be found that the file will touch all of the surface except the smallest indentations. Then file the whole surface down to a smooth surface and polish with emery paper.

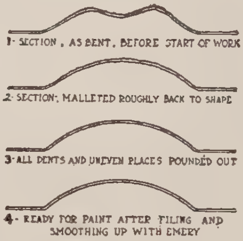
1- SECTION, AS BENT, BEFORE START OF WORK
2- SECTION; MALLETED ROUGHLY BACK TO SHAPE
3- ALL DENTS AND UNEVEN PLACES POUNDED OUT
4- READY FOR PAINT AFTER FILING AND SMOOTHING UP WITH EMERY

Fig. 48. The four steps in removing a dent from a sheet of metal.

The four steps in this work are shown in Fig. 48, the section being that of a crowned mudguard. But whether the part to be straightened be mudguard, lamp or body, the principle involved is absolutely the same. (*Motor World.*)

Painting Fenders

Before applying the paint, the surface must be thoroughly cleaned with turpentine. This removes all grease that would otherwise prevent the paint from sticking. If the surface is that of a mudguard, the under side should also be cleaned and painted to prevent rusting.

For hurry-up jobs a quick-drying enamel or a black japan may be used to paint the repaired section, the latter, of course, being suitable only for use on black guards or parts. The japan, mixed in turpentine, will dry in about 15 minutes, and, after a few washes, cannot be detected from the rest of the finish.

Enameling Fenders, etc.

Enameling of fenders and of metal parts of bodies is a profitable business. Concerns who supply equipment for this class of work are: Despatch Mfg. Co., 104 N. Second St., Minneapolis, Minn.; Industrial Heating Mfg. Co., Cleveland, Ohio; National Rubber and Specialty Co., 4433 Chicker-ing Ave., Cincinnati, Ohio; Young Brass Co., 6500 Mack Ave., Detroit, Mich.

Painting Outfits

Painting outfits for automobile work can be secured of DeVilbiss Mfg. Co., Detroit, Mich., and Phillips Ave., Toledo, Ohio; Peasche Air Brush Co., 1219 W. Washington Blvd., Chicago, Ill.

Straightening Bodies

Upholstery must be removed or the body must be raised to get at both sides of the surface. Another difficulty is that two men are often required—one to hold the hand anvil and the other to use the mallet or hammer. The co-operation between the two must be perfect, or the anvil will not be back of the hammer blow and the surface will be bent still further. Body work is more difficult,

Dent in Gasoline Tank

A dent can be removed from a gasoline tank by plugging the vent, filling with water, and applying a 20-lb. air pressure. A lead or wood mallet is used by tapping gently around the outer edge of the dent (Fig. 49). (*Motor World.*)

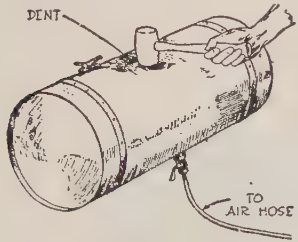

Fig. 49

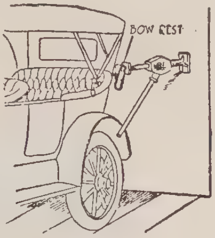

Fig. 50

Jack for Straightening Parts

An ordinary jack may frequently be used to advantage in straightening bent parts. For example (Fig. 50), one of the rests for the top bows was bent in a slight accident, and it was quickly straightened by backing the car up close to the garage wall, as shown, and using a jack.

To Stop Noises about the Car

When seeking to stop **rattling noises** about the car, attend first to the fenders, then to the brakes, hood fasteners, and lamps, and finally to doors and springs. As a rule the fenders, doors, and springs are the most troublesome source of noises on the average present-day machine.

FITTING EXHAUST MUFFLER CUT-OUTS, EXHAUST HORNS, AND SHOCK ABSORBERS

Fitting an exhaust "cut-out": Mufflers sometimes are not large enough, or are clogged up, and offer "back pressure" or resistance to the full passage of the exhaust. A "cut-out" is helpful in climbing hills and to assist in keeping the engine cool. The muffler cut-out is also a convenient method of ascertaining (by listening) whether all cylinders are firing regularly.

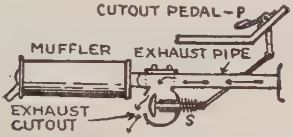

Fig. 51. Method of installing the exhaust cut-out.

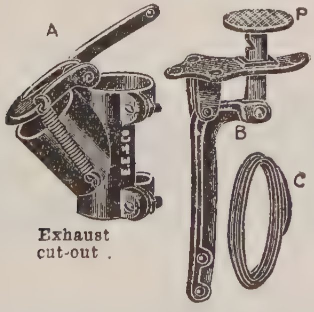

Fig. 52. Exhaust cut-out outfit. (A) exhaust cut-out; (B) foot pedal for operating; (C) flexible wire for connecting.

Note. When ordering an exhaust cut-out, measure the outside diameter of the exhaust pipe to which it is to be fitted, and specify this measurement. (See Index under "Sizes of exhaust pipes.")

Exhaust "cut-outs" are installed by cutting a hole in the exhaust pipe just ahead of the muffler (Fig. 51). Fittings, as shown in Fig. 52, ready to fit and with full instructions can be had from supply houses.

Attention to the cleaning of the muffler must not be neglected, for this is a point having a great effect upon efficiency. For open cars the writer considers a cut-out a necessity: not for roaring through towns or villages, but for the purpose of testing the firing and carburetion.

Although it is necessary to remove the muffler for a thorough cleaning, it is quite possible to effect a satisfactory temporary cleaning of the badly obstructed passages by tapping its sides all over lightly with a hammer or mallet. The result will be that much sooty accumulation will be knocked off and blown out through the tail pipe.

Fitting an exhaust whistle: The exhaust whistle (Fig. 53) is blown by the exhaust pressure; for instance, instead of the exhaust going out into the open air, as in the muffler cut-out (Fig. 51), it passes into the whistle.

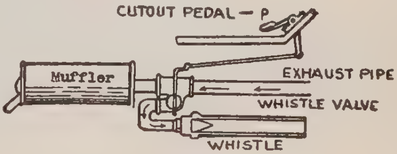

Fig. 53. Method of installing an exhaust whistle.

When fitted to an exhaust pipe, the exhaust is temporarily cut off from the muffler and thrown into the whistle by a special valve attached to the exhaust pipe. Multiple engines blow a whistle almost steadily, but single and double-cylinder engines blow in jerks or uneven blasts.

Attaching Shock Absorbers

Attaching Connecticut shock absorbers: Shock absorbers are necessary accessories. They prevent the rebound of springs after the spring action and thereby prevent springs being broken by the sudden up motion of the car, which is a common occurrence, in going over crossings, etc. If properly fitted, they are worth many times their cost. There are a number of different principles in use. The Connecticut friction type will be used as an example.

To fit: First fill the grooves inside the bushing in the end of each arm with graphite grease.

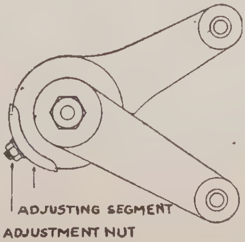

Fig. 54

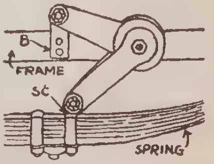

Fig. 55

In order to secure satisfactory results it is important that the angle of the arms be correctly adjusted, so that the cam which operates against the springs in the absorber will be in normal position when the car is loaded and standing still.

Care should be taken that the absorbers are so located that they will not strike the frame when the car is in motion. After the fittings have been attached, slip the absorbers on to the studs of the fittings by loosening up the adjustment nut, so that the arms can be pulled apart any desired distance.

Load the car with the full number of passengers that the car is designed to carry, and tighten up the adjustment nut. The lock washer should be on the stud and the nut tightened securely, so that there will be no danger of the adjusting segment slipping. See that the cotter pins are all in place in the end nuts.

After the absorbers are attached, no further adjustment or attention is required. (Manufacturers are Connecticut Shock Absorber Co., Meriden, Conn.)

REPAIRING AND ADJUSTING SILENT CHAINS

Silent chains are used to drive the cam shaft, generator, water pump, magneto, fan, etc., instead of gears.

The Morse silent chain, as used on many cars (see the next page), differs from other silent chains only in that the Morse employs two pins in the joint, one called the "seat pin" and the other the "rocker pin."

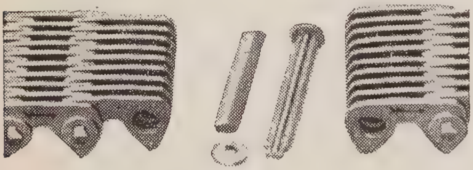

Fig. 56

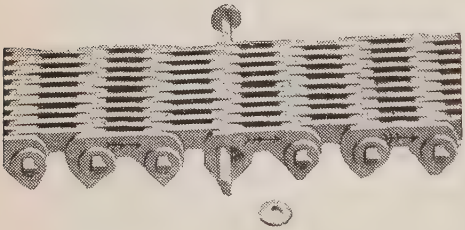

Fig. 57

To connect the ends of a Morse silent chain: Place the chain over the wheels to run in the direction indicated by arrows. On all automobile front-end drives the arrow side of the chain will be the near side, as shown in Figs. 56 and 57.

Bring the ends of the chain together and lap the link plates in regular order, as shown in Fig. 57; insert the "seat pin" (with washer riveted on one end) from the far side of the chain, taking care that the ribbed side of the pin points in the direction of rotation of the chain as shown in Fig. 57.

Insert the "rocker pin" from the near side of the chain as shown by Fig. 57, with the segmental, or pointed, side of the pin against the flat side of the "seat pin," and toward the direction of rotation of the chain. The relative positions of the two pins, when properly inserted, will be as shown by Fig. 63.

Place the washer on the end of the "seat pin" and, after backing up with a bar or wedge, rivet over the end with a few sharp blows of the hammer.

To shorten the chain one pitch by removing the "hunting link": All chains containing an odd number of links must include the thin-leafed section (HL) (Fig. 58). This row of leaves (collectively) is called the "hunting link."

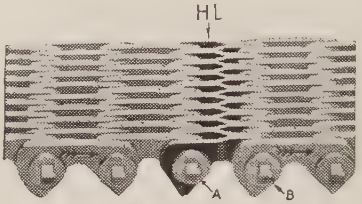

Fig. 58

To remove it, move the chain until the hunting link is on top of a wheel; then with a chisel in vertical position and the edge of the blade at right angles to the plane of the washer, strike sharply with a hammer until washers (**A**) and (**B**) are split sufficiently to make them fall off. This releases the pins in the two joints which can then be driven out, and the leaf-plates of the hunting link will fall away when the chain is lifted up.

The chain is thus reduced in length one pitch (one link), and all that is necessary to put it again in running order is to bring the ends together, mesh the link plates in regular order, and make proper connections as stated above. **The "pitch" of a silent chain** is the distance from center to center of the pins.

To shorten the chain one pitch, by removing four links and inserting three, one of which is the "hunting link": Arrange the chain with the arrow side as the near side, either flat (as shown) on some solid foundation, or on top of one of the wheels.

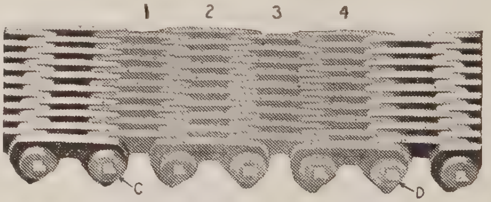

Fig. 59

Select a joint at the **head** of an arrow, and, with hammer and chisel, cut washer (**C**) (Fig. 59) until it falls off. Move to the right four links and cut washer (**D**), also at the **head** of an arrow, in the same manner.

Be careful that each severed washer is at the **head** of an arrow, otherwise the leaf-plates of the three-link section will not mesh in regular order with the chain.

Drive the pins from joints (**C**) and (**D**) and remove the links marked 1, 2, 3, and 4 in Fig. 59. Insert a three-link section in place of the removed section, making sure that the arrow on the new section points in the same direction as the arrows on the old chain. Bring the ends together, mesh the leaf-plates in regular order, and make connections.

Note. It is necessary to remove only four links and to insert the section of three links, as described above, where the chains are used with an even number of links and do not contain a hunting link (HL) (Fig. 58). If the chain contains a hunting link, it should always be shortened as described in the comments on Fig. 58.

Some of the engines on which the Morse "front-end" drive is used: Cadillac, Chalmers, Clyde, Colonial, Drexel, Erie, Ferro, Gray, Hackett, Haynes, Hupmobile, Jeffery, Jewett, King, Lozier, Scripps-Booth, Monitor, Maxwell, National, Nash, Olympian, Pullman, Packard, Winton, Princess, Stearns-Knight.

Silent Chain Adjustment[1]

Various methods are used for adjusting chain tension: For instance, if the chain drives the generator shaft, the generator can be moved in the slot holes to adjust the chain tension, as shown in Fig. 37 (page 75), or the shaft on which the sprocket is mounted can be rotated on an eccentric bearing (Fig. 36, page 74), or, if mounted in a separate case, shims can be installed under the case.

To adjust while running, tighten the chain until it becomes noisy; then slacken to the point where noise ceases. The chain should be as tight as possible without causing noise.

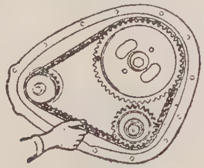

Fig. 60

To adjust where the cover is removed, as in Fig. 60, take hold of the chain and pull the long strand as far as it will go, to test the free movement. The total free movement will vary with the length between sprockets. If the length is from 5″ to 7″, the total free movement should be ⅜″ to ½″; if the length is from 8″ to 11″, the free movement should be from ½″ to ⅝″. If it becomes noisy remove 2, 4, or 6 links each; never an odd number.

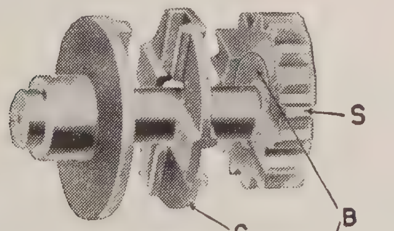

Fig. 61. Morse adjustable sprocket and vibration dampener for silent chains.

The Morse adjustable sprocket (Fig. 61) is designed for shafts, such as generator shafts, etc., when the shaft cannot be moved for adjustment. The sprocket (S) (Fig. 61) is mounted on a bearing which is eccentric to the shaft. By rotating the bearing, the sprocket is moved, thus adjusting the chain tension. The drive is through the sprocket to a plate-type universal joint (C) at the left end (Fig. 61), to the shaft. This joint also tends to relieve vibration of the chain, and is called a "vibration dampener." (Manufacturer, Morse Chain Co., Ithaca, N.Y.)

Chain alignment: When tightening a silent chain by movement of the generator, make sure that it is moved in perfect alignment, otherwise it will cause the chain and sprocket to wear rapidly. This is most important. If it is too tight, it will sing and also cause wear.

Example of Silent Chain Disassembling and Assembling (Cadillac models 53 and 55)

Detecting looseness: Looseness in the silent chains grows so gradually that it is scarcely to be noticed until the chains have become so loose that they jump the teeth of the gears. This, of course, destroys the timing. **The extent of the looseness may be felt** by grasping the generator shaft and rocking it back and forth. Any great looseness destroys the proper timing of the valves and necessitates a replacement of the chains.

Disassembling: After removing all parts so that access is gained to the chains, then turn the engine until one tooth of the cam-shaft-driven sprocket (A) (Fig. 64), which is marked with an arrow, is diametrically opposite the tooth with an (O). A tooth on the crank-shaft sprocket (B) has a similar arrow upon it, and the two teeth opposite each have an (O) mark. All should line up, as shown in Fig. 64.

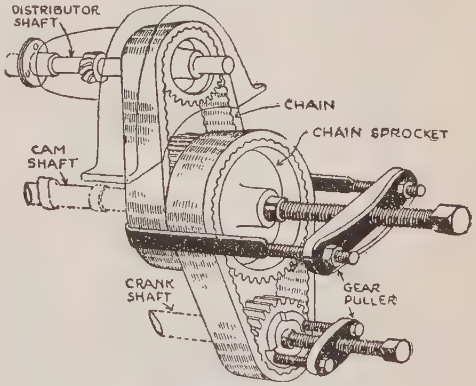

Fig. 62. Using special pullers, both gears and chains together with the distributor housing are removed at once. The generator universal must first be disconnected.

Apply the special gear puller, as shown in Fig. 62, to the crank-shaft gear; next apply the special cam-shaft gear puller, as also shown in Fig. 62.

Working both pullers together, remove both cam-shaft and crank-shaft gear, at the same time sliding the distributor housing and fan-drive chain forward. All will come off together. (The usual method is first to cut the riveted head of one of the seat pins on the driving chain, and to remove the seat pin and rocker pin. The driving chain is then removed. In refitting the new chains by this method, it is necessary to rivet the seat pins while on the gears and in the case. This is a difficult and tedious job. By the method outlined here, the chains are riveted on the bench easily, quickly, and with a certainty of the work being right.) Place the gears, chains, etc., on bench, removing cam-shaft driving chain.

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[1] See pages 74 and 75 for remeshing timing gears when using silent chains. Chains have a tendency to wear in the pins, so much so that they will often have sufficient slack to strike the case covering it. A 17″ chain has been known to have $1\frac{1}{16}''$ slack after 8,000 miles running. In this case a new chain is necessary, or enough links must be removed to take up the slack.

The repair: Cut off the riveted head of one of the seat pins on the fan-shaft driving chain, and remove the seat pin and rocker pins. Remove the fan-shaft driving chain. Clean all parts with gasoline, and examine the gears for wear. If worn, the faces of the teeth will be ridged, showing the marks of the chain links, and must be replaced.

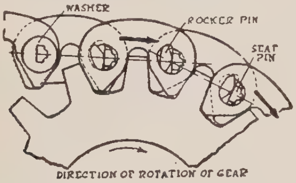


Fig. 63. In replacing the chains, make certain that the **arrows point in the direction of rotation,** and that the rocker and **seat pins are in the position shown.** Otherwise the chain will quickly ruin itself.

Place a new fan-shaft chain over the fan-shaft gear with the arrows on the outside links pointing in the direction in which the chain is to run (Fig. 63).

Rivet a small washer to one end of a seat pin in a vise. Bring the ends of the chain together. Insert a rocker pin; then drive the seat pin with its washer into place. Be certain that the rocker pin and seat pin are in the position shown in Fig. 63. Head over the end of the seat pin. Rivet up the new cam-shaft driving chain in the same manner.

Assembling: Place the cam-shaft gear on the fan chain, with the mark (O) in the lowest position. Place the cam-shaft chain on the gear, with the arrows pointing in the direction of rotation. Place the crank-shaft gear into the cam-shaft chain with the marks as shown in Fig. 64. Now slide the whole assembly into place on the engine, driving the gears home with a brass bushing and machinist's hammer. Replace the nut and washer on the crank-shaft end; and then replace the parts which are disassembled.

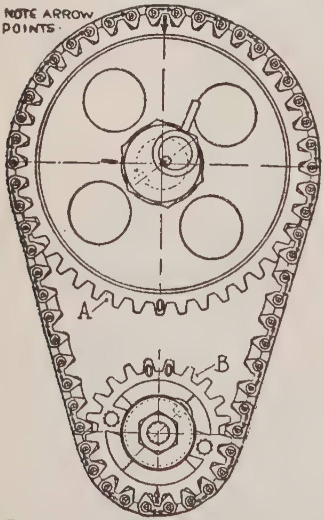


Fig. 64. The marks on the cam-shaft gear (**A**) should line up with those on the crank-shaft gear (**B**) before the gears are removed, and should be replaced in exactly the same position.

The valve timing: The valve timing was automatically cared for in replacing the cam-shaft driving chain as directed, providing the valve tappets have the proper clearance. The exhaust tappet should have .003″ clearance, the intake .002″; the exhaust should close and the inlet open on dead center. The inlet should never open at a point more than 1″ past dead center on the flywheel.

Ignition timing: Open the compression relief cocks, crank the engine until No. 1 cylinder (the one nearest the radiator, on the right-hand side when facing the engine from the front) is on the firing center. The pointer above the flywheel will then be exactly over the mark 1-5 on the flywheel, and both valves of No. 1 cylinder will be closed.

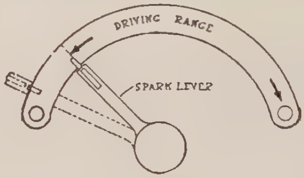


Fig. 65. Position of the spark lever, when timing the ignition. The end of the lever on the quadrant should line up with the point of the arrow, as illustrated.

With the timer open, as shown in Fig. **6A**, page 215, loosen lock screw (**A**) slightly. Then set the spark lever as shown in Fig. 65.

Connect the test lamp into the primary circuit, as shown in Fig. 65**A**. When the breakers are closed, the light will be lighted, if the ignition switch be closed.

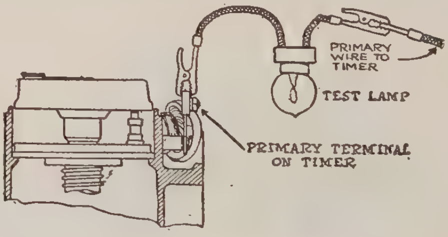


Fig. 65**A**. By placing a test light in the primary circuit, the exact instant that the spark occurs can be determined, as the light then goes out.

Replace the distributor rotor, and turn by hand until the distributor brush is under the terminal marked No. 1 on the distributing cover. Turn on the ignition switch. The light should light. Turn the rotor very slowly, in the direction in which it is driven by the engine, until the lamp goes out. Remove the rotor; tighten screw (**A**) of Fig. **6A**, page 215.

Replace the rotor and retard the spark. Then move the spark lever slowly back toward the point of the arrow, as shown in Fig. 65. When the point of the arrow is reached, the light should go out. If it does not, reset the rotor and cam, as directed.

GASKETS

Gaskets are used on the engine and transmission and other parts of the car, the **purpose** being to make tight joints. Thin gaskets are preferable to thick ones, and should always be used on all joints that come together square. Metal to metal joints are best, but it is next to impossible to make both flanges meet absolutely square. It is for this reason that some sort of flexible material is interposed to make up for the inequalities in material and workmanship.

There are several kinds of gaskets: Paper, asbestos, asbestos wire-lined, copper, copper-asbestos lined, cork, and felt, and in some instances, lead can be used.

For engine cylinder heads (if of the detachable type), the type of gasket almost universally used is the soft copper gasket, either lined with asbestos on each side, or copper on each side with asbestos inside, usually the latter.

When taking off the cylinder head for removing carbon, etc., the old gasket can be used again, but many repairmen find it advisable and economical in the long run to take no chances and to fit a new gasket.

When using a gasket of this type the use of **shellac is not recommended.** It has a tendency to set after the engine has run a short time, which interferes with the final tightening.

When applying a new gasket, in order to insure compression in all cylinders, the cylinder head should be drawn down firmly on the gasket and block with an even pressure at all points before the later operations of tightening are attempted.

The Victor Mfg. Co. states that while grease and shellac are used in applying gaskets, experience dictates that the best practice is to see that the face of the head and cylinder block, as well as the gasket itself, are **thoroughly clean,** and then to apply the gasket without grease or shellac. With the Victor gasket, soft copper is used, which works into the uneven parts.

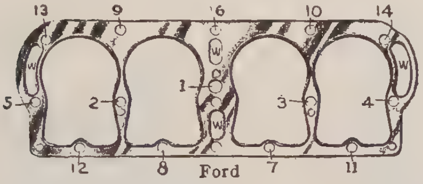


Fig. 66. **When putting on a new gasket, the bolts should be tightened in the order indicated above;** that is, tighten 1, then 2, 3, and so on to insure against lessening of compression and against leakage of water into the cylinders. This illustration also shows the shape of a typical copper asbestos-lined cylinder-head gasket used on cylinders with detachable heads.

The stud or bolt holes are numbers 1 to 14. The holes in the gasket provided for water circulation from the cylinder head to the cylinder water jacket are the other holes (W). Sometimes, when gaskets do not fit properly, the water works its way into the cylinder, thus causing water in the crank case, as well as a loss of compression.

Fig. 66 shows the **order in which cylinder-head stud bolts should be tightened.** The same general principle applies to all "fours," "sixes," "eights," and "twelves." A socket wrench is the best tool to use.

After the first operation of drawing down the nuts, they should be gone over in the same order a second and third time until they are as tight as it is safe to make them without stripping the threads.

The final tightening should be done after the engine has run a few hours, when, it will be noted, about a full turn can be taken on all nuts.

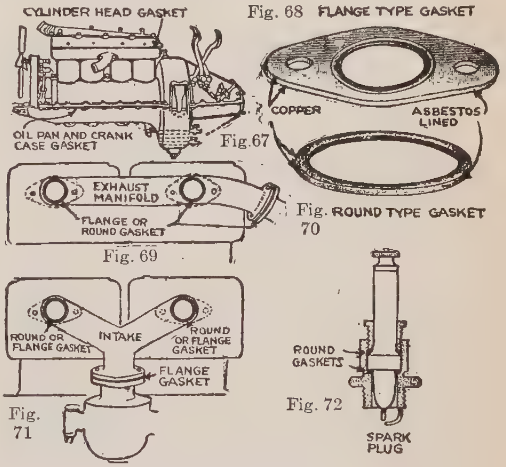
A type of gasket used extensively is the Victor gasket, made of pure copper and asbestos. When properly installed, they will not leak or blow out. See Fig. 66, showing a typical example of this type of gasket, and Fig. 67 showing how it is placed between the cylinder head and the cylinder block of the engine. Gaskets of this type can be secured in sets or singly for different engines.

Where old gaskets are used over again, the important point is to see that the surfaces are **clean,** and that the gasket is not damaged.

If there is a water leak or compression leak, a new gasket should be fitted after cleaning all surfaces thoroughly. If a new one is not available, then put shellac on each side of the gasket and apply before it dries, but be sure to scrape and clean the surfaces carefully before applying, otherwise a leak will occur. Alcohol is used to clean surfaces which were previously coated with shellac. Bear in mind that if there are any rough surfaces the gasket will leak.

Asbestos gaskets for cylinder heads of marine, stationary, and such types of engines are often used. The copper and asbestos gaskets are preferable, however. The following explanation will serve to make this clearer.

Asbestos gaskets of this type can be purchased ready to apply, or cut from sheet stock. They are made of closely woven, long-fiber asbestos yarn and brass wire closely woven and impregnated with a heat and water-resisting compound. The red compound on one side sticks to the flange when a joint is broken. The graphite on the other side allows the joint to be easily taken apart. Sold in rolls or in gaskets cut to order. This is also used in many places, such as the water plate, but it is more commonly used where there is a great deal of heat. If sheet asbestos (not wire-woven) is used, it ought first to be soaked in linseed oil.



Figs. 67 to 72. Showing the different places where the round and flanged type of gasket can be used.

Copper (also brass) asbestos-lined gaskets, termed the "flange" type (Fig. 68) are used extensively for placing between the intake manifold and cylinder (Fig. 71), and also between the carburetor and the intake manifold; between the cylinder and the exhaust manifold; between the exhaust manifold and the exhaust pipe (Fig. 69).

The round type of copper asbestos-filled gasket (Fig. 70) is used in spark plugs (Fig. 72). The Victor Mfg. Co., 5750 Roosevelt Road, Chicago, supplies gaskets of this type. When ordering, the inside diameter is given, or else name the make of car and where the gasket is to be used.

Paper gaskets are often used in many places on the engine, but cork gaskets are preferable. Some of the places where paper can be used are between the cylinder and crank case (not between the cylinder head and cylinder); on the oil and water pumps; on the generator and starter motor; on the carburetor (lead, cork, and leather gaskets are also sometimes used here); on the transmission gear-case cover. The housing cover over the differential is sometimes fitted with a gasket, but more generally it is simply given a coat of shellac. The hub flanges of wheels, clutch members, valve-case covers, etc., also require paper gaskets.

When using paper gaskets, select a heavy wrapping paper and cut it to size, or order direct of the manufacturer.

A gasket paper which is oil and water-proof is made by the Weber Supply and Specialty Co., 127 N. Dearborn St., Chicago, Ill.

Many repairmen make a practice of coating the gasket with grease in order to hold it in place while fitting the parts together.

To remove paper on the running-boards of new cars: A new car usually has brown paper over the running board and floor boards, to protect them in transit. A good way to remove this neatly is to fasten a safety-razor blade in a small block of wood and trim close. No ragged edges will then be in evidence.

Cork gaskets are not suitable for cylinder heads, as they would burn or blow out under the extreme heat and pressure to which they are subjected in this particular spot. The cork gasket is used extensively for the same purposes mentioned in connection with paper gaskets, such as for oil, water, and gasoline connections. They are particularly adaptable for pressed-steel parts because of their flexibility, which enables them to fill up all the rough spots and unevenesses in such parts. Their main applications are between the oil pan and the crank case; on the oil-pan bottoms; on the valve-plate covers; in the water-manifold connections; in the timing-gear case; on hand-hole covers on the transmissions, clutch and differential housing, and hub flanges of wheels, and for all similar purposes.

Felt gaskets are seldom used.

Cutting Gaskets

Perhaps one of the first things at bench work that a young repairman is taught on entering a shop is that of cutting gaskets.

The gasket between the base of the cylinders and the crank case and the cover of the gear box are usually made of paper (or of cork, which is obtained already cut. Paper gaskets are also obtainable from the manufacturer, already cut).

If care is not exercised in removing a cylinder from the crank case, or other parts, the paper gasket may easily be damaged by part of it adhering to the cylinder and another part to the crank case. Should the gasket be ruined by any chance, a new one can easily be made in a few minutes.

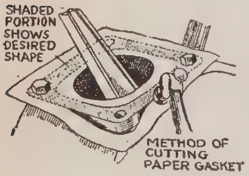

SHADED PORTION SHOWS DESIRED SHAPE
METHOD OF CUTTING PAPER GASKET

Fig. 73

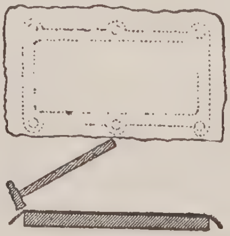


Fig. 74

Fig. 73. Cutting a **gasket for the lower part of the cylinder,** where it fits to the crank case.

Fig. 74. Cutting a gasket for the transmission cover.

Cutting gaskets: A sheet of fairly heavy wrapping paper should be obtained and a hole made just large enough to accommodate the piston. The paper is then rested on the crank case or cylinder (Fig. 73), and with the aid of a ball peen hammer tapped all around the edges. It is, however, best first to mark the holes for the holding-down bolts, and to insert the latter to hold the paper in position.

When making the corners and also the holes for the bolts it is best to use the peen or round end of the hammer.

It is not necessary to strike the paper a hard blow, a series of slight taps only being required. With these, it will be found that the gasket will have a nice clean cut edge, and will conform exactly to the desired shape.

It does not matter much how complicated the shape of the gasket may be, for if these suggestions are followed, making a new one will be fairly simple.

The hardest part of the whole procedure is to keep the paper in place on the crank case, but if the holes for the holding-down bolts are first made and the bolts are then inserted, as shown in the illustration, no difficulty should be experienced.

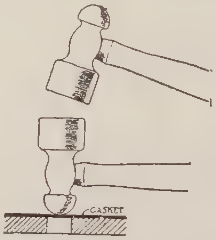


Fig. 75

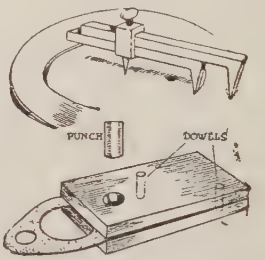


Fig. 76 (upper)
Fig. 77 (lower)

Fig. 75. When cutting gaskets from metal and asbestos packing, felt, and other materials, it is sometimes difficult to **cut bolt holes,** especially those close to an edge, without damaging the material. A way out of the difficulty is to use two round-headed hammers, placing the round head of one over the hole and striking it with the other.

Ball bearings of various sizes are also useful in cutting small holes, such as for studs, in gaskets. After the gasket is cut to shape by hammering around the edge of the gasket flange, a ball bearing is put over the hole and hammered until the hole is cut in the gasket. This method produces sharply defined edges. In cutting paper gaskets it is advisable to grease the paper first, so that it will stick to the surface.

Fig. 76. **A device for cutting circular gaskets** may be made out of two pieces of steel shaped as shown and fitted with a clamp which forms the center. The two cutting members are adjustable, so that practically any size of gasket may be cut.

Fig. 77. It is difficult to cut holes in gaskets and not have ragged edges. When there are a great **many holes of a given size to be made, it is advisable to construct a die** consisting of two plates of metal doweled together and with a hole or series of holes through which the dies may be pushed. The gasket material is slipped between the plates, and then the die is forced through with a hammer.

Another method is to file a chiseled edge on short sections of different sized iron pipes, which can be used as punch cutters.

Cutting gaskets for gear box or transmission cover: The same principle applies here (see Fig. 74). Be careful in tapping to see that the edges are not broken. Sometimes it is possible to press the paper by hand and to make indentation enough from which to cut the gasket.

Other gaskets, such as mobolene and asbestos gaskets, are made in a similar manner, but are usually marked off by pressure of hand or finger, when placed over the part to be fitted, and then cut out with a sharp knife. Asbestos gaskets for cylinder heads are sometimes made when nothing else can be had. The asbestos is soaked in linseed oil before applying.

Packing for Water Pumps and Lubricators

Packing for water pumps and lubricators: For packing the water-pump shaft, etc., nothing has been found better than asbestos string plentifully smeared with a mixture of heavy oil and graphite. Candle wicking can also be used if asbestos string is not handy.

Shellac

Shellac is an excellent preparation to insure a good tight joint, and ought to be used on only one side of a gasket. Shellac dries up; but a good way to handle it is to have a wooden stopper which can be used for applying the shellac as well as serving as a stopper.

When a workman wishes to spread a coat of shellac upon a gear-case cover, or a gasket, he has but to invert the bottle with the stopper in place, then remove the stopper and roll the large end over the surface to be smeared, and a coat of shellac is left in its wake.

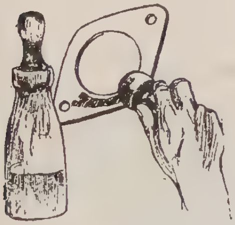


Fig. 78

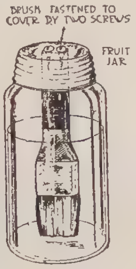

BRUSH FASTENED TO COVER BY TWO SCREWS
FRUIT JAR

Fig. 79

Figs. 78 and 79. Methods of keeping shellac on hand for ready use.

How to mix shellac: Secure an open-mouth bottle; fill nearly full of flake shellac, and pour in alcohol, and let it dissolve. This will make a very thick solution. To make it thinner, put in less flakes of shellac. The flakes can be secured at any drug store.

Using shellac: In replacing detachable cylinder-heads, only the smallest possible amount of shellac should be used, and this should be quite thin. If the shellac is heavy and any considerable quantity is used, it will squeeze out into globules and the first explosion will blow these into the valve ports, where they will start an accumulation of carbon.

Note. When using shellac on a gasket, use it on but one side. The gasket can then be used over and over again. Otherwise it will be necessary to make a new one each time it is removed. Common grease is used by many to hold a gasket in place until the part is placed in position and drawn up.

Berry Bros., Detroit, Mich., manufacture shellac, and also a substitute called **"gasket cement,"** which is made from grasstree gum. It is stated that this is as satisfactory as shellac.

Shellac with copper gaskets: Where copper gaskets are used, it is best to clean all surfaces thoroughly and to use a new gasket and draw it tight. After running the engine for a day or so, draw the gasket up. If the surface is not clean, the gasket will leak.

If a new gasket is not obtainable and the old gasket is used over again, and if shellac was used, then clean the shellac from the surface and also clean the old gasket with alcohol. Shellac can then be used on both sides, as there will probably be some rough surfaces still left. Do not get shellac in the valves or cylinder.

Shellac with paper gaskets: Use shellac on one side only, that is, coat one of the metal surfaces and then put the gasket over it, and bolt down the other metal side before it dries. This leaves one side of the gasket dry, and before bolting down the metal surfaces, a light coating of oil or grease can be given to the other metal surface. This will facilitate the easy removal of the gasket without ruining it.

Paper gaskets are not always shellacked, for if one proves to be damaged, then the shellac and the paper gasket itself will have to be removed by scraping and by the use of alcohol before another can be applied.

Many mechanics simply put **a light coat of grease** over both sides which hold the gaskets in place, while fitting the metal surfaces.

If there are studs to hold the gaskets, while the parts are being put in place, it is best not to use grease or shellac.

RADIATOR REPAIRING

Radiators are divided into two classes: **tubular radiators** with straight vertical tubes with crimped fins, as in Fig. 14, page 147, and with vertical tubes with horizontal fins, as in Fig. 15, page 147. The **cellular type** comprises both the tubular type, resembling the genuine cellular, as in Fig. 18, page 147, and the cellular type, as in Fig. 19, page 148.

Equipment

The equipment necessary for repairing tubular radiators, as well as those of the cellular type, consists of the following:

1. **A table,** as shown at (1) (Fig. 81) for assembling or disassembling, or a **work bench** as shown in Fig. 80. The latter is designed for Ford radiators. This work bench (Fig. 80) includes a table, dimensions of which are given on the illustration, covered with tin, and with racks for turning radiators upside down or otherwise.
2. **A test tank,** as shown in (2) Fig. 81, or in Fig. 80. Air pressure is necessary, but not over 8 or 9 lbs.
3. **A compressor** (12) (Fig. 81) should be provided for the air pressure, and a hot-water tank can be used for an air receptacle with a gauge (8) on the tank to indicate pressure. This air tank can be used for testing radiators, as explained on pages 736, 737. It can also be used for the air supply to the torch (Fig. 80), in connection with gas.

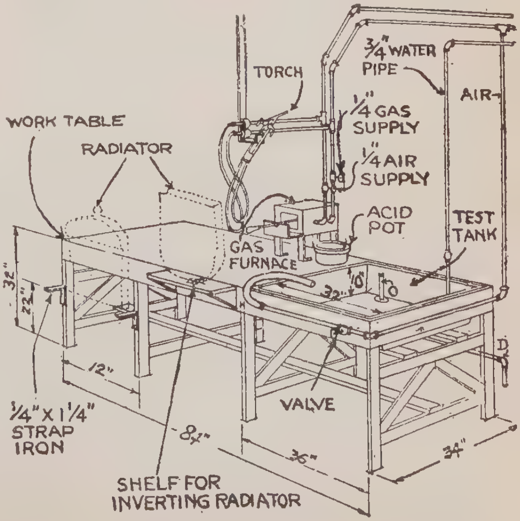


Fig. 80 Radiator repair outfit.

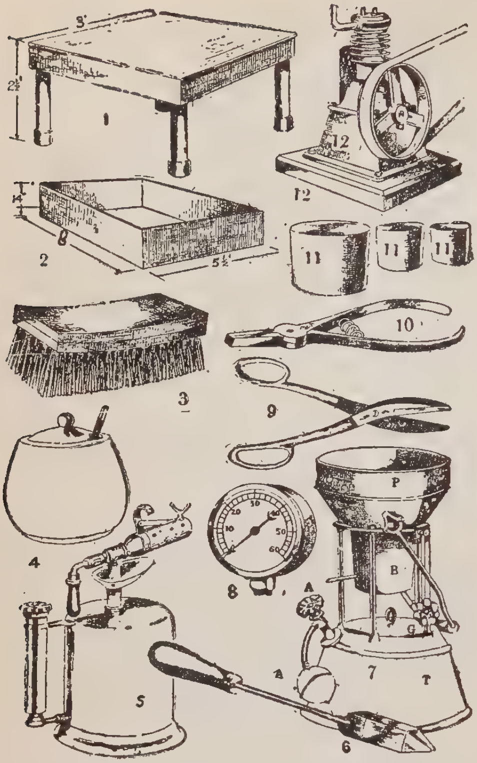


Fig. 81. Radiator repair tools and devices.

4. **A gasoline fire-pot torch** (7) (Fig. 81) or a gas furnace (Fig. 80) must be provided for heating the soldering irons.
5. **Two soldering irons** (6) (Fig. 81) heavy enough to convey sufficient heat to the work. The iron should taper to a flat point as in Fig. 82. Long-pointed irons for core work are also necessary.
6. **Acid** (4) (Fig. 81) must be kept in a stone pot. It is made of commercial muriatic acid cut with zinc, that is, zinc is placed in the acid and left in it until boiling stops. It is used for cleaning parts before soldering, and as a flux for soldering.
7. **A blow-pipe torch** (5) (Fig. 81) must be used, but should be of a type which will give a concentrated or flooding flame. It is used for soldering, loosening, or removing sections.
8. **A combined gas and air-type torch** (Fig. 80) is necessary. This torch should throw a fine needle-point flame (see page 751). With such a torch and with wire solder, inside core leaks, honeycomb radiators, and hard-to-get-at places can be reached, but a torch of this kind must be kept in motion, otherwise part will be burned.
9. **Wire brushes** (3) for cleaning off rust. See also page 740 for small scrapers.
10. **Metal snips,** or shears (9).
11. **Weaver pliers** (10) for straightening core material, also rods for running through bent tubes.
12. **Rubber plugs** (11), ½" to 4" diameter in ¼" sizes for closing openings in radiators when testing with air. See also pages 737, 740.

Soldering Pointers

Solder: Use "50-50" solder. It can be secured in wire or bar form. See also pages 738, 720.

The soldering iron should be well tinned. When iron becomes so dirty that it cannot be cleaned on sal-ammoniac it should be filed and re-tinned.

To tin an iron, heat it, dip it into the acid, and rub it on a piece of sal-ammoniac, at the same time holding a bar of solder on the iron and thus coat its surface with the solder. Or, if a pot of molten solder is at hand, dip the iron into it. Never permit the iron to become red hot.

To clean old fittings hard to solder, heat the part light red and plunge it into raw muriatic acid.

Sweating: When extra strength is desired, seams are "sweated." Sweating is accomplished by first putting the soldering iron (Fig. 82) on the seam to be sweated so as thoroughly to heat the metal. The solder is then flowed on to and between the pieces of metal to be united. The iron is again laid on the seam, in order to make sure that the solder flows in as deeply as possible. The iron must be **very hot.**

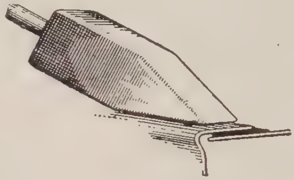


Fig. 82. Sweating a seam.

Torch for radiator work: Although the soldering iron, which is drawn to a very fine point, is used extensively for soldering radiators in close places, the torch can also be used, especially for reaching the inner part of cells of a cellular radiator. The torch must throw a very fine **needle-point** flame.

The type R-1 torch, not illustrated, of the Imperial make, is suitable for this work. It operates from city or coal gas. See also page 751.

The Wasburn Burner Corpn., Kokomo, Ind., also manufactures a torch designed especially for radiator repair work, producing a fine needle-point flame.

A gasoline gas generator, manufactured by F. L. Curfman, Maryville, Mo., is a very satisfactory method of generating gas for a torch for radiator repair work where gas is not obtainable, and the price is very reasonable ($12.50).

A gas torch, No. 70, to operate from this gasoline gas generator throws a needle-point flame and sells for $3.00. Supplied by F. L. Curfman.

Testing Radiator for Leaks

After the removal of the radiator from the car, the first thing to do is to test it. The inlet, outlet, and filler cap must be plugged, so that air pressure may be applied to the overflow pipe. Then if the radiator be put under water, the bubbles will show where the leaks are.

When removing a radiator, the hose and flange are left on, as shown in Fig. 83. If the radiator is to be repaired, then the lower hose is removed.

The openings in the radiator are then stopped up by means of expanding rubber plugs, or by an arrangement as shown in Fig. 84. (Similar plugs can be secured of F. L. Curfman.) One plug is inserted in the intake, another in the water return, and another in the filler opening.

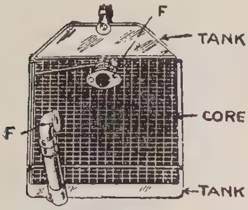


Fig. 83

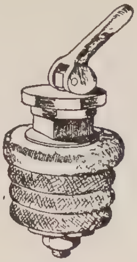


Fig. 84

The air pressure is applied to the radiator through the overflow pipe, by slipping the rubber hose from the air line over the overflow tube. The radiator is then immersed in a tank full of water (Fig. 85), and the **leaks determined by the bubbles.** The leaky parts are then marked.

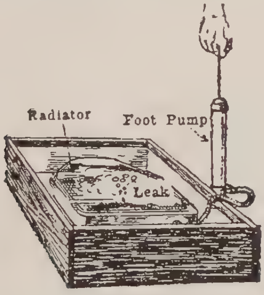


Fig. 85. Testing a radiator submerged in water with air pressure.

Another method for closing up a radiator for testing is to solder a piece of tin in the filler opening and to put a rubber plug in the bottom outlet and bolt a rubber gasket at (F) (Fig. 83). Then place the air-pressure hose on the overflow pipe.

Another plan is to remove the radiator from the car and plug up all but one opening; then run the tube of a tire pump through a **cork** and place the cork in this last opening.

Note. **A radiator should never be subjected to a pressure greater than 2 to 4 lbs.** New units will withstand from 8 to 15 lbs., but that is seldom necessary.

The next procedure is to determine if the radiator is a tubular or cellular type, by studying page 147.

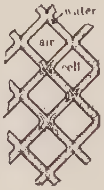
Removing Core of Radiator for Repairs

The core of a radiator consists of all the tubes or cells through which the water flows from the upper tank to the lower tank (see Fig. 83). The core is connected to the upper tank and the lower tank by projecting it into the tanks and then soldering it.

The core can be a tubular or cellular type, as shown in Figs. 86 and 87.

In the cellular type (Fig. 86), the water flows **around** the cells and air circulates **through** the cells, whereas **in the tubular type** of core, the water flows **through** the tubes (Fig. 89), and air circulates around the tubes.

When a **radiator core is damaged badly,** the core must be removed. Place the radiator on the repair bench, face down, and unsolder the lugs which hold the shell to the body. Then with a torch and a pry bar (Fig. 87), unsolder the core from the bottom tank; next unsolder the core from the top tank, starting at the lower flange or header. The core can then be removed. Do not hold the flame in one place too long.



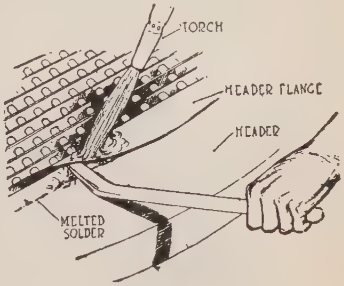


Fig. 86 Fig. 87

Fig. 86. Cellular type of radiator core.

Fig. 87. Tubular type of radiator core.

Repairing Radiator Tubes

To straighten damaged radiator tubes when the core is removed, use a long steel bar (Fig. 88). This will also clean the tubes and all tubes should be subjected to this process.

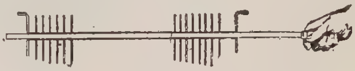
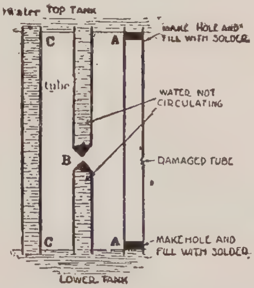
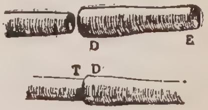


Fig. 88

When only one or two tubes are damaged,[1] the tube can be cut out of service altogether; for instance, see (**A**) (Fig. 89). Make holes at the extreme top and bottom of the tube and as close to the header as possible, using a prick punch. Flow solder into the holes liberally, and let it set until hard. See (**A**) (Fig. 89).





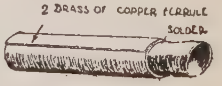


Fig. 89

Fig. 90 (upper)

Fig. 91 (below)

Sometimes **tubes are cut out of service** by cutting the tube and pinching it, and soldering as shown at (**B**). This, however, is not good practice, as the water will collect and freeze in winter.

To splice a tube (see Fig. 90): Cut out the damaged part of the tube. Select another piece of the same diameter as the piece removed, but slightly longer. Spread one end by reaming with a punch or any tapered tool, and make the other end smaller by making a few cuts in it lengthwise, and then compress the end. Fit the large end (**D**) over the end of the tube being repaired, and the other end over the other part of the tube, and solder.

---

[1] It is not necessary to remove the core or to tear down the radiator for slight repairs. Simply force the fins to one side and straighten them after the repair. Before making a repair, it is, of course, necessary to test, in order to find out where the leak is. This should then be soldered without removing the core, if it is only a slight leak.

Another method (see Fig. 91) is to wrap a piece of light brass or copper around the injured part of the tube, so that the edges of the patch just meet or fail to do so by a slight margin, and then to solder it.

There are many methods of repairing radiators: A method for repairing a leaky tube is shown in Fig. 92.

The radiator is placed on a bench, and the leaky part of the tubes is heated with a blow-torch. When quite hot—a little hotter than boiling—muriatic acid soldering solution is poured through the fins, all over the leaky tubes, to clean their surfaces. The cleaning process is very important.

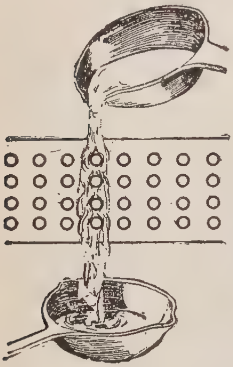


Fig. 92

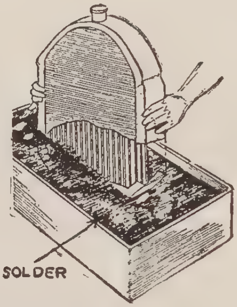


Fig. 93

Fig. 92. Illustrating how solder is poured over the leaky radiator tubes.

Fig. 93. Illustrating dipping a radiator in a solder bath.

A ladleful of solder is then melted. The radiator is bolstered up from the bench on blocks, and the melted solder is poured through the fins, over the leaky tubes. Note the method of catching the excess solder.

Then the radiator is turned over and the solder is poured in from the other side in exactly the same manner.

A little more acid is then added and a torch is applied to melt the solder and sweat it into all the leaks, closing them permanently.

What is known commercially as "50-50" solder is adapted to this work.

Though leaks and splits of quite a large size may be fixed in this way, it is occasionally necessary to tear the radiator down and to put in new tubes. The hardest part of the job is tearing the radiator down to the core and building it up again. New cores can be purchased with the top of the bottom tank soldered on.

There are many other methods of cleaning and soldering leaks. The leaky parts are often scraped bright with small **scrapers** made from three-cornered files with the teeth ground off, and then acid is applied and the parts are soldered with **a soldering iron made especially for this work** by taking a 1½ lb. soldering iron, heating it red hot, and drawing out long and slim. Then tin the iron carefully.

Soldering by dipping: In large shops the tubular radiator is dipped into a solder bath (Fig. 93). The parts to be soldered are thoroughly cleaned and treated with muriatic acid solution, then dipped. The solder naturally will adhere only to the parts that are clean. **The solder** is made of 50 per cent lead and 50 per cent bar tin melted together.

Radiator Fin Repair

Where the lateral fins of a tubular radiator (Ford type) have been removed for a repair, a false fin (**D**) may be made as shown in Fig. 94, by folding a ¾″ strip of light brass, copper, or even sheet iron longitudinally upon itself to make a double strip ⅜″ wide. Bridge it across the gap in the fin or fins, and then paint the patched place the same color as the rest of the core.

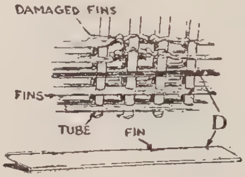


Fig. 94

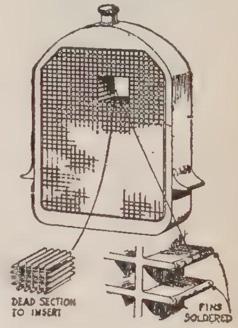


Fig. 95

Another fin repair (Fig. 95) is shown of a cellular-type radiator.

Repairing Cellular Cores

The cellular core is removed from the tank by melting the solder with a blow-pipe torch. As inch by inch is melted away, insert a piece of sheet iron between the core and the tank, so that when the flame is removed the solder hardens and the core and tank are not reunited.

Inside leaks in cellular cores[1] can be soldered with a torch throwing a fine needle flame. Be very careful, however, to not burn the light metal up. Squirt acid or soldering flux on the spot with an ordinary oil squirt can. Deposit solder on the spot, using wire solder and the blow-torch. Smooth the solder over afterward with a small thin iron. A suitable iron for this work may be made from ordinary ¼″ iron.

To remove a leaky cellular section from a core, the leaky section is cut out (Fig. 95) and all water passages into all sides are soldered up. After testing, a dummy section is inserted and soldered. The cooling capacity will be reduced slightly.

It is advisable to secure an old radiator core and to practice soldering it before attempting a repair.

Remember, when soldering parts of the radiator, that the metal must be scrupulously clean before the flux is applied, or else the solder will not hold.

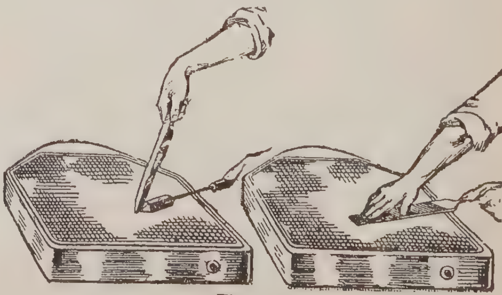


Fig. 96

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[1] It is not necessary to remove the core from the radiator shell unless there are several leaks or the core is damaged.

After completing the soldering, file smoothly and then place the radiator in the water and again test it with air pressure, in order to see if the leak is properly repaired.

Small leaks are dealt with on pages 151, 152.

Painting a Radiator

It is very difficult to paint a radiator quickly and thoroughly with a paint brush, and the usual plan, where a great deal of the work is done, is to dip the radiator in a paint solution. A very satisfactory job can, however, be quickly done with a spraying outfit. A very simple home-made device is here illustrated.

It consists simply of a construction such as is shown in Fig. 97, in two sizes and designs, which comprises a can (**D**) for the paint, consisting of a mixture of lampblack and turpentine, a hollow cylindrical tin handle (**B**) attached to the can, an air pipe (**A**) passing through the handle and through the can, as indicated by the dotted lines; and another similar pipe or tube extending downward at right angles from the one end of the horizontal tube into and near to the bottom of the can, as is also indicated by dotted lines. This is merely an adaptation of the principle employed in most atomizers.

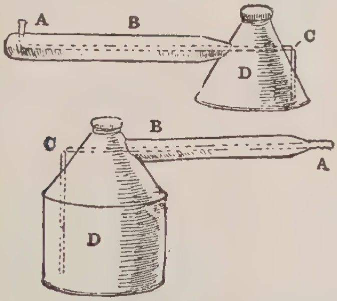

Fig. 97. A home-made sprayer for painting radiators.

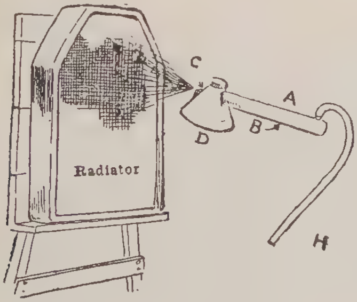

Fig. 98. Showing how the paint is sprayed on the radiator.

When a stream of air is forced through the air tube (**H**) and (**A**), passing through the handle, and directed across the opening (**C**), at the top of the vertical tube the fluid from the inside of the can is drawn up and sprayed on to the radiator. It is best to tilt the radiator when spraying, so that the solution will drain off. (*Motor Age.*)

A home-made spraying outfit similar to the one shown above is shown in Fig. 99.

The outfit consists of a ½-gal. oil can, made into an atomizer by attaching a tire pump to the end of the air pipe (**B**). A piece of small brass pipe (**A**) is mounted in one side of the can, the upper end of it extending a short distance outside of the top. A second piece of pipe is mounted in a horizontal position in the top of the can, as shown at (**B**). If a handle is attached to the can, as at (**C**), the piece of pipe (**B**) may pass through it lengthwise and extend a short distance beyond the end of the handle. Both pipes are soldered to the top of the can, and the screw top is provided with a gasket to make it tight.

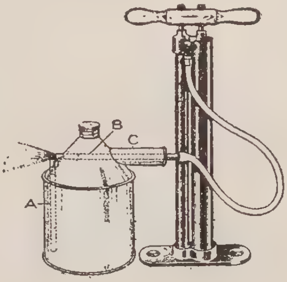

Fig. 99. Spraying device made of an oil can and a foot pump.

When the air is forced through the horizontal tube (**B**) and caused to pass across the opening in the upper end of the vertical tube (**A**), the liquid in the can is drawn up and forced out in a fine spray. A mixture for spraying the radiator may be made of lampblack and turpentine. A sheet of paper should be placed back of the radiator to protect the engine, and around the outer edge, to prevent the liquid from bespattering the finish. Wipe off any of the mixture which may splash on the painted part of the radiator before it dries. At first the color will appear gray, but will soon darken. (*Popular Mechanics.*)

Paint for a radiator: Mix 3 oz. boiled linseed oil, 4 oz. lampblack, 1 oz. turpentine, and thin down with turpentine to the proper consistency. In applying, the radiator must be either dipped into the solution (in this case a great deal more must be mixed), or sprayed, or the radiator can be placed on boxes, face up, and painted with a thin mixture as described above, applied plentifully so that it will run through the cellular parts of the radiator. A camel's hair brush can be used to reach places not covered.

Paint for fins can also be made from drop-black ground in japan and gold size, thinned with turpentine.

Radiator Leak Preventives

There are many so-called leak preventives. For instance, the manufacturers claim for a cement called "cold solder" that if it is pasted externally on a leak (Fig. 100), it will harden and stop a leak temporarily until the radiator can be repaired. (Made by Stone Solder Co., Cleveland, Ohio.)

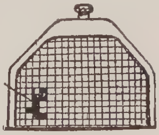

Fig. 100

Another leak preventive is a chemical mixture of cement which is placed internally into the radiator when the water is hot. The solution is supposed to pass out of the leak in the radiator, and as it is exposed to the air it hardens and closes the leak. It is claimed that this preparation will also close cracks in water manifolds, etc. It is stated that slight leaks in radiators, and even a crack in the water manifold, can be stopped by the use of some of the radiator cements circulated in the water system. Some of the manufacturers of radiator cements are, Woodworth Mfg. Corpn., Niagara Falls, N.Y.; X-Laboratories, 630 Washington St., Boston, Mass.; N. W. Chemical Co., Marietta, Ohio.

Cleaning a Radiator

The circulating system should be carefully washed out, early in the spring, because the anti-freezing solutions, used in the winter, are prone to leave the tube clogged up. In summer, it is advisable to flush out the circulating system about once a month (see page 151).

To do this properly, the radiator inlet and outlet hose should be disconnected, and the radiator flushed out by allowing the water to enter the filler neck at ordinary pressure, whence it will flow down through the tubes and out at the drain cock and hose. The water jackets can be flushed out in the same manner.

To remove scale from the inner surface of the radiator: One method is to use hot water, in which a small amount of ordinary washing soda has been dissolved, afterward rinsing this out with clean water.

For very hard deposits a solution of one quart of commercially pure muriatic acid to five gallons of water should be circulated through the cooling system slowly for five minutes.

Another good method is, to one pint of glycerine add enough boiling water to fill the system, then run the motor slowly and drain out after running, and flush with fresh water. Reversing the flow of water in flushing also helps.

When it is necessary to clean the radiator spaces of accumulated mud, the radiator should be flushed from the rear, not from the front. In that way you avoid getting water into the magneto or ignition system, which is often short-circuited when the moisture enters it.

Radiator Repair Pointers

The following paragraphs will give an idea as to where to obtain some of the parts, such as cores, fins, etc.

Radiator Cores

The Ford radiator has a tubular core with fins (see Fig. 83).

The core of a radiator is the principal part, and can be purchased separately from the upper and lower tanks.

The core can often be purchased cheaper than it can be repaired. For instance, if any great number of tubes, say more than ten, need repairing, then a new core is advisable.

The core is usually measured by its thickness. The Ford radiator is 2⅝" thick.

A firm that makes a specialty of supplying cores to repairmen is the Ideal Auto Radiator Co., 213-23 N. Morgan St., Chicago, Ill. **Cores are sold by the square inch.** The height of the core is multiplied by the width, to find the number of square inches in a core. The manufacturers just named make five standard thicknesses, 2", 2¾", 3½", 4", 4½", to fit Ford, Chevrolet, Dodge, Studebaker 6, Cadillac, and Maxwell.

Radiator Parts

The material listed below can be secured of F. L. Curfman, Maryville, Mo. Mr. Curfman also issues a very interesting **booklet on radiator repairing** of a practical nature, covering repairs of both "tubular" and "cellular" radiator cores.

False fins made of tin or brass.

Paint for radiator fins.

Side walls, bottom and lower tanks, cores, filler necks, brass rivets, etc.

Copper tubing tinned, ¼" outside diameter, in lengths of 15", 17¼", 20", and 22".

Brass pipes 5/16" tinned, for overflow pipes, 29" long.

Soft sheet brass, hose clamps, drain cocks, etc.

Radiator Repair Tools

In addition to the tools listed on page 736, the following are further suggestions:

Electric flash light for examining close places, and also a special magnifying mirror.

Brushes for cleaning, acids swabs, etc.

Soldering irons made specially for small places.

Scrapers for close places.

Rubber stoppers: a gasoline torch of special design with a needle-point flame.

Torch with larger flame.

Flux and a flux squirter.

Air compressor of special design which can be operated from a 1/6 h.p. motor and from a lamp socket, to be used for air pressure for testing and for a gasoline torch. No tank required.

Gasoline gas generator for use with a gasoline torch.

Coil spring for placing in copper overflow tubing, so that it can be bent, etc.

Radiator Solder and Flux

Cleaning parts to be soldered is most important. This can be done by **scraping** and also, if in a close place, by using **muriatic acid** applied to a cloth attached to a wire.

Soldering flux, which is applied after cleaning in order that the solder may stick, is made of cut muriatic acid, as described on pages 736, 720, 721.

Wire solder with acid or flux in the core of the solder is best for radiator work. Write Chicago Solder Co., 218 No. Union Ave., Chicago, Ill.

Thawing Radiators

This would seem to be a simple matter, but, as in everything else, there is a right and a wrong way of doing it. The common practice is to block off the air and run the engine with a retarded spark, depending upon the heat generated to do the work. This method is permissible if the freezing is slight. However, if the unit is frozen solid, damage to the engine may result long before the solid mass liquifies, for the reason that the water in the jackets very quickly boils away, leaving the engine dry. By far the better plan is to remove the radiator and immerse it in hot water in the testing tank, as shown in Fig. 101. See also pages 153, 150, 154.

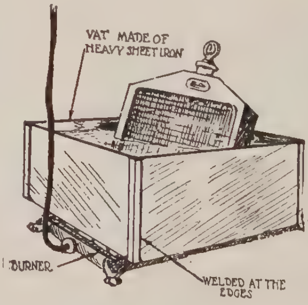
VAT MADE OF HEAVY SHEET IRON
BURNER
WELDED AT THE EDGES

Fig. 101

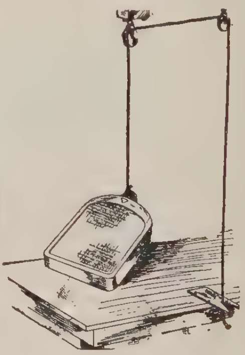

Fig. 102

Fig. 101. **To thaw out a solidly frozen radiator,** place it in hot water in the testing tank. Do not have the water so hot that it will damage the finish.

Fig. 102. A device which is quickly and easily made for **elevating a radiator while soldering.** (*Motor Age.*)

INSTRUCTION No. 66

OXY-ACETYLENE WELDING AND CUTTING

OXY-ACETYLENE WELDING[1]

Blow-pipe welding is a very ancient art, and was first practiced by the Egyptians. The early process consisted of heating metals of a low melting point by means of a torch, using a crude fuel gas and drawing the necessary oxygen from the air.

The modern process of blow-pipe welding is somewhat similar, but it is applied successfully to the welding of high melting-point metals,[2] as well. This was not possible until oxygen was obtainable on a commercial scale, and a fuel gas giving the necessary high-flame temperature could be provided in safe, convenient, and purified form.

Blow-pipe welding is generally known as "autogenous" welding, although the same term could apply to electric welding. Autogenous welding must not be confused with brazing or soldering. Brazing or soldering is where a joint is made in which a different metal, having certain adhesive qualities, is used as a binder—it adheres, but does not "fuse." Oxy-acetylene welding is where pieces of metal are **united,** or new metal is added, as in the case of **building up worn parts**—welding iron, steel, cast iron, malleable cast iron, aluminum, brass, copper, etc.

Before this process of welding was invented, when a crank case or an exhaust manifold, gear case, cylinder, or other metal part was cracked or broken, it was necessary to get a new part, fully machined, from the factory. This was quite an expensive proposition. With the oxy-acetylene outfit it is possible to repair these at a very slight cost and to save those parts which would otherwise be worthless. Steel, iron, aluminum, brass, copper, platinum, and other metals can be perfectly united by this process.

Method of welding: To those who are not familiar with the method by which welding operations are performed with this process, it may be said that welds are made by directing the oxy-acetylene flame on the pieces to be welded at the place where they are to be joined, until the metal is molten, and then adding additional metal of the same character, which is provided in the form of wire or sticks of suitable dimension for the purpose.

There are two types of oxy-acetylene outfits: the **stationary** type and the **portable** type. The parts of the stationary outfit consist of a generator which generates the acetylene gas from carbide, a tank of oxygen, a torch of special design, and a special iron table with a brick top.

The portable outfit consists of the same parts, but instead of there being a gas generator, the acetylene gas is compressed into tanks by concerns who make a specialty of this work in all large cities. This type is the one mostly in use in small shops. The portable outfit can be put into a car and carried right to a garage for the work to be done, and will often save dismantling the engine or broken part.

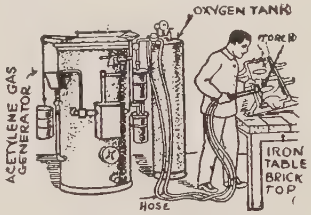

Fig. 1. The stationary oxy-acetylene outfit. Note the iron table with brick top.

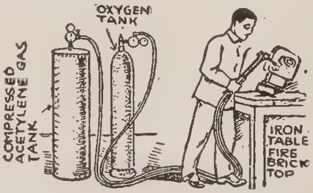

Fig. 2. The portable oxy-acetylene outfit.

The oxy-acetylene welding and cutting outfit can be used for various purposes as follows:

1. Welding broken frames, gears, shafts, crank cases, engine supports, axle parts, castings, cylinder water jackets, gear-sets, etc.
2. Cleaning tire vulcanizer molds.
3. Removing solid tires.
4. Burning carbon from cylinder (see Index under "Carbon removal").
5. Removal and replacement of terminal straps, plates of storage batteries, and other lead parts (see Index under "Lead burning").

Qualifications of a Welding Operator

A few weeks' practice will develop the skill necessary to handle ordinary work likely to be met with in the average shop. Very thin plate work and neat work will, of course, require skill and longer practice.

Welding of plates over ¼″ thick should not be attempted on particular work, until the operator has demonstrated his ability by first welding some sample pieces.

The operator must have a fair knowledge of the nature and properties of the metals being welded, the effects of expansion and contraction, the reason for the use of fluxes and filling rods (see page 746), the proper kind of filling material, how to apply heat without burning the metal, etc., all of which can be learned from books treating on the subject.

With this knowledge and practice the business can be made very remunerative.

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[1] An instruction book on oxy-acetylene welding can be obtained of A. L. Dyke, Pub., Granite Bldg., St. Louis, Mo. (price $1.10 prepaid). It treats on carbon burning or decarbonizing, cutting and welding. A larger book, which is the most complete book published on the subject, can now be obtained also from A. L. Dyke, at the address given above (price $3.00 plus 25c. postage).

[2] See Index under "Melting points of metal."

Gases Used for Welding

The oxygen needed is furnished to customers in portable steel cylinders into which the oxygen is compressed to 1,800 lbs. to the square inch.

To estimate the pressure readings, a gauge is supplied. Take, for instance, an oxygen cylinder that holds 100 cu. ft. at 120 atmospheres, or 1,800 lbs. pressure approximately; each atmosphere represents 5/6 cu. ft. With a 250 cu. ft. oxygen cylinder, each atmosphere, or 15 lbs. pressure, represents 2.08 cu. ft. of oxygen.

Acetylene is supplied to users in specially constructed steel cylinders of various capacities. The maximum charging pressure is 250 lbs. to the square inch at 70° F. The cylinder contains about ten times its own volume of acetylene for each atmosphere of pressure that is on the gas. The porous substance, such as pumice stone or charcoal which is in the tank, is saturated with a liquid solvent which has the peculiar property of absorbing or dissolving many times its own volume of acetylene at atmospheric pressure. When pressure is applied, the solvent continues to dissolve acetylene.

Cylinders are, as a rule, charged to 15 atmospheres pressure at 60° F., so they contain 150 times their own volume when charged. Thus a cylinder that would hold 2 cu. ft. of water when empty will hold 300 cu. ft. of acetylene at 225 lbs. pressure at 60° F.

Prest-O-Lite acetylene cylinders for welding are furnished in large-sized cylinders, style "WC," having approximately 100 cu. ft. capacity, and style "WK," with approximately 300 cu. ft. capacity. They are made as small as 30 or 40 cu. ft. capacity.

No cylinder should be exhausted at a rate greater than one-seventh of its total capacity per hour. Where the needed amount of acetylene per hour exceeds one-seventh of the capacity of one cylinder, connect two, three, or even more cylinders so that the total capacity is at least seven times their hourly discharge.

It should be borne in mind that the contents are not accurately determined by pressure or gauge readings, which are affected by variations in temperature. The only accurate method of determination is by weight, one pound of gas equalling 14½ cu. ft. Gauge pressures, however, are of great convenience in **estimating roughly** how much gas remains in the cylinder. In the case of a 100 cu. ft. cylinder, each 15 lbs. of pressure represents 6 2/3 cu. ft. of gas (approximately), and in a 300 cu. ft. cylinder each 15 lbs. of pressure represents 20 cu. ft. (approximately), according to temperature.

Sources of Gas for Welding and Cutting

For welding, oxygen and acetylene gases are needed.

For cutting, oxygen and acetylene are also most generally used. However, other gases are frequently substituted for the acetylene.

Hydrogen, carbo-hydrogen, and butane are gases which can be substituted. These gases do not give enough **heat for welding** purposes, and so are not adaptable to it.

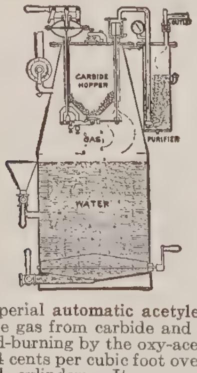

Fig. 3. The Imperial **automatic acetylene generator** produces pure acetylene gas from carbide and water, for welding and cutting and lead-burning by the oxy-acetylene process at a saving of from 2 to 4 cents per cubic foot over the cost of acetylene in compressed cylinders. It possesses many marked advantages, the most important of these being the absence of weights, clock-work, and complicated mechanism. In the Imperial generator, the carbide feed is simple, sure, and dependable, and is automaticaly controlled by the gas consumed by the torch. The generating of gas automatically stops when the torch is extinguished, and automatically starts generating when the torch is relighted, thus automatically maintaining a constant, even gas pressure. (15 lb. generator, $155.00; 25 lb. generator, $180.00; 50 lb. generator, $275.00; 100 lb. generator, $425.00.)

Note. This method saves from two to four cents per cubic foot over the cost of gas compressed in cylinders. Carbide in 100 lb. cans is easily obtainable anywhere in the United States, and usually costs from $5.00 to $6.00 per 100 lbs. in small lots, and less in ton lots. 100 lbs. of carbide will produce 500 cubic feet of acetylene gas in an Imperial generator.

The acetylene gas can be generated from carbide and water in a generator (see Fig. 3), or can be secured in portable steel tanks (Fig. 4) from one of the several companies mentioned farther on, who compress gas into a special tank and ship it to you. When the gas is used out of this tank, it is returned and exchanged for a refilled one.

The usual pressure in a full acetylene tank is 250 lbs. per square inch at 70° F., and the **capacity** is either 100 cubic feet, 225 cubic feet, or 300 cubic feet, depending upon the size of the tank.

Smaller tanks of 40-ft. capacity are also obtainable, but are intended for lighting purposes only. It is not advisable or practical to use these 40-ft. cylinders for welding or cutting.

Oxygen gas is obtained in steel tanks. The usual **pressure** is very high, ranging from 1,800 to 2,000 lbs. per square inch, with a **capacity** of either 100 or 250 cu. ft. of gas.

On the welding torch (Fig. 5, page 743) there are two connections, one for acetylene and one for oxygen. Each gas is carried through a separate tube in the handle of the torch under pressure. Each is controlled by the valves located just ahead of the handle, and the gases are led into the mixing chamber located just ahead of the valves. In the mixing chamber they are thoroughly mixed and are then led to the tip through a tube and burned.

Parts of the Prest-O-Lite Welding Outfit[1]

The welding blow-pipe is shown in Fig. 5. Various sizes of tips are used for different kinds of work.

The acetylene regulator (Fig. 6) is connected to the valve of the acetylene cylinder by means of the union nut (**M**), which must be drawn up tightly.

The oxygen regulator (Fig. 7) is connected to the valve on oxygen cylinder by means of union nut (**AA**).

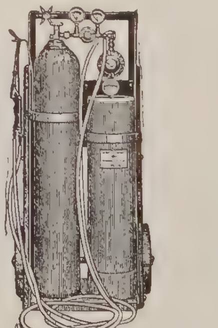

Fig. 4. The Standard Prest-O-Lite, type H, **welding outfit:** 1 cylinder of Prest-O-Lite, dissolved acetylene; 1 cylinder of compressed oxygen; 1 welding blow-pipe with seven interchangeable welding tips, Nos. 1, 2, 3, 4, 5, 6 and 7 (Fig. 5); 1 automatic constant pressure acetylene regulator, fitted with inlet and outlet pressure gauges (Fig. 6); 1 automatic constant pressure oxygen regulator fitted with inlet and outlet pressure gauges (Fig. 7); 2 suitable lengths of rubber hose; 1 set of four hose clamps; 1 box-end wrench for needle on Prest-O-Lite dissolved acetylene cylinder valve (T-socket); 1 wrench for attaching oxygen regulator; 1 stuffing nut wrench for Prest-O-Lite dissolved acetylene cylinder and for attaching acetylene regulator; 1 box end wrench for welding blow-pipe; 1 box wrench for welding tips; 1 pair special-colored lens goggles.

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[1] Next four pages from Prest-O-Lite instruction book.

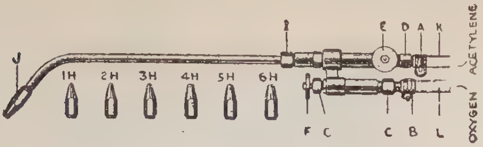
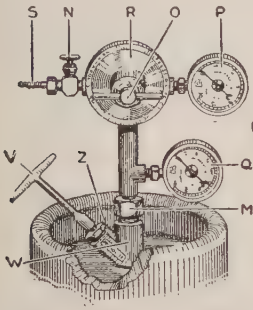
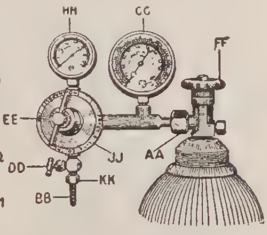


Fig. 5. Prest-O-Lite equal-pressure **welding blow-pipe.** (A) clamp for holding acetylene hose on nipple; (B) clamp for holding oxygen hose on nipple; (C) union nut on oxygen hose nipple; (D) union nut on acetylene hose nipple; (E) needle valve for controlling acetylene supply; (F) needle valve for controlling oxygen supply; (G) stuffing nut on oxygen needle valve; (I) union nut for disengaging or changing angle of barrel of blow-pipe; (J) interchangeable welding tip, size 7H, 1H, 2H, 3H, 4H, 5H, and 6H are extra interchangeable welding tips.



ACETYLENE REGULATOR ASSEMBLY

Fig. 6



OXYGEN WELDING REGULATOR ASSEMBLY

Fig. 7

Fig. 6. Prest-O-Lite automatic constant pressure **acetylene regulator:** (M) union nut securing regulator on acetylene cylinder-valve; (N) acetylene regulator outlet needle valve; (O) acetylene pressure regulator screw; (P) low or working pressure gauge; (Q) high or cylinder pressure gauge; (R) acetylene reducing valve; (S) acetylene hose nipple; (V) wrench on acetylene cylinder valve; (W) acetylene cylinder valve; (Z) gland nut on acetylene cylinder valve.

Fig. 7. Prest-O-Lite automatic constant pressure **oxygen regulator:** (AA) union nut securing regulator on oxygen cylinder valve; (BB) nipple for hose to blow-pipe; (DD) oxygen regulator outlet valve; (EE) oxygen pressure regulating screw; (FF) main valve on oxygen cylinder; (CC) high or cylinder pressure gauge; (HH) low or working pressure gauge; (JJ) oxygen reducing valve; (KK) union nut on oxygen hose nipple.

The Welding Flame

The welding flame should be obtained gradually, by increasing the regulating screws alternately, until the correct flame is obtained. The correct oxygen and acetylene working pressures vary slightly for the various sizes of blow-pipe tips which are used for different work. All adjustments are made at the regulators while the blow-pipe is alight.

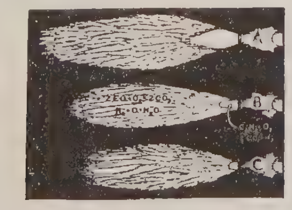


Fig. 8. The **oxy-acetylene flame.** (A) shows a welding flame with an excess of acetylene; (B) shows a correct natural welding flame; (C) shows a welding flame with an excess of oxygen.

Flame adjustment: It is absolutely necessary at all times that the welding flame be neutral, that is, that there be no excess of oxygen or acetylene. A correctly adjusted (neutral) flame is shown at (B) (Fig. 8). It will be noted that the **inner cone is clear, and well defined.** (A) (Fig. 8) shows a flame having an excess of acetylene. The inner cone is ragged in appearance. To make such a flame "neutral," the acetylene should be cut down by reducing the pressure either at the regulator or at the blow-pipe, or by increasing the oxygen supply. (C) (Fig. 8) shows an excess of oxygen. The inner cone has a very pale violet color, and is shorter than the cone in the neutral flame at (B). Proper adjustment, in this case, is accomplished by reducing the oxygen pressure or increasing the acetylene pressure at the regulators or at the blow-pipe.

The temperature of the oxy-acetylene flame is 6,300° F.

The regulation of the welding flame really means the regulation of the white inner cone. This cone should always be as large as possible, provided its outline is sharp and distinct. A long, clear inner cone should always be sought. The gases should be readjusted several times, if necessary, until the desired result is obtained.

When the blow-pipe is first lighted, it is cold. Radiated heat from the molten metal will gradually warm it. This is likely to affect the welding flame slightly. It usually will be found necessary to make readjustment of the gas pressures by means of the oxygen and acetylene needle-valve on the blow-pipe after the blow-pipe has been at work for a few minutes.

Method and Material for Welding

Preheating and reheating is sometimes necessary, in order to bring the metal to a uniform heat to insure uniform contraction while cooling. Figs. 9 and 10 show devices for this purpose.

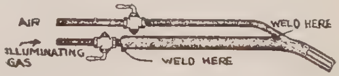


Fig. 9. Construction of air-illuminating gas **preheating torch.** Over-all length, approximately 2 feet.

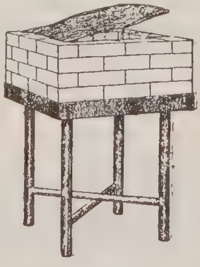


Fig. 10. Fire-brick **furnace** mounted on small welding **table.**

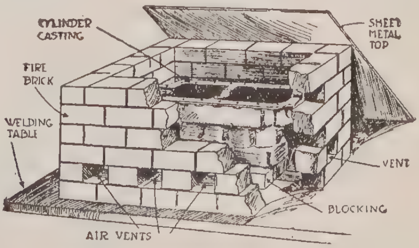


Fig. 11. Brick **oven for preheating work.** The work should remain in the oven while the welding is done. When the welding is finished the cylinder should be covered with a fresh layer of charcoal, heated; then allow it to grow cold slowly. Many shops will not take in water-jacketed cylinder work, because of the difficulty in making the job hold. Difficulties of this sort are generally due to improper preheating. Small jobs may be preheated with a welding torch, a blow torch, or a forge (*Motor World*).

Fig. 11 shows a small **furnace for preheating automobile cylinders.** After a layer of firebrick has been placed on the table, the cylinder is supported on several bricks, and the walls of the furnace built up around it. Half-bricks are used for the second layer from the bottom, so that openings are left for the air supply.

The fuel used should be of the best grade of hardwood charcoal obtainable. This burns freely, without smoke or odor, requires no forced draft, and does not injure finished surfaces. It is necessary only to pack it around the piece to be heated, to light it, and let it burn at will. When in use, the top of the furnace should be covered with a sheet-metal plate. Vent holes should be closed when cooling (cool slowly).

Filling rods are used to fill in gaps or cracks. Rods or wires are used of various lengths.

Fluxes: Some metals do not flow together rapidly when heated (owing to oxidation); therefore a suitable flux, in the form of powder, is used. It is sprinkled in the weld by dipping the heated filling rod from time to time into the flux.

The size of the blow-pipe tip is decided upon before welding. For instance, cast iron requires a larger flame than steel.

Preparation before Welding

In all welding operations, the parts to be welded should be set in proper alignment before the flame is applied. In the absence of precautions of this nature, the work is sometimes found to be out of alignment, and the part is rendered useless otherwise.

It is always advisable to **have on hand a good supply of different size clamps, "V"-blocks, and mandrels.** These are always useful in setting up various jobs. See Figs. 12, 13, 14, and 15.

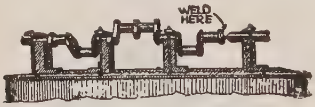


Fig. 12. Example of six-throw crank shaft lined up on V-blocks and clamped on the face plate for welding. The broken sections are shown beveled to a chisel edge.

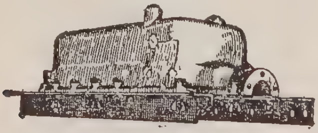


Fig. 13. Lower half of aluminum crank case clamped to angle irons to insure true alignment. A patch is shown "tacked" in position ready for welding.

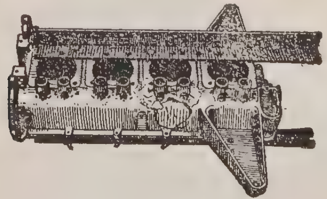


Fig. 14. Upper half of aluminum crank case bolted to angle irons to insure true alignment while patching.

Expansion and contraction: In every case of welding, internal strains are inevitably set up, as a result of expansion when heating and contraction when cooling. When parts being welded form part of a structure and are not free to move during the welding process, the strains produced may cause the metal to crack. This is especially true of cast iron.

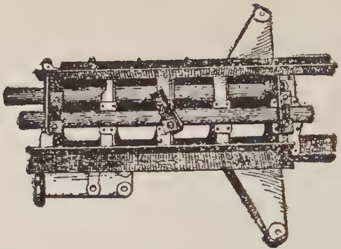


Fig. 15. Under side of upper half of aluminum crank case shown in Fig. 14. Note mandrels clamped in crank and cam-shaft bearings.

If cooling after welding is too rapid, or is irregular, a crack is liable to occur. Therefore it is advisable to heat the parts before welding (termed "pre-heating") and then to heat after welding (termed "reheating").

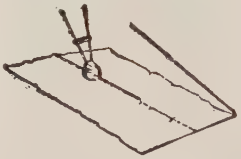


Fig. 16

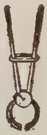


Fig. 17

Fig. 16. Method of holding flanged thin sheets in position for welding.

Fig. 17. Clamp with locking ring.

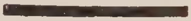


Fig. 18

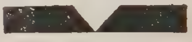


Fig. 19

Fig. 18. Example of butt joint before welding employed on thin sheet metal up to 1/8 inch in thickness where beveling is unnecessary.

Fig. 19. Example of bevel employed on metal less than 5/8 inch or ¾ inch in thickness and over ⅛ inch in thickness.

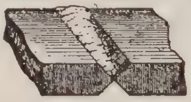


Fig. 20

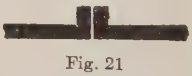


Fig. 21

Fig. 20. Example of beveling and welding of sections over ¾ inch in thickness. Parts are beveled and welded on both sides as shown.

Fig. 21. Example of flange made on thin sheets before welding.

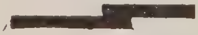


Fig. 22

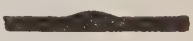


Fig. 23

Fig. 22. Examples of a lap joint before welding.

Fig. 23. Shows appearance of a weld made on thin sheets, flanged before welding, as shown in Fig. 21.

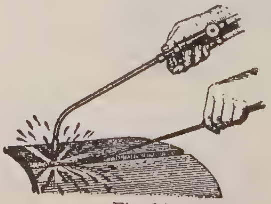


Fig. 24

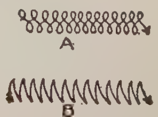


Fig. 25

Fig. 24. Correct method of holding the blow-pipe with relation to the line of weld.

Fig. 25. **Two correct movements** to give the **welding flame.** (A) "figure eight" movement best suited to ordinary work. (B) zigzag movement which some operators prefer.

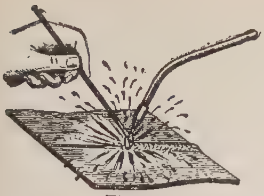


Fig. 26

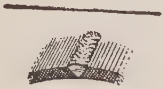


Fig. 27

Fig. 26. Incorrect method of applying filling material. The blow-pipe is also held at the wrong angle with relation to line of weld.

Fig. 27. Metal is slightly built up over beveled joint.

Examples of Welding

Fig. 28 shows a **section of one side of a steel cylinder and a convex head** which is to be welded on. The weld should be made in the straight portion of the cylinder as shown, and not directly at the bend.

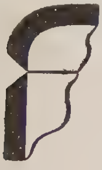


Fig. 28

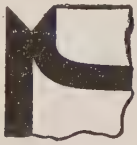


Fig. 29

Fig. 28. Location of joint when welding convex to steel cylinder.

Fig. 29. Example of welding concave head in steel cylinder. Note: Both head and shell are beveled. This shows the method of accomplishing the same result in the case of a **concave end.** If the parts are beveled as shown the joint will be a strong one.

Fig. 30 shows the **correct method of welding pipe.** The pipe, where possible, should be rolled away from the operator in such a way that the portion being welded will be on top. "Tacking" at several points is necessary before the actual welding is started. However, if rolling is impossible, the pipe may remain stationary, and the operator can weld entirely around it without difficulty after some practice, although this method is bound to be somewhat slower.

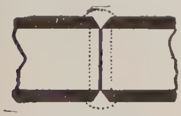


Fig. 30

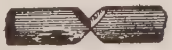


Fig. 31

Fig. 30. Pipes beveled before butt welding.

Fig. 31. Correct method of preparing shaft (beveled to chisel edge) for welding.

Fig. 31 shows the **proper method of preparing a shaft for welding.** Note that this is beveled to a chisel edge, and not pointed.

If the shaft is pointed (Fig. 32), the molten metal will fall upon the cold part of the shaft and adhesion will result, which means that the new metal is merely "plastered" on at certain points, and is not "fused."

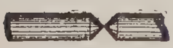


Fig. 32

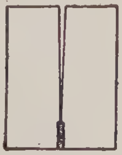


Fig. 33

Fig. 32. Incorrect method of preparing shaft (pointed) for welding.

Fig. 33. Sheets spreading apart away from point of weld.

When butt-welding two lengths of plate, or when welding the longitudinal seam of a cylinder (Fig. 33), it is advisable to "tack" along the line of weld before commencing on the finished weld. This will prevent the overlapping of the sheets at the end farthest away from the point of welding. When starting to weld two lengths of sheet at one end, which have previously been placed in proper alignment, it will be found that they tend to spread apart, as shown in the illustration. As the welding progresses, this spreading movement of the sheets ceases, and later they come together again with a tendency to overlap.

"Tacking" (Fig. 34) holds the sheets in true alignment and prevents this overlapping.

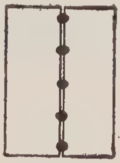


Fig. 34

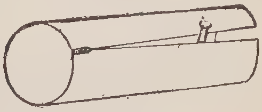


Fig. 35

Fig. 34. Sheets "tacked" before welding, to prevent spreading. The black spots are small welds.

Fig. 35. Wedge inserted to split tube ahead of weld, to prevent overlapping.

Another method of preventing over-lapping of the plates (Fig. 35), in the case of cylinders, is to insert a wedge a short distance ahead of the weld, moving the wedge as the weld progresses.

In some cases when welding a longitudinal seam, it will be found advantageous to start to weld in the middle of the seam, and to work first toward one end and then toward the other.

When welding angle-iron rings to cylinders where the thicknesses are the same (Fig. 36), both edges should be set up as shown.

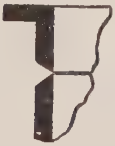


Fig. 36

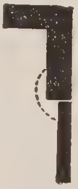


Fig. 37

Fig. 36. Preparation of angle iron and tube of same thickness before welding.

Fig. 37. Dotted line shows how filling material must be built up when welding angle to thinner section plate.

When the angle to be welded to the plate is thicker than the plate (Fig. 37), apply the flame more on the angle than on the plate. This will tend to bring the parts to the fusion point at the same time. Metal must be added, as shown by the dotted line.

When welding a flat end into a tube (Fig. 38), prepare the end as shown, making a driving fit.

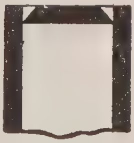


Fig. 38

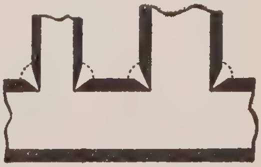


Fig. 39

Fig. 38. Preparation of flat end to be welded into tube.

Fig. 39. Shows preparation of pipes before welding to form branches.

To weld a branch into a pipe (Fig. 39), prepare the work as shown, adding metal as indicated by the dotted lines.

The welding of flat flanges to tubes (Fig. 40) is an operation that requires care, as the flange is usually considerably thicker than the tube and has to stand a good deal of strain. The flange and tube are best prepared as shown. The welding flame should play more on the flange than on the tube.

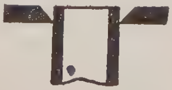


Fig. 40

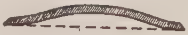


Fig. 41

Fig. 40. Preparation of flange to be welded to a thinner section plate.

Fig. 41. Patch plate bellied and with edges beveled before welding.

When repairing cracks in plates (Fig. 41), always see that the crack is beveled through its entire thickness. The plate being welded should be free to move. If it is impossible to provide for this, instead of attempting to repair the crack, use a patch. A patch piece should always be slightly bellied and have edges beveled, as indicated in the illustration.

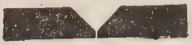


Fig. 42

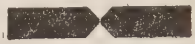


Fig. 43

Fig. 42. Beveling cast iron. Note that the bevel does not penetrate the entire thickness to be welded.

Fig. 43. Beveling from both sides in thick section of cast iron. Note that the points of the bevels do not meet.

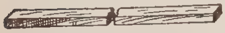


Fig. 44

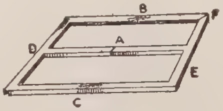


Fig. 45

Fig. 44. Fracture in the middle of a long bar to be welded. No precautions to overcome expansion and contraction strains are necessary, as the parts are free to move.

Fig. 45. Fracture in cross-member (A) of frame. The broken bar will contract on cooling, causing a strain on the end members (D) and (E). Risk of fracture may be avoided by heating the side members (B) and (C), or by cutting at the corner (F). The cut (F) may be welded up without risk of fracture after the break (A) is welded and cooled.

Selection of blow-pipe tip: The size of tip to use for welding iron and steel depends upon the thickness of the metal. Do not forget that the flame should be neutral at all times.

Welding Iron and Steels

Under this heading are included commercial wrought iron and mild or "low-carbon" steel.

Practically all of the so-called **"wrought" iron** on the market today is in reality a **mild steel.** For this reason, wrought-iron and mild-steel metals are discussed as one.

"Low-carbon" or mild steel is quite ductile and malleable, but has a lower tensile strength and lower elastic limit than the "high-carbon" or hard steels. No close distinction can be made between high and low-carbon steels, but, in general, anything below 25-point carbon (0.25 per cent) may be designated as mild steel, while those containing more than this amount are either half-hard or hard.

Most of the steels that the operator will be called upon to weld are mild. There are various special or alloy steels, such as vanadium, nickel, chrome, manganese, etc., which will be taken up separately.

Preparation of parts: Mild-steel parts are prepared in the manner described in the general instructions. Several methods of preparing the various parts to be welded are shown in the illustrations on page 745.

High carbon or hard steel: Weld as directed for mild steel or wrought iron, and use a larger blow-pipe tip. For filling, use a drill rod of hard steel. This can be tempered; ordinary mild steel cannot. Use cast-iron flux. Execute weld rapidly. A slight excess of acetylene may be advantageous.

Cast steel: Weld in accordance with instructions on cast iron. Cast bars of the same material or of vanadium steel or of Norway iron will answer for fillers.

For special steels, such as manganese steel (low carbon), use as a filler the same material or Norway iron.

Nickel steel (low carbon) is to be welded in the same manner as mild steel, but use a nickel steel filling rod.

Vanadium steel (low carbon) probably uses most of the various steel alloys. Weld as mild steel; use vanadium steel filler.

Chrome steel: Weld as mild steel; use a chrome steel filler. Many chrome steels are in the high-carbon class, and the general remarks on "special steels" apply.

Welding Cast Iron

This is **more difficult to weld.** Carbon exists in cast iron in different states. In what is called white iron, which is very hard, the carbon is combined with or dissolved in the iron. In the grey iron, which is soft and easy to work, most of the carbon is in a free state in the form of graphite. Since it is generally necessary to machine or file a weld in cast iron, it is indispensable that the line of the weld be constituted of soft grey iron. Thus, in welding cast iron, always remember that too rapid cooling brings about a combination of the carbon and iron, forming hard, brittle white iron; while slow cooling or reheating after the weld is completed keeps the carbon in a free state, resulting in a softer, more workable material.

Preparation of parts: Castings, before welding, should be very carefully freed from grease and rust. Cracks in metal over 3/16″ thick must always be beveled before welding. When beveling cast iron it is not necessary that the groove penetrate through the entire thickness of the metal. It will be found best to leave about ⅛″ of the thickness unbeveled, as shown in Fig. 42, above. When the metal is over 1″ in thickness, and it is possible to weld from both sides, it will be well to bevel as shown in Fig. 43. A diamond point or cape chisel may be used for beveling cast iron. Remember that careful lining up and clamping is very necessary when broken flanges or lugs are to be welded.

A larger blow-pipe tip is used. To overcome expansion and contraction, preheat. While welding is in progress and after its completion, it is advisable to apply a blow-torch or light a fire under some part of the casting away from the weld.

Filling material: Use a cast-iron filling rod containing a percentage of silicon. The percentage must not be too great or the weld will be soft. For **flux,** a cast-iron flux is necessary.

Malleable cast iron is probably more difficult to weld and treat than any other metal. Castings to be made malleable are made of white iron. Use the same process as for cast iron with a white iron filler.

Welding Cast Aluminum

This metal has a **low melting point** (1,200° F.). See Index under "Melting point of metals" for other melting points. A large welding flame is used. Aluminum is not generally used in pure form. Alloys of aluminum and copper or zinc are generally used. Alloys of aluminum and copper are easier to weld; there is less tendency to crack. Parts over ¼″ thick must be beveled as in the case of cast iron.

In order to prevent collapse during the welding and preheating operations, it is good practice to place a sheet of paper on the inside of the casting next to the crack to be welded. Back this paper with damp fire clay and pack up with asbestos fiber until a firm support is obtained. The paper prevents the fire clay from getting into the weld. With this light backing, or mold, the castings can be welded easily. The mold should be large enough to cover a sufficient area around the crack so that the heated aluminum in the vicinity of the weld will not break down. Whenever a weld is to be made close to a bearing, it is necessary to remove the babbitt (which would melt), and then to clamp mandrels (Fig. 15, page 744) in the bearings to keep them in alignment.

Preheating should not be done except in cases where there is a projecting lug or flange. Preheating must be done carefully and slowly. A blow-torch is generally used, but must not be left on one part too long. When preheating, test with a stick of half-and-half solder—if it melts on touching the casting it shows sufficient heating.

Filling: Alloy rods or pure aluminum rods can be employed of the same thickness as the metal to be welded.

Flux: Opinions differ. Use aluminum flux, if any.

Welding Copper, Bronze, and Lead

Copper radiates heat very rapidly and is also a good conductor of heat. Preheating and continued heating are therefore necessary. The metal is prepared in a manner similar to steel and iron. Cover as much as possible with asbestos. It should be left free to allow for contraction when cooling. **Filling:** phosphor copper. **Flux** must be used the same as when welding brass.

Brass: Preheating is not necessary. Use a special flux for brass and bronze, with a filler of brass spelter. Tobin bronze with brass flux may be used where great strength is desired. The weld should be made rapidly, but the white cone of the flame must not touch the metal.

Lead: Can be readily welded, but the operation is known as "lead burning." (See Index.)

Welding Thin Castings

The inexperienced operator will find it a big help to build a form of fire clay as a support for the broken sections while repairing thin castings. This holds the parts true, and also assists in the control of the molten metal.

Whenever it is necessary to weld in a patch, a new piece of the same metal should be cut to the proper size and shape, the edges of both parts should be beveled, and the patch held in place temporarily by **"tacking,"** that is, welding at several spots some distance apart along the line to be welded. To hold a large patch in position while being "tacked," it may sometimes be necessary to drill a small hole in the center of the patch into which a length of rod can be inserted, and by which the patch may be handled. This hole may afterwards be plugged and welded up. Small patches, that must be placed in difficult positions, may be conveniently handled by simply welding a filling rod to the center of the patch. This may later be melted off.

Sundry Uses of Welding Outfit

Tool hardening: The welding flame will be found useful as a source of heat for the heat treatment of small tools.

Gear-tooth hardening: Gear teeth may be hardened by playing the welding flame along the face of a tooth and then allowing the heat to be conducted away by the body of the gear. The intense heat of the flame permits a single tooth being heated very rapidly, before much heat is conducted to the rest of the gear. As soon as the flame is removed the heat in the treated tooth is conducted away to the body of the gear. This causes hardening of the tooth. This operation is repeated until the desired depth of hardening is reached.

Teeth may be hardened by this method to a depth of about 3/32″. The rapidity with which the treated tooth may be chilled will be increased if the gear is partly immersed in water while the treatment is performed.

Burning battery terminals or connections: For this operation, see Index under "Lead burning."

The metals and parts mentioned above, and many other parts from an automobile too numerous to mention, can be welded successfully.

All up-to-date welding and cutting shops have the latest modern equipment installed to take care of all classes of work, such as preheating cylinders, cases, etc.

The cutting process of this art consists of the cutting and wrecking of all kinds of "I-beams," "channel iron," "girders," cutting of boilers, tanks, cutting and opening of safes, "steel pilings," etc.

Pure **oxygen** used in the process of **removing carbon from cylinders** is one of the most advantageous agents at the service of the automobile owner. See also page 751.

Channel Iron, Angle Iron, etc.

These terms are often used in connection with automobiles. For instance, the front axle is often spoken of as an **"I-Beam"** (see Fig. 46); **"channel iron"** or steel is used for chassis frames of a car, and an end section is shown in the illustration; other sections are also shown.

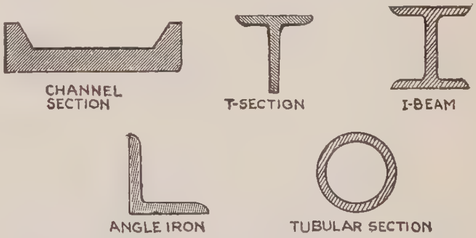


Fig. 46. Sections of iron and steel members which explain why certain shapes are termed **"I-Beam," "Channel," "Angle,"** etc.

Molybdenum steel is a steel that is lighter than any other steel of equal strength, and stronger than any other steel of equal weight.

Oxy-Acetylene Cutting

The cutting blow-pipe is commonly usd for cutting through various thicknesses of wrought iron and steel up to 14 inches. (Wrought iron and steel are the only metals that can be cut by this process.) As an adjunct to a welding equipment, it is used for beveling and for cutting out patches and holes.

The process is based on the fact that a jet of oxygen directed upon a previously heated spot of iron or steel causes it to ignite, with the result that the metal, acting as its own fuel, burns away rapidly in the form of iron oxide. A special blow-pipe is provided for this work (Fig. 47).

The oxygen cutting blow-pipe cannot be used for welding, any more than can the welding blow-pipe be used for cutting.

The difference between the cutting and the welding torch lies principally in the fact that three jets are used, but two gases are used in cutting the same as for welding.

The same source of gas supply is used as for welding. The same acetylene regulator is used, but if work over 3″ thick is to be cut, a special oxygen regulator must be employed. This is exactly the same in appearance as the oxygen regulator for welding, but it is fitted with a stronger spring and a higher reading outlet or "working" pressure gauge.

The special oxygen regulator, as used for cutting thick work, should not be used for welding, as the regulation is not delicate enough to maintain a strictly neutral flame, especially when the smaller tips are in use. The oxygen regulator for welding however, can be used for cutting on work up to 1½″ in thickness.

The oxygen cutting regulator is connected to the oxygen bottle in the same manner as the welding regulator. The cutting blow-pipe is connected to the gas supply through the regulators in exactly the same way as the welding blow-pipe.

There are two kinds of oxy-acetylene cutting blow-pipes, known as the "central" and "following" jet types. The "central" jet type has a number of oxy-acetylene heating flames surrounding a central hole through which oxygen only passes. The "following" jet type consists of one oxy-acetylene heating jet and one oxygen jet. The holes for these jets are usually drilled in the same tip, but sometimes have separate tips which are set close together.

The principles of construction and operation of an oxy-acetylene cutting blow-pipe of the central jet type are shown in Fig. 47. The oxygen and acetylene supplies are connected up through the regulators and rubber hose to the hose nipples on the blow-pipe.

The outlet valves on both regulators and also all valves in the blow-pipe are closed. The gas is then turned on at the cylinders, as in welding, and the regulators are adjusted until the outlet or working pressure gauges show the working pressures specified on the instructions issued with the cutting blow-pipe by its manufacturer. The acetylene valve in the blow-pipe is then slightly opened and the blow-pipe lighted; the oxygen for the heating flame is then turned in at valve (**D**) (Fig. 47). This permits oxygen to mix with the acetylene at (**J**). The flow of the mixture of the gases is indicated by arrows. Valves (**D**) and (**I**) are adjusted until a neutral heating flame is produced. The cutting oxygen is then turned on at (**E**).

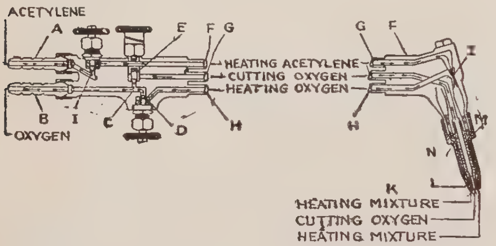


Fig. 47. Diagram illustrating the principle of the oxy-**acetylene cutting** blow-pipe torch.

The line of flow of the cutting oxygen is shown by arrows. The nipple or inner tip through which it discharges is interchangeable, and manufacturers indicate in their instructions the number or size of tip to be used on different thicknesses of metal.

Watch the working pressure gauge on the oxygen regulator, and see if it reads the right pressure for the metal to be cut as originally set; if not, adjust the regulator, and when this is done readjust the heating flame if necessary. Do this as quickly as possible, to avoid waste of oxygen. Now shut off the cutting oxygen at (E), and the blow-pipe is ready for work.

When the metal to be cut is sufficiently heated at the point where the cutting is to start, the cutting oxygen is turned on. When the cutting operation is once under way, the heating and cutting proceed together. The cutting operation is very simple, and can be mastered in a few hours.

The point to observe is that (I) is the acetylene valve and (D) is the oxygen valve, which are turned on first. With them the part to be cut is heated. Then valve (E) is opened, which permits a stream of oxygen to be directed upon the heated spot. See the two preceding paragraphs.

Cutting may be made to follow any desired line. When special forms and shapes have to be cut, it is advisable to make a special mechanical contrivance with which to steady and guide the blow-pipe and thus to insure a clean cut. Hold the blow-pipe tip about ¼" away from the surface of the metal to be cut.

A cut should start from the edge of the metal, whenever possible. When it is desired to cut a piece out of the center of a plate, start inside the circumference of the piece to be cut (Fig. 48). On thick plates, where the cut cannot be started from the edge, it may be necessary to drill a hole to get a quick start.

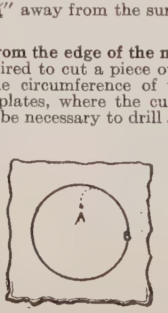


Fig. 48. Shows point of start (A) when cutting circular hole in plate (From Prest-O-Lite instruction book).

Certain precautions are necessary before the operator starts to work on a piece of metal. A bucket of water should be near at hand for cooling the cutting tip when necessary. Both oxygen and acetylene should be shut off at the blow-pipe to extinguish the flame before dipping the tip of the blow-pipe into the water. To expel any steam formed inside the tip, turn on the oxygen valves at the blow-pipe and allow oxygen to flow for a moment before turning on acetylene and lighting it.

Approximate Prices to Charge for Welding Broken Parts by the Oxy-Acetylene Process

The following list gives approximate prices usually charged for welding, and the cost. The prices are not standardized.

Cylinders, Water-Jacket Fractures

Double	$8 .00	to	$15.00
Single	4.00	to	8.00
Block of four or six	10.00	to	15.00
Lug or ears each	$3.50	two or more	3.00

Aluminum Crank Case and Lower Cases

It is very difficult to determine an exact price on this line of work without a thorough examination of the fractures, but as a general rule the average cost of welding is as follows:

Top cases	$ 6.00	to	$25.00
Lower cases	6.00	to	12.00

Manifolds—Aluminum

1 lug or ear	$1.50	Two or more $1.00 each.

Manifolds—Cast Iron

1 lug or ear	$1.25	Two or more $0.75 each.

Crank Shafts

1 throw crank	$ 6.00	to	$ 8.00
2 throw crank	8.00	to	10.00
4 throw crank	10.00	to	14.00
6 throw crank	12.00	to	16.00

Body Frames

Two inches	$ 7.00
Three inches	8.00
Four inches	10.00
Five inches	12.00
Six inches	15.00
Eight inches	17.00

Rear-Axle Housings

Prices vary according to size and fractures, but they average from $3.00 to $18.00.

Lamp brackets	$0.50	to	$1.50
Levers	.75	to	2.00

The Cost of Welding[1]

Thickness Metal	Size tip to be used	Acetylene		Oxygen	
		Consumption per hour	Cost of gas per hour	Consumption per hour	Cost of gas per hour
3/16" to ¼	No. 3	15 cu. feet	$0.30	17 cu. feet	$0.34
⅜" to ½	No 5	43 cu. feet	.86	47 cu feet	.94

The total cost of gas per hour would be 30c. + 34c. = 64 cents, and 86 cents + 94 cents = $1.80.

The approximate capacity per hour of welded seams (3/16" to ¼") would be 15 to 20 lineal feet, and 7 to 12 lineal feet on ⅜" to ½".

Note. In welding metals of from 3/16" to ¼" in thickness, the average approximate capacity, expressed in terms of lineal feet of welded seam, would be from 15 to 20 feet per hour, being a cost for gas of from 3 to 4 cents per lineal foot. For metals ⅜" to ½" in thickness, the approximate capacity would be from 7 to 12 lineal feet per hour, being a cost for gas of from 15 to 25 cents per lineal foot.

Under continuous use with the No. 3 tip, a cylinder containing 100 cubic feet of acetylene will run about 6½ hours, while the same quantity of oxygen would run about 6 hours.

With the No. 5 tip, a cylinder containing 100 cubic feet of acetylene would run about 2 1/3 hours, while the same quantity of oxygen would run about 2 hours.

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[1] The acetylene prices quoted above are based on a price of 2 cents per cubic foot, whereas the price is now 3 cents. Oxygen prices given are based on a price of 2 cents per cubic foot, whereas the price is now 2⅓ cents.

The Cost of Cutting[1]

Thickness of Metal	Acetylene		Oxygen	
	Consumption per lineal foot	Cost per lineal foot	Consumption per lineal foot	Cost per lineal foot
¼	.13 cu. feet	$0.003	.50 cu. feet	$0.01
⅜	.18 cu. feet	0.0036	.90 cu. feet	0.018

The time required per foot of cutting length of the ¼″ thickness of metal named above is 1 minute and 1¼ minutes for the ⅜″ thickness.

The total cost of gas per cutting foot on the ¼″ thickness would be 1¼c. to 1½ cents, and 2¼ cents to 2½ cents on the ⅜″ thickness.

Note. In continuous cutting through metal ¼″ thick, the cost for gas would be about 2 cents per running foot and the time about one minute.

For metal ⅜″ thick, the cost of gas per running foot would be about 3 cents per foot and the time about 1¼ minutes.

When cutting ¼″ metal, a cylinder containing 100 cubic feet of acetylene would run about 12 hours, while the same quantity of oxygen would run about 3 1/3 hours.

For ⅜″ metal, a tank containing 100 cubic feet of acetylene would run about 11½ hours, while the same quantity of oxygen would run about 2 1/3 hours.

It will be noted that in the process of cutting the extra quantity of oxygen required is due to the cutting jet of pure oxygen which is used in addition to that mixed with the acetylene.

Tanks containing 200 cubic feet of gas would run twice as long as the 100-foot tanks.

The foregoing estimates are based on acetylene and oxygen gas costing $2.00 per 100 cubic feet. The cost of labor should be added to the total cost of gas.

Where to Obtain Gas Tanks for Welding

Gas tanks can readily be obtained at branches of the various firms mentioned below.

Oxygen and Acetylene Gas for Use with Imperial Welding and Cutting Outfits

Oxygen for welding and cutting can be obtained from the Linde Air Products Co., of Chicago, and New York, which has twelve plants and twenty-five warehouses in various parts of the country. It furnishes oxygen in tanks containing 100 and 200 cubic feet respectively, with free use of tanks.

Acetylene Gas for Welding and Cutting

Some manufacturers of acetylene gas are mentioned below:

The Prest-O-Lite Company of Indianapolis, Ind., which has branches in nearly all the large cities of the United States.

The Commercial Acetylene Ry. Light & Signal Company of New York has numerous branches. We are advised it supplies acetylene for welding and cutting. The tanks contain 120 and 225 cubic feet.

Approximate shipping weights are as follows:

Linde	100 cu. ft.	122 lbs.
Linde	200 cu. ft.	150 lbs.
Prest-O-Lite	100 cu. ft.	85 lbs.
Prest-O-Lite	300 cu. ft.	220 lbs.
Searchlight	100 cu. ft.	75 lbs.
Searchlight	225 cu. ft.	180 lbs.
Commercial	120 cu. ft.	120 lbs.
Commercial	225 cu. ft.	180 lbs.

The weight of acetylene is approximately 14½ cu. ft. to a pound.

The price of oxygen and acetylene varies somewhat, depending on location, prices in the extreme West and South being somewhat more than in the East. The prices in the East for both oxygen and acetylene are approximately $2.00 per hundred cubic feet at the filling station or warehouse.

You can obtain full information regarding oxygen and acetylene by corresponding with the companies named above, at the branch nearest to you.

To provide a constant supply of gas for your shop, you can no doubt arrange to get the use of from three to six cylinders or more, according to requirements which would eliminate possibility of running out of gas by having extra cylinders on hand for use while getting empties recharged.

Your automobile supply house with whom you are trading may be able to give you additional information on this subject.

Oxy-Hydrogen

An important feature to the Imperial welding and cutting equipment is its adaptability for use with oxy-hydrogen as well as oxy-acetylene. When it is desired to equip for both oxy-hydrogen and oxy-acetylene, the only change necessary is the addition of one hydrogen regulator and a set of hydrogen tips.

Tips for welding as well as cutting with hydrogen can be furnished. The tip is marked with the pressure of gases required.

Where a supply of hydrogen is available at reasonable prices, **it is recommended in connection with oxygen for cutting of wrought iron and steel of any thickness. The cut will be found smoother and the operation more economical** than by the use of acetylene for the preheating flame.

For **welding in general repair work, such as gears and castings, aluminum crank cases and other alloyed metals, the use of the oxy-hydrogen flame is recommended.** For welding thin sheet steel, from 16 gauge up, the oxy-hydrogen flame is found very effective. Its temperature being about 4,000 degrees F., the metal is not burned so easily and as hydrogen contains no carbon, the weld is softer and very uniform. Cast iron may be welded with oxy-hydrogen very successfully up to ¾″ in thickness.

For welding steel of more than ¼ inch in thickness, the oxy-acetylene flame should be used under all circumstances.

Internal Construction of Regulators for Acetylene and Oxygen

Two regulators are necessary, one for **oxygen** and one for **acetylene,** except when a stationary type of generator is used, such as the Imperial (Fig. 3, page 742), as in that case the acetylene regulator is not necessary.

The regulator is a very important part of the equipment and in order further to simplify its operation, a sectional view of the Imperial regulator (Fig. 49) will be used.

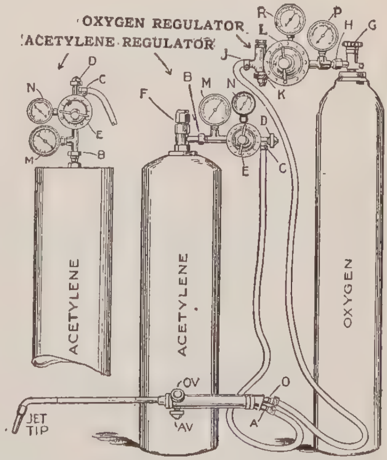

Fig. 48. Showing **Imperial welding outfit** connected to tanks: (**A**) acetylene inlet to torch; (**AV**) acetylene valve on torch; (**B**) tank coupling; (**C**) hose coupling; (**D**) outlet valve to hose; (**E**) acetylene regulating screw; (**F**) acetylene tank valve; (**G**) oxygen tank valve; (**H**) tank coupling; (**J**) hose coupling; (**K**) outlet valve to hose; (**L**) oxygen regulating screw; (**M**) acetylene tank pressure gauge; (**N**) acetylene working pressure gauge; (**O**) oxygen inlet to torch; (**OV**) oxygen valve on torch; (**P**) oxygen tank pressure gauge; (**R**) oxygen working pressure gauge.

Note. When either the Air Reduction or Commercial Companies' acetylene tanks are used, the acetylene regulator stands out at right angle to the tank, as shown in center tank.

When Prest-O-Lite tanks are used, the regulator stands up on end, as shown in partial view of tank at left.

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[1] Used most.

In order to weld successfully, it is necessary that two gases be used by delivering the gases in equal proportions to the torch, in order to make a flame of the proper intensity.

The purpose of the regulator is to reduce the pressure in the cylinders or tanks to a working pressure.

The pressure of the acetylene tank, when full, shows 250 lbs. The regulator reduces the pressure to from 1 to 10 lbs. for **welding** and from 10 to 15 lbs. for **cutting.**

The acetylene regulator and the oxygen regulator, one of which must be used on each tank, are similar in construction.

The acetylene regulator has a German silver diaphragm.

The oxygen regulator has a bronze diaphragm, the thickness of which is approximately one one-hundredth of an inch.

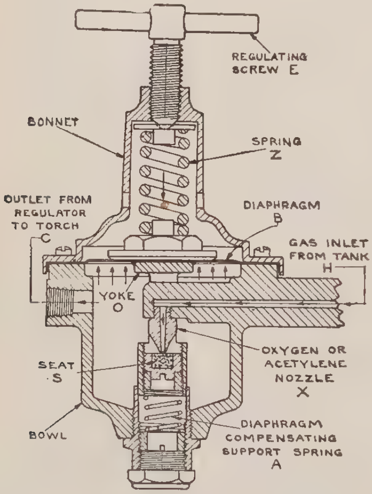
REGULATING SCREW E
BONNET
SPRING Z
OUTLET FROM REGULATOR TO TORCH C
DIAPHRAGM B
GAS INLET FROM TANK H
YOKE O
SEAT S
OXYGEN OR ACETYLENE NOZZLE X
BOWL
DIAPHRAGM COMPENSATING SUPPORT SPRING A

Fig. 49. Sectional view of the Imperial pressure regulator.

Regulator action (Fig. 49): The gas enters the regulator through the gas inlets (B) and (H) and travels through the passage indicated by arrows to the nozzle (X). It is stopped here because the seat (S) is held against the end of the nozzle by the spring (A) which pushes against it.

To make the regulator operate, the regulating screws (E) and (L) are screwed in (to the right), thus placing tension on the spring (Z) which forces the diaphragm (B) downward.

Inasmuch as the seat (X) is carried in the yolk (O) which is fastened to the diaphragm, this spring tension pushes the seat (S) away from the seat (X) and allows the gas to flow into the bowl of the regulator.

This gas forms a pressure against the inside of the diaphragm, as indicated by small arrows, and has a tendency to push the seat back against the nozzle. The pressure on the spring (Z) and the gas pressure against the diaphragm balance, and the regulator is held open just enough to allow as much gas to escape through the nozzle as is being drawn out at the outlets (C) and (J).

To obtain more pressure, screw in on the regulating screws (E) and (L). **To reduce the pressure,** unscrew the regulating screw.

The oxygen and acetylene regulators are the same except that in the oxygen regulator there are two springs, and in the acetylene, only one, and the gauges are different.

The pressure of the oxygen tank, when full, is 2,000 lbs. The regulator reduces the pressure to anything from 1 to 15 lbs. for welding, and from 20 to 150 lbs. for cutting.

The cutting torch (Fig. 47, page 748), has two connections, one for acetylene and one for oxygen, but the difference here is that after the two gases are used to heat the article to be cut, more oxygen is admitted through a third tube, with the result explained on pages 747, 748.

Acetylene Gauges

Refer to the illustration (Fig. 48) and note the location of the gauges.

In Fig. 48 **(M) is calibrated in pounds from 0 lbs. to 500 lbs.,** and is the gauge connected with the acetylene tank (Fig. 48).

(N) is calibrated in pounds from 0 lbs. to 50 lbs., and is the gauge from the regulator to the torch, and shows the reduced pressures (Fig. 48).

Oxygen Gauges

High-pressure oxygen gauges (P) (Fig. 48) are graduated to show both the tank pressure and the percentage of gas in the tank. The outside reading from 0 to 3,000 lbs. gives the pressure of the gas in the tank.

The smaller readings are to be read as follows: If the regulator is being used on a tank of 100 ft. capacity, the readings from 0 to 100 are used. If the regulator is being used on a tank of 250 cu. ft. capacity, the scale from 0 to 250 is used. Therefore, if, after completing a job, the pointer on the gauge should show on the 200 point and the regulator was being used on a 250 ft. cylinder, it would mean that there were 200 cu. ft. of gas left in the tank.

(R) is calibrated in pounds from 0 lbs. to 150 lbs. (Fig. 48), and shows the reduced pressure from the regulator to the torch.

Sometimes gauges are calibrated in atmospheres. An "atmosphere" is equal to about 15 lbs. Therefore, if a tank is full, and the gas is compressed to 1,800 lbs. to the square inch, the gauge would show 120 atmospheres (see page 442 explaining atmospheres). If tanks are placed where there is considerable heat, the gas will expand and increase the pressure.

Sometimes both an atmosphere and pound calibration is used on the same gauge.

Capacity of tanks generally used is 50, 100, 150, and 200 cu. ft. The size of the tank gives its capacity.

The Cost of Welding, Cutting, and Decarbonizing Outfits[1]

No. 1 Imperial welding outfit (Fig. 50): For all general welding work, from thin sheet metal to heaviest castings. Consists of type B welding torch, with ten welding tips, extension, decarbonizing torch, regulators, gauges, hose, connections, goggles, complete supply of welding materials, ready for service. Weight, approximately 75 lbs. net, each $75.00

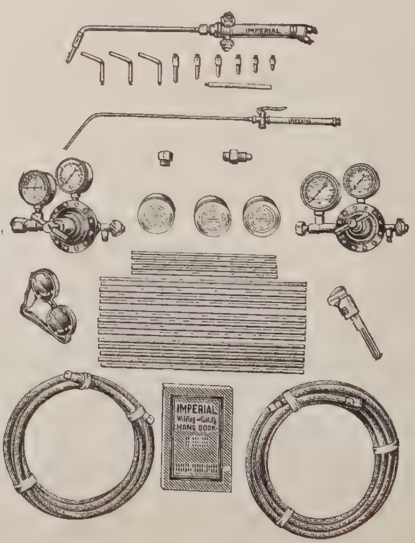

Fig. 50. No. 1 Imperial welding outfit.

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[1] A book of instructions on welding and cutting, as supplied with the Imperial outfits, can be secured of A. L. Dyke, Granite Bldg., St. Louis, Mo., price $1.10 prepaid.

No. 2 Imperial all-purpose garage welding outfit (Fig. 51). This fills the requirements of the small shop or garage, as with this outfit it is possible to do welding, carbon burning, lead burning, radiator soldering, brazing, preheating and cutting. The No. 2 cutting attachment (Fig. 52) which will cut steel and wrought iron up to 2½″ thick, is $10 extra.

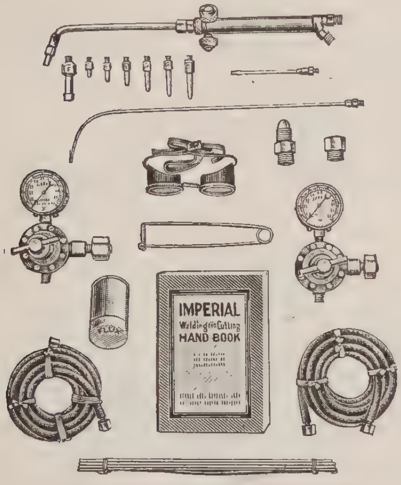

Fig. 51. No. 2 Imperial welding outfit.

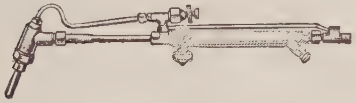

Fig. 52. No. 2 cutting attachment.

The No. 2 Imperial Welding outfit (Fig. 51) consists of:

1 type BB welding torch, with 6 welding tips, Nos. 1, 2, 3, 4, 5, and 6.
1 type H carbon-removing tip.
1 type OO lead-burning tip.
1 type G radiator-soldering tip.
1 type F brazing tip.
1 type D oxygen regulator, with 50-lb. working pressure gauge.
1 type DD acetylene regulator, with 50-lb. working pressure gauge.
1 No. 60-H adaptor for Prest-O-Lite tank.
1 No. 61-H adaptor for commercial and air-reduction tanks.
1 10-ft. oxygen hose, with couplings.
1 10-ft. acetylene hose, with couplings.
1 pair welding goggles, supply of cast iron, and Norway iron welding rod, flux.
1 spark lighter and welding handbook, weight 16 lbs., packed in carton.

The price of the No. 2 welding outfit complete, without cutting attachment, is $44.50; with cutting attachment, $10 extra.

No. 4 Imperial combination welding and cutting outfit: A splendid equipment for all general work, garages, repair shops, etc. The combination welding and cutting torch performs both operations with one torch. Consists of type B welding torch, with type DB cutting attachment, ten welding and three cutting tips, decarbonizing torch, regulators, gauges, hose, connections, goggles, complete supply of welding materials, ready for service. Weight, approximately 80 lbs., net, each $90.00.

No. 5 Imperial duplex welding and cutting outfit: This is a combination of the Nos. 1 and 3 outfits for both welding and cutting, and is the best all-purpose apparatus obtainable at any price, being fully adequate to handle all kinds of welding and cutting within the limits of the process. Consists of a complete No. 1 welding outfit as described, and also includes a type E cutting torch with two housings and four tips, and an extra pair of goggles and 25-ft. lengths of hose. Weight, approximately 90 lbs., net, each, $120.00.

(**Manufacturer**, The Imperial Brass Mfg. Co., 1200 W. Harrison St., Chicago, Ill.)

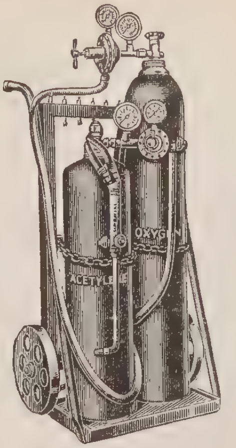

Fig. 53. Imperial portable truck.

Oxygen Decarbonizing or Carbon Burning (Also Called Decarbonizing)

All traces of carbon can easily be removed from the cylinders and the head of pistons of an automobile engine with the No. 6 Imperial carbon burning outfit (Fig. 54) in less than thirty minutes, at the small cost of from 10 to 15 cents per cylinder.

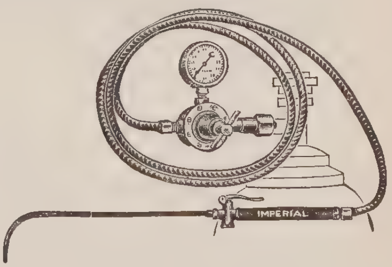

Fig. 54. Decarbonizing outfit.

This is a wonderful improvement over the old, expensive, and slow process of removing carbon by scraping the cylinder.

Oxygen can be purchased from service stations located in most prominent cities. The outfit consists of type G carbon burning torch, type D regulator, gauge, hose, connections, etc. ($15.00).

Brazing and Soldering Outfit

An outfit ideal for radiator repair work and which can also be used to advantage for all kinds of soldering, brazing, and light preheating work in garages and repair shops, is the Imperial No. 30 brazing and soldering outfit shown in illustration (Fig. 55).

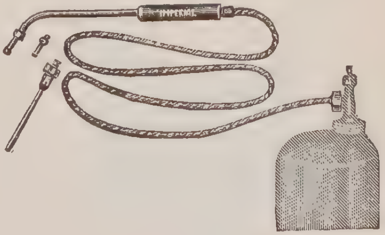

Fig. 55. Brazing and soldering outfit; also used for radiator repairing.

The torch burns acetylene and the tip draws in the necessary oxygen from the atmosphere, making it economical to use.

The tank connection fits the small automobile acetylene lighting (Presto) tank, but the outfit can be used on large-size cylinders by means of an adapter fitting. The outfit consists of type AD torch, 3 tips (one with a long spout for radiator soldering), 6 ft. of hose and connections ($4.50).

Lead Burning

Lead burning of connectors on storage batteries, etc., with acetylene, oxygen, or illuminating gases, etc., including the equipment and torches used, is explained elsewhere; see Index under "Lead burning."

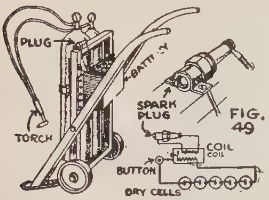

Fig. 56

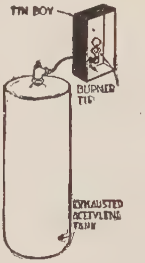

Fig. 57

Fig. 56. A means of **electrically lighting the welding torch** is shown above. A box, holding several dry cells, and a spark coil are mounted at the rear of the welding truck, and are connected to a spark plug attached to the top of the frame. The plug is thrown into operation by a push button connected into the battery circuit. This system of lighting is adapted to short welding jobs.

Fig. 57. A **welding pilot light.** When the gas in the welding tank becomes too low for welding purposes, there is still sufficient gas for supplying a pilot light as in Fig. 57. The light comprises a small gas tip arranged in a tin box as shown.

Welding Precautions

1. Always shut off the gas at the cylinder valves when the work is finished.
2. Never leave pressure in the regulators when not in use. The pressure gauges will indicate.
3. Never clean out a blow-pipe tip with a sharp, hard tool.
4. Before attaching rubber hose to a blow-pipe or regulator, make sure that the inside of the hose is free from dust or powder (used as a preservative), which is apt to choke the blow-pipe.
5. Do not under any circumstances use oil or grease on oxygen cylinder valves or regulators.
6. Always see that the hose is clamped securely to the blow-pipe and regulators before using.
7. Always turn on the cylinder valves slowly.
8. Never open the acetylene cylinder valve more than one full turn of the spindle.
9. In case the flame goes out at the tip or burns back of the tip, shut off first the oxygen, then the acetylene, at the blow-pipe.
10. Always have a bucket of water handy while welding or cutting, for cooling the blow-pipe tips when necessary.
11. If the flame is not blue and the part being welded is smoked black, then the oxygen line is likely to be stopped up or the tank is empty.
12. In disconnecting an empty acetylene cylinder from the welding outfit, remember to **close the cylinder valve** tightly. Remember that the acetone in an empty cylinder is inflammable, and that, should the temperature in the room increase, an open valve would permit vapor to escape, as well as any slight quantity of gas which might yet remain in the cylinder. For these same reasons, the railroads require that valves be closed before shipping.
13. Remove "inflammable" red labels from acetylene cylinders before shipping back, and ship as "empty returned gas cylinder," in order to get the lowest freight rate.

INSTRUCTION No. 67

TOP REPAIRING[1]

Any repair shop, by the investment of a small amount of money in equipment, and the exertion of reasonable care, can develop a profitable top repair department. It is as essential a part of the trade as is the machine shop or the vulcanizing shop.

Only a small amount of equipment is necessary in a top repair shop, and this, with the exception of the sewing machines, may be made by the repairman himself.

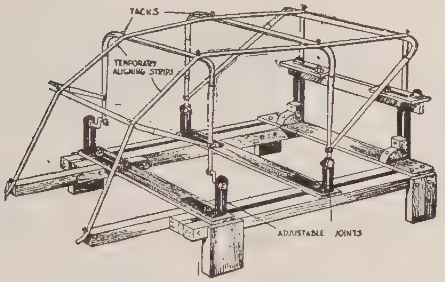

Fig. 1. When the car cannot be left in the shop, this adjustable frame enables the mechanic to duplicate the method of holding used on the car.

The top building frame is shown in Fig. 1, and it is used only when the car for which the top is being repaired cannot be left during the work. It is simply an adjustable framework upon which the top may be placed in exactly the position it occupies when up, and on the car. For each car the frame is set to duplicate the measurements of the top-supporting irons and the car body. Then the workman can repair or rebuild the top with assurance that it will fit when returned to the car. When possible, the top should be left on the car during the repair.

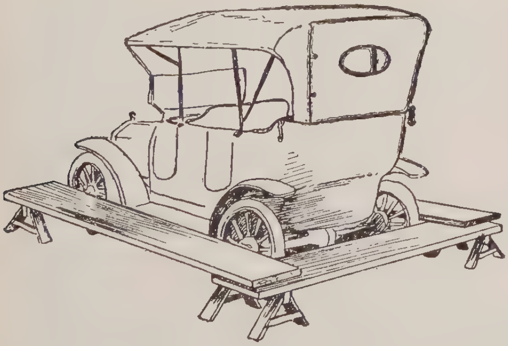

Fig. 2. Most tops are repaired right on the car, and a framework on three sides of the car renders all parts accessible.

In order to render all parts of the top accessible, when left on the car, a framework shown in Fig. 2 is set up around three sides of the car. This framework is about 18″ high, and comprises three planks resting on four small wooden horses.

Another method of accomplishing the same result, yet one which the author has never seen, would be to construct a pit below the floor level. This would permit the workman to work directly from the floor and save the time lost in stepping to and from the platform.

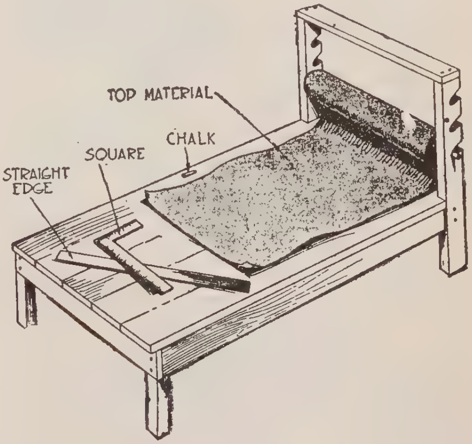

Fig. 3. The rolls of top material are carried on rods hung in a notched upright, and the material is marked out and cut to form on the laying-out table.

All work is laid out and cut on the laying-out table shown in Fig. 3. This table is about 6 ft. wide, 12 ft. long, and 28 in. high. A notched rack at one end supports the rolls of top material and enables the workman to obtain or replace the top material readily when desired. Rolls may be easily removed from the frame, or as many as three rolls of material may be carried at one time.

The tools of the workman are few, comprising a light cross-peen **hammer,** with a tack puller fitted to the end of the handle; a heavy pair of **shears,** a small **cold chisel,** and a **nail set** or **punch.** These are carried in a special apron, made of top material, as shown in Fig. 4. In addition, **a carpenter's square,** a 10-ft. **straight edge, a yardstick,** and a **plumb bob** are required. The plumb bob is used to plumb up the edges of the back curtain, when fitting, to make certain that they are hung straight.

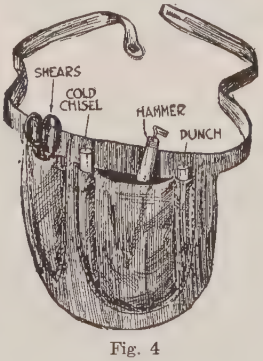

Fig. 4

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[1] From *Motor World*, by S. Thorton Williams. Note. The shop layout and special tools, together with the procedure, were obtained from the Barton Auto Top Co., Detroit, Mich.

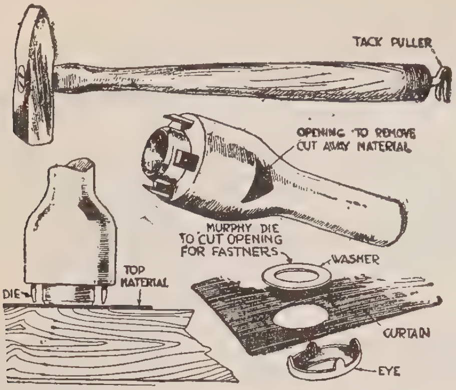
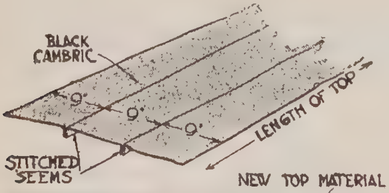

TACK PULLER
OPENING TO REMOVE CUT AWAY MATERIAL
MURPHY DIE TO CUT OPENING FOR FASTNERS
WASHER
TOP MATERIAL
DIE
CURTAIN
EYE

Fig. 5. The other end of the hammer (at top of illustration) is fitted with a tack puller, thus combining the two tools. Special dies are required to cut the openings for the fasteners. The most common type is shown in the lower part of the illustration.

In addition, several special punches and dies will be necessary for cutting the openings for the curtain fasteners. One of these—styled the **Murphy die**—is shown in Fig. 5, and corresponding dies are used for each type of fastener.

The sewing machine used in this work is of extra heavy construction, and is similar to those used by harness makers. These machines should be motor-driven, and may be purchased from almost any reliable sewing-machine manufacturer. See page 755.

So much for the equipment. Now for **the method of doing the work.** Briefly this consists of removing the top material, part by part, using the parts as patterns to cut the new parts by; fitting the parts to the top frame; removing the parts; sewing them together, and then placing them again on the frame. Careful work is essential, and after carefulness has become a habit, speed may be developed. Carefulness, then speed, are the only two requirements for a successful top repairman.



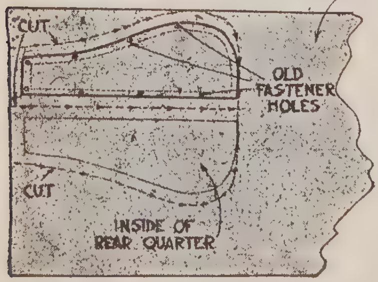


Fig. 6. The side pads are a single strip of cambric 9" wide and sewed as shown.

The following is a typical example of the method used in re-covering an automobile top. Though it specifically applies to a Ford top, it may, in general, be applied to any car.

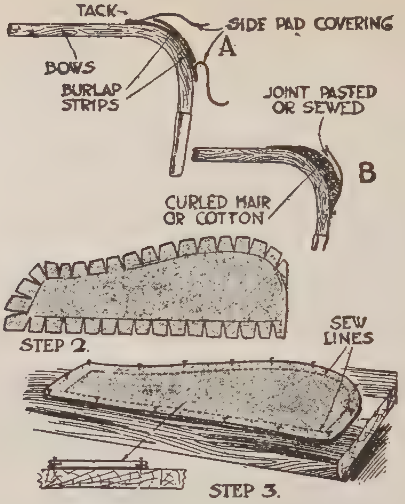


Fig. 7. In the upper half of the illustration is shown the method of building up the side pads.

The lower half of the illustration shows the various steps in laying out and cutting a rear quarter. It is then taken to the machine and sewed.

1. **Remove the top covering from the frame,** part by part, using the hammer and cold chisel as tools. Note how each part is fastened, as the rebuilding must be exactly the reverse of the tearing down.

2. **Using each part as a pattern, one by one, mark out the new parts on the top material.** Care must be taken to allow extra material at the edges for fastening the material to the frame. The method of constructing the rear quarter is shown in Fig. 7 (lower half), and this method applies in general to each of the top parts.

All metal fastener holes should be punched, using the holes in the old parts as guides, and all square corners should be checked up by means of the square. The parts are then sent to the machine, and the necessary sewing is done. The celluloid windows are also placed in the rear curtain at this time.

In the meantime, the top frame should be placed in good condition. If any bows are broken, new bows should be fitted. Ordinarily, new wrapping should be tacked around the bows, but if this wrapping is only faded, it may be dyed to conform to the inside of the top material.

3. **The side-pad covers should now be made,** according to the pattern shown in Fig. 6. On the Ford, black cambric is used, but in every case the material should conform in color and quality to that used in the top material.

4. **Line up the top bows.** The method of doing this is shown in Fig. 1. Heavy canvas straps are passed over each side of the bows, drawn tight, and tacked in place. The front bow should fit down over the windshield; the two middle bows should be vertical, and the position of the rear bow can be gauged by the length of the straps holding it down to the body back.

5. **The side-pad liners are next tacked in place,** and the burlap strips are tacked tightly in place.

After this the curled hair, or cotton packing, is replaced, and the side-pad flaps are pasted into place. If desired, the edges of the pad may be sewed together. These operations are shown in detail in Fig. 7 (upper part).

6. **The rear quarters and back curtain are now fitted and tacked in place,** after the metal fasteners have been applied, as shown in Fig. 5. All vertical edges are plumbed up with a plumb bob, as any edge out of the vertical here is particularly noticeable.

7. **The two side quarters are now temporarily tacked in place,** beginning at the front and working to the back. These quarters should be drawn tight, without wrinkling. The edges of the deck are then turned under, and the deck is temporarily tacked in place.

8. **By carefully fitting and changing, the top may be fitted to the bows in exactly the position it is to occupy.** When everything appears to fit correctly, the side curtains should be placed in position, and if necessary, the tacks should be removed and the top pieces shifted until the side curtains fit. (In most cases new side curtains do not have to be made; but if so, the new curtains should be fitted at this point.)

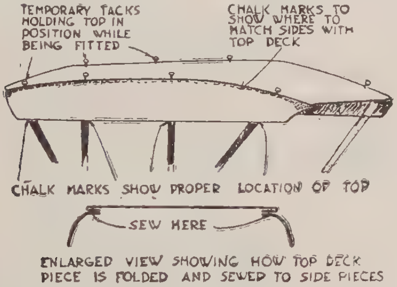

TEMPORARY TACKS HOLDING TOP IN POSITION WHILE BEING FITTED
CHALK MARKS TO SHOW WHERE TO MATCH SIDES WITH TOP DECK
CHALK MARKS SHOW PROPER LOCATION OF TOP
SEW HERE
ENLARGED VIEW SHOWING HOW TOP DECK PIECE IS FOLDED AND SEWED TO SIDE PIECES

Fig. 8. After all parts of the top are made, they are temporarily tacked to the bows and fitted. When a perfect fit is secured, the edges are marked, and the parts removed and sewed. They may then be replaced on the frame, and permanently fastened in place.

9. **When everything is right, the mating edges of the top pieces should be marked with chalk,** and these marks should be crossmarked, as shown in Fig. 8. Then, by joining the corresponding marks together, the sewing-machine operator can sew the parts together correctly. Chalk marks should also be placed at the points where the edge of the top crosses the bows. This permits the top to be correctly replaced after a sewing.

10. **The parts of the top are then removed, and the flaps on the edges that are to be sewed are trimmed down to a width of about 2 in.** The parts are then sent to the machine and sewed together.

11. **To complete the work it is only necessary to replace the top covering and tack it securely in place.** All extending edges are removed and the joints covered by a narrow strip of cloth material fastened by black upholstering tacks.

The foregoing covers the method of completely replacing the top covering, with the exception of the side curtains. As stated, this is rarely necessary, as the side curtains are little used. If desired, any one part of the top may be replaced with new material, providing the other parts are in good condition. However, if either the deck or side-quarters must be replaced, it is necessary to tear the top completely down in order to sew it together again.

In cases where it is necessary to replace some parts of the top covering, it will usually be found advisable to renovate the interior and exterior of the rest of the covering to make it conform to the appearance of the new part. Or this renovating may be done at any time to improve the appearance of the top.

After applying any patches that are necessary, replacing broken windows, and tacking on new binding at the edges where required, the top should be thoroughly brushed and cleaned. Gasoline should never be used for this purpose if rubber is used in the top material construction, as its action tends to destroy the rubber. Soap, warm water, and a brush are all that are usually required.

When the top is thoroughly cleaned and dried, **top dressing may be applied** to the outer surfaces, and the faded inner surfaces may be dyed black. There are many brands of top dressing on the market for this purpose, and any well-known brand should prove entirely satisfactory. By exercising a little care, the appearance of a shabby top may be greatly improved by this simple cleaning, patching up of loose ends, and application of top dressing.

Top roof patching strips adapted for mending tops can be cut to fit any repair needed in roof, side or back curtains and are permanent and waterproof; they are convenient for all repair shops, and are made of different material to meet different requirements. They can be secured of supply houses.

Fig. 9

An assortment of window and all styles of top roof patching materials, known as the "Stik-Tite" brand, can also be secured of supply houses.

Celluloid windows, bound with suitable material to match different curtains, can be attached in ten minutes by anyone, without removing and without stitching the back curtain.

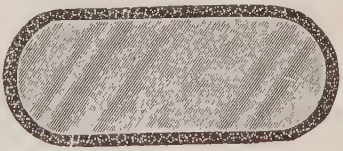


Fig. 10. **Celluloid windows.**

They are made to fit almost all popular cars, and can be secured of supply houses. A well-known brand is the "Stik-Tite," already mentioned.

Where to Obtain Top Material

Tools, such as eyelet punches and dies for sockets and eyelets, special hand screwdrivers, curtain fasteners, etc, are obtainable from Carr Fastener Co., Cambridge, Mass.; G. W. Murphy Co., Amesbury, Mass.

Top material is sold by Cray Bros., Cleveland, Ohio; Thomas Auto Top Co., Muncie, Ind.; Cincinnati Auto Specialty Co., 312 Main St., Cincinnati, Ohio; Du Pont Fabrikoid Co., Wilmington, Del.; F. S. Carr, Boston, Mass.; L. C. Chase Co., Boston and Chicago; Pantasote Co., 11 Broadway, New York, N.Y.

Top and upholstering dressing and celluloid for curtain, lights, etc. is to be had of Cray Bros., Cleveland, Ohio; F. S. Carr, Boston, Mass.; Ero Mfg. Co., 753 W. Jackson Blvd., Chicago, Ill.; Boyer Chemical Co., 940 N. Clark St., Chicago, Ill.; Cincinnati Auto Specialty Co., 312 Main St., Cincinnati Ohio.

Sewing machine: The Singer Sewing Machine Co., Singer Bldg., New York, manufactures a sewing machine especially designed for top and curtain work, seat covers, etc. It is known as "class 1688."

Rain shields, similar to that shown in Fig. 14, for placing over the windshield to prevent snow and rain accumulating, is another profitable accessory to handle (manufactured by Jos. N. Smith Co., Detroit, Mich.; Gemco Mfg. Co., Milwaukee, Wis.).

Seat covers are also profitable to handle (obtainable from Cray Bros., Cleveland, Ohio; Glover Eq. Co., Indianapolis, Ind.).

Top and upholstering dyes and dressing are to be had of Cray Bros., Cleveland, Ohio; Northwestern Chemical Co., Marietta, Ohio.

Complete tops are also to be had of Cray Bros., Cleveland, Ohio.

Glass curtain lights (Fig. 11) are very popular. They are rather expensive, however, but add considerably to the appearance of a car. The glass is beveled and comes with a frame ready to place in the curtain. Can be secured of supply houses or of Frankel Specialty Corpn., 356 W. 56th St., New York, N.Y.; Wm. R. Johnston Mfg. Co., 451 E. Ohio St., Chicago, Ill.; Nurre Mirror Plate Co., Bloomington, Ind.

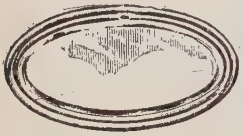


Fig. 11

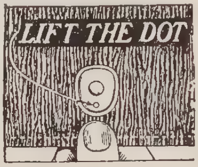


Fig. 12

Fig. 11. Glass curtain light.

Fig. 12. "Lift-the-dot" curtain fasteners.

The "Lift-the-dot fastener" is a very popular curtain fastener (Fig. 12). To unlock and remove, lift the dotted end of the socket which is placed nearest the edge of the curtain. It is natural to lift the edge of the curtain, so there should be no difficulty in remembering always to "lift-the-dot" and avoid tearing the curtains. Manufactured by Carr Fastener Co., 31 Ames St., Cambridge, Mass.

Miscellaneous

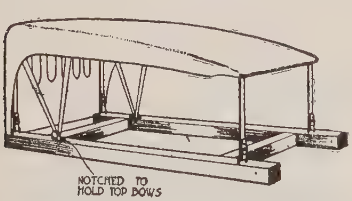


Fig. 13. It is often desired **to paint or repair a top** without leaving the car in the repair shop. A simple support that permits this is a rectangular wooden framework notched to hold the top irons. The top is placed on this framework.

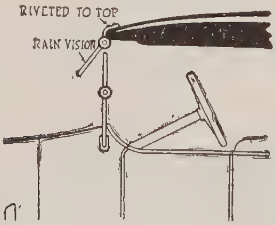


Fig. 14. **Rain vision windshields** are common on closed cars, but unusual on open ones. It is a simple matter, however, to add this feature. The upper section of a windshield is mounted on the front of the top, two specially made brackets being used to hold it in place. It catches the rain and the regular windshield protects the driver from the wind.

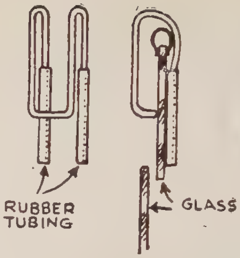


Fig. 15

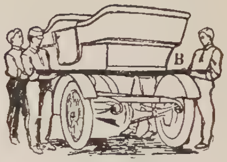


Fig. 16

Fig. 15. One of the essentials of bad-weather driving is some provision for keeping the **top glass of the windshield free from snow or rain.** Chemical preparations are sometimes used to give the surface of the glass a greasy surface, so that the rain will run off rapidly, but this method is not effective against snow.

Scraping off the surface of the glass is perhaps the most effective method yet devised.

A simple cleaner may be made of a piece of rather heavy steel or brass wire, about a quarter of an inch in diameter, and a piece of rubber tubing. The wire is bent in the form of a double loop, and a piece of rubber tubing is slipped over each free end of the wire. If the wire is coated with rubber cement, before the rubber tubing is pulled on, there will be no chance for the tubing to come loose.

The middle of the wire loop should rub on the inside of the glass at a point about opposite the middle of the rubber tubes, so that an even pressure will be exerted by the rubber tubes over their whole length on the surface of the glass. (*Ford-owner.*)

Fig. 16. **Removing a body.** Showing how the body of a car can be lifted easily from or on to the chassis, and conveniently transported about the garage or shop.

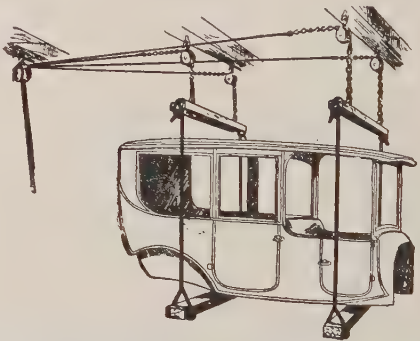


Fig. 17. **Closed bodies** may be **removed** without strain by the aid of the hoisting cradle illustrated. Two cross-pieces are attached to separate chain hoists and are so spaced that they hang 2 ft. from the ends of the body to be removed. First one end of the body is pried up, and a lower cross-member slipped beneath it. Then the other end is raised, and the other lower member put in place. The steel stirrups are then used to attach the lower and upper cross-pieces, after which the body may be raised and the chassis rolled from under.

Vulcanizing Small Holes in Tops

Dr. S. A. Peake's method of **vulcanizing small holes** as large as ½" in tops is as follows: First clean both sides of the surface with gasoline; then use "Mastic" or "Tire-Doh" and work it to a point, and insert in the hole, so as to fill it completely. Cut off on each side. Then place a hot sad-iron underneath and on top. This will vulcanize the Mastic in the hole.

Cleaning Tops, Upholstering, Etc.

On this subject see Index under "Care of a car."

INSTRUCTION No. 68

REPAIRING AND ADJUSTING A CAR: Overhauling a Car; Cleaning and Lubricating; Removing Carbon; Causes of Loss of Power; Compression Tests; Grinding Valves; Testing for Engine Knocks; Refacing and Reseating Valves

WHAT CONSTITUTES A CAR OVERHAUL

Automobile overhauling is essentially a process of general cleaning, inspection, tightening-up and re-adjusting, involving, perhaps, some minor replacements, all of which will be taken up in their respective order.

Engine[1]

Test compression: Test for knocks; clean carbon; grind valves; adjust valve clearance; fit new rings if necessary; re-bore cylinders if necessary; take up on bearings; check the valve timing; examine valve springs; examine gaskets.

Ignition and wiring: Test the ignition timing; test battery and electrical apparatus; clean spark plugs and adjust gaps, also clean, oil, adjust and tighten the generator and starter, nuts, etc., and see that all ground connections are tight.

Clean engine: Flush out old oil as explained on page 167. Refill oil pan with a good grade of oil.

Miscellaneous engine parts: Examine water pump; see if water hose requires replacement; examine intake and exhaust manifolds and see that gaskets and joints are tight; tighten all cylinder and cylinder head bolts and nuts.

Radiator

The radiator should be disconnected and a **stream of water forced through it** for several hours. **If scale exists,** cleaning can be done with a solution of 1 lb. ordinary washing soda and 5 gallons of water, allowing it to stand for an hour (see Index under "Cleaning radiator").

Carburetion

The carburetor should be removed and thoroughly **cleaned and tested for float leak.** Examine the gasoline line and see that all joints are tight.

Clutch and Transmissions

The clutch is one part that should receive attention, and here the repairman should resort to a large extent to the maker's instruction book, if it is still at hand. The cone clutches are usually faced with leather or fabric. The leather can be cleaned with a dry cloth and can then be painted very lightly and evenly with neatsfoot oil. The fabric facing can be given a squirt-gunful of kerosene. Be free with oil on all the clutch connections, and take especial care that the clutch thrust bearing is properly fed. Oil all connections from the clutch pedal lever to the clutch proper. Do not take up on the clutch spring unless you are certain that it is needed.

With wet-plate clutches the housing should be flushed with kerosene and the engine turned over a number of times. At the same time that the engine is turned over someone should push the clutch pedal in and out. This works the kerosene around the plates and tends to remove any gummy deposits. Then drain the housing, and repeat the operation. That finished, fill to the required level with oil. Usually 1 pint is used with ½ pint of kerosene.

With a dry-plate clutch the only thing that may be needed is a cleaning with kerosene, to remove gum. However, use a squirt gun in this case. No matter what the type of clutch, be free with oil at all the various connections.

Look for small oil holes which are clogged with dirt. Oil the clutch cross-shaft, the clutch collar, and all the parts which move.

Universal joint: Back of the clutch or transmission there may be a universal. Clean it thoroughly with kerosene, whether it is exposed or housed. Allow this to dry, and then pack with graphite. If you have no graphite, get some, or use a good grade of grease.

Next, proceed to the transmission. Drain the old lubricant, replace the drain plug, and remove the cover if there is one. Fill the case half-full of kerosene, and with a clean cloth mop it. This is a dirty job, but it will be worth your while, because the gear-set usually is neglected throughout the year and is required to give efficient service with oil that is perhaps a year old. With the case clean, add a grade of oil as recommended by the manufacturers, or see page 171. Do not put too much oil in the case. There usually is a level-plug, but if there is none, allow the level to be about up to the shaft of the highest or upper gears.

Running-Gear Parts

Wheels: First in order come the wheels. The car has been jacked up, and the next step is to see that the wheels run true on their bearings. There are many ways of doing this. A good way is to sight with one eye closed, while the wheel is revolving. Any irregularity in wheel movement is easily detected. However, sometimes the rim is bent a little and one will imagine the wheel is running untrue. Grip the wheel firmly with both hands and test for side play and up-and-down play by pushing and pulling on the wheel in all directions. A loose bearing usually causes this trouble, and in many cases the looseness can be overcome by tightening the nut slightly. Sometimes new bearings are needed, because they are worn excessively. This subject is more fully treated farther on, under discussion of the cause of "wobbly wheels," etc.

Align the wheels, as explained farther on.

The steering assembly, brakes, and other parts require the same sort of attention and will be taken up in their separate order farther on.

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[1] See Index under "Testing a car before overhauling."

The rear axle should be cleaned and lubricated, and the drive pinion tested as to its relation with the drive gear on the differential. If noisy, it is probably loose and requires adjustment, as will be explained under "Adjustment of rear-axle gears."

Inspection after Repairing

See that the following are in proper condition:

1. Cylinder head tight.
2. All spark plugs firing, and tight.
3. Fan belt tight.
4. Fan bracket bolt and cotter pins tight.
5. Adjust carburetor properly.
6. Water connections tight and no leaks.
7. Hood fits properly.
8. Head lamps burn, properly focused; connections tight.
9. Front wheels adjusted, lubricated, and lined up.
10. Fenders and running board bolts and nuts tight.
11. Doors work properly.
12. Brakes adjusted.
13. Transmission bands adjusted (on Ford car).
14. Floor boards fit properly.
15. Grease in rear axle.
16. Grease in all cups.
17. Oil in engine.
18. Water in radiator.
19. Tires properly inflated.
20. Examine tool kit.
21. Curtains fit.
22. Horn in working condition.
23. Starting motor and generator is in working condition.
24. Battery fully charged.

A SUGGESTED METHOD OF OPERATING A REPAIR SHOP; ALSO A GUIDE FOR OVERHAULING A CAR

The following lay-out is one recommended by Mr. K. R. Wilson, Buffalo, N.Y. Note the flat rate system of charging for the work, as shown in column A, and the flat rate to pay the mechanic, as listed in column B. This method of "selling service," as it is termed, is meeting with success. The list below refers to the Ford, but can be worked out for other popular cars.

The idea involves dividing the shop into divisions for doing a certain class of work; to charge for the work done, as enumerated, and to pay the mechanics accordingly. Note that each job of work is numbered.

The following data give information covering the overhauling of the entire Ford car, so far as labor cost is concerned, and the average schedule of prices charged for doing the work as shown under column A. This is worked out on the piece-work basis, as shown in column B. Therefore, as you will note, the repair shops get practically 60 cents out of every dollar taken in, and the mechanic gets approximately 40 cents.

Engine Division

		A	B
1A.	Remove motor from car	$3.00	$1.10
1B.	Overhaul motor and transmission out of car	20.00	8.00
1C.	Replace motor in car	7.00	3.00
2.	Overhaul motor only—out of car	15.00	6.00
3.	Overhaul transmission only, or repair, replace magneto out of car	5.00	2.00
4.	Braze crank-case arms; support or repair leak in case by taking out the motor	12.00	5.00
5.	Install or refit one piston or one connecting rod	3.00	1.20
6.	Install or refit two or more pistons or connecting rods	5.00	2.00
8.	Tighten two or more connecting-rod bearings	4.00	1.50
9.	Replace transmission bands without starter	2.50	1.00
9A.	Replace transmission bands on cars equipped with starter	3.50	1.40
15.	Grind valves and clean carbon	3.00	1.10
20.	Replace cylinder-head gasket	1.00	.40
21.	Replace radiator or all three hose connections	.75	30
22.	Replace one hose connection only	.40	15
23.	Replace crank-shaft starting pin, or pulley	1.50	.50
24.	Tighten motor to frame	1.25	.45
25.	Clean crank case or install gasket under lower cover	.50	.15
26.	Replace carburetor or manifold; repair leak in manifold	.75	.25
27.	Install new butterfly spring	.75	.25
28.	Overhaul carburetor	1.50	.50
32.	Replace commutator pull-rod joint	.60	.20
33.	Replace or rebush fan-pulley assembly	.60	.20
34.	Adjust clutch fingers and transmission bands	.60	.20
35.	Adjust transmission bands only	$ .40	$ .15
40.	Tune and adjust motor, regular, only	1.25	.40
41.	Tune and adjust motor, special, only	1.75	.60
42.	Tune and adjust motor, regular, with operation No. 15	1.00	.40

Parts Brought in or Shipped in for Repairs

		A	B
57B.	Overhaul transmission, only	4.00	1.60
58B.	Rebore cylinder only	2.75	.50
59B.	Rebore cylinder only, including fitting of pistons	3.00	.60
60B.	Rebore and re-babbitt cylinder, including fitting pistons	5.00	1.00
61B.	Re-babbitt cylinder only	2.75	.40
62B.	Re-babbitt cylinder, fit crank shaft, and run in	6.00	2.00
63B.	Rebore and re-babbitt cylinder fitting of pistons, crank shaft, connecting rods, and running in	8.00	3.00
64B.	Rebore and re-babbitt cylinder, fit pistons, valves, push-rods, cam shaft, crank shaft, connecting rods, and run in	11.00	4.00
66B.	Rebore and fit pistons, valves, and push rods, and straighten and fit cam shaft	4.00	1.50
68.	Rebush three transmission drums	1.50	.50
69B.	Rebush transmission drums, each	.60	.20
70B.	Rebush and re-rivet three triple gear assemblies	.75	.25
77B.	Straighten cam shaft and fit bearings	1.25	.50

Rear System Division

Model "T" Chassis

		A	B
96.	Overhaul rear axle and re-bush springs and perches when necessary	7.00	2.75
96A.	Overhaul rear axle when car has shock absorbers, truss rods, or special hub brakes	8.00	3.25
98.	Repair or replace one rear radius rod	1.50	.60
99.	Replace rear spring; tie bolt or new leaf, including polishing and graphiting or leaves and lining up of body	3.00	1.20
102.	Pad rear spring to line up body or replace rear spring tie bolt only	2.00	.80
107A.	Install felt and steel washers—both sides	1.25	.50
108.	Install brake shoes and equalize emergency brakes—one shoe	.75	.30
108A.	Install brake shoes and equalize emergency brake—both shoes	1.00	.40
116.	Adjust pull rods or replace one	.75	.30

Model "TT" Chassis

		A	B
96T.	Overhaul rear axle and re-bush springs and perches where necessary	15.00	6.00
97T.	Repair or replace drive-shaft tube	7.00	2.80
98T.	Repair or replace one rear radius rod	3.00	1.20
99T.	Replace rear spring (one)	3.00	1.20
99TA.	Replace rear spring (both)	5.00	2.00
100T.	Remove front and rear springs, polish and graphite only	7.00	2.80
101T.	Replace spring perches—one	1.50	.60
101TA.	Replace spring perches—both	2.50	1.00
104T.	Install universal joint	5.50	2.20
106T.	Tighten rear radius rod	1.75	.70
107T.	Install felt and steel washers (one side)	1.25	.50
107TA.	Install felt and steel washers (both sides)	2.25	.90
108T.	Install brake shoes and equalize emergency brakes—one	1.25	.50

		A	B
108TA.	Install brake shoes and equalize emergency brakes—both	$2.25	$ .90
109T.	Tighten universal ball-cap bolts	.75	.30
110T.	Install or tighten rear-spring clips	1.50	.60
111T.	Tighten rear hub lock nut—one side	.50	.20
111TA.	Tighten rear hub lock nut—both sides	1.00	.40
112T.	Fit new hub keys—one side	1.00	.40
112TA.	Fit new hub keys—both sides	1.75	.70
113T.	Replace pull-rod supports—one	.50	.20
113TA.	Replace pull-rod supports—both	.75	.30
114T.	Replace or re-bush hub-brake cam—each side	2.50	1.00
115T.	Replace rear axle assembly	5.00	2.00
117T.	Straighten radius rod in car	1.50	.60
118T.	Install outer roller bearing—each	2.00	.80

Front System Division

167.	Overhaul front axle, including re-bushing of springs and perches when necessary, straightening and lining up and readjusting of wheels	5.00	2.00
167A.	Overhaul front axle when car has shock absorbers, special front radius rod, etc.	6.00	2.40
168.	Rebush spindle bodies and arms—each side	1.50	.60
169.	Replace or straighten front axle (no other repair)	2.50	1.00
171.	Rebush spindle arm—each	.75	.30
173.	Replace front spring tie bolt or new leaf, including polishing and graphiting of leaves	2.50	1.00
174.	Replace front spring or tie bolt only	1.50	.60
177.	Replace radius rod	.75	.30
179.	Replace spindle arm or body, and line up assembly	.75	.30
181.	Tighten all sockets and joints of front end	1.25	.50
182.	Replace or straighten spindle or steering-gear connecting rod	.60	.25

Chassis Division

Front End and Frame

228.	Replace front cross-member	6.50	2.50
230.	Straighten front cross-member without removing from car	2.50	1.00
232.	Replace side member of frame	20.00	8.00
242.	Repair hand-brake lever assembly, including replacing of pawl	1.00	.40
243.	Replace hand-brake lever quadrant without removing running-board shield	1.25	.50

Fenders and Running Boards

258.	Replace one fender or running board	1.00	.40
259.	Replace one fender or running board and straighten iron or bracket	1.25	.50
260.	Remove fender or running board and straighten	1.00	.40
261.	Replace running board shield—one	1.25	.50
264.	Replace rear fender iron	.75	.30
265.	Replace truss rod—one rod	.40	.15

Dash

276.	Replace dash	4.50	1.80
279.	Replace coil box, install new switch, or repair the box	.60	.25

Steering Gear

291.	Overhaul steering gear, including replacing of quadrant or gear case, and re-bushing of bracket	3.50	1.40
292.	Overhaul steering gear when motor is out	2.50	1.00
298.	Re-bush steering-gear bracket only	2.00	.80

Muffler

310.	Change long exhaust pipe	.75	.30
311.	Replace muffler	.60	.25
312.	Repair muffler	1.00	.40
313.	Repack exhaust pipe pack nut	.40	.15

Gas Tank and Line

324.	Clean sediment bulb and gasoline feed line, and clean carburetor	.75	.30

Radiator

350.	Repair radiator, solder one or two tubes, and replace one or both sides	3.00	.90
352.	Solder casting to lower or top tank when necessary to remove radiator	1.50	.50

Wheels

		A	B
365.	Change hub, rear or front	$1.00	$ .40
366.	Replace wheel and tire—each	.75	.30
367.	Adjust and dope front wheels	.60	.25
368.	Remove front wheels and replace bearing parts—one wheel	.75	.30
369.	Line up front wheels	.40	.15
370.	Oil and dope car (including material)	.75	.25

Body Division

412.	Install new lock—Touring or Runabout—each	1.00	.40
413.	Replace Town Car or Sedan door lock	1.50	.60
415.	Install new leather on door panel—one	.60	.25
418.	Re-upholster Touring body—using new materials	10.00	4.00
419.	Re-upholster Runabout body—using new materials	6.00	2.40
420	Change closed body	10.00	4.00
421.	Change Touring or Runabout body	6.00	2.40

For removing dents and other general repairs to bodies make contract price, according to amount of work necessary, using operation No. 2000.

Paint Division

Make contract price according to quality of job desired and condition of car when brought in. Consult paint foreman. Use operation No. "P."

Top and Windshield Division

455.	Overhaul Touring car on Torpedo Top, including re-covering, lining up, and fitting of curtains	7.50	3.00
456.	Replace top deck or side quarters—each or both	3.00	1.20
458.	Install and fit top	2.00	.80
464.	Replace back curtain	1.50	.60
465	Install celluloid lights in side curtains, per light	.60	.25
469.	Replace windshield and line up windshield frame	1.00	.40
470.	Replace upper windshield glass	1.00	.40
471.	Replace lower windshield glass	1.00	.40

Special

530.	Trouble calls (from any point within city limits)	1.50	.60
531.	Tow-in (from any point within city limits)	3.00	1.20
536.	Inspect and prepare new cars for delivery, including stamping identification number, pasting sticker on windshield, and installing or adjusting any minor parts when necessary, each	3.00	1.20
537.	Deliver car to purchaser's address	1.50	.60
538.	Wash and polish Touring car or Runabout	1.50	.60
539.	Wash and polish Touring Car or Runabout—wire wheels	2.00	.80
540.	Wash and polish Coupé or Sedan	2.00	.80
511.	Wash and polish Coupé or Sedan—wire wheels	2.50	1.00
545.	Clean car for placing on show floor, each	1.00	.40
533.	Teach car purchaser to drive, each lesson	2.00	.80

Commercial Bodies

605.	Install slip-on body	2.00	.80
B.	Install any new commercial body	CONTRACT	

Electrical Accessories

650.	Install Ford alarm	.50	.20
654.	Remove battery from car for recharging and install rental battery, including recharging of battery	.75	.25
655.	Remove rental battery from car and install customer's recharged battery	.25	.10
656.	Install electric horn	.50	.20
660.	Install electric tail light on dry cells and magneto	2.00	.80
661.	Install electric dash light	1.00	.40
662.	Install electric dome light	2.00	.80
663.	Install electric spot light	1.00	.40
664.	Install headlight lens	.40	.15
667.	Install standard Ford electric starter, complete	7.50	3.00

Wheels and Tires

702.	Change tires, each	.30	.15
703.	Install side-tire carrier	.75	.30

		A	B
704.	Install rear-tire carrier	$1.50	$ .60
705.	Install rear holder for wire wheels	1.50	.60
706.	Install 30″ x 3½″ Ford wheels or demountables in front only	3.00	1.10
707.	Install complete set of demountable rim wheels	4.00	1.60
708.	Install complete set of wire wheels, not including holder	5.00	2.00

Miscellaneous Accessories

		A	B
751.	Install Ford fan belt	.25	.10
752.	Install leather starter belt	.75	.30
753.	Install tool box	.50	.20
754.	Install front and rear license plates when brackets are in place	.25	.10
755.	Install front license brackets and license plates	.40	.15
756.	Install bumper (front)	1.00	.40
757.	Install rear bumper	1.50	.60
758.	Install set of three pedal pads	.25	.10
761.	Install cut-out	$1.50	$ .60
762.	Install exhaust deflector	.25	.10
763.	Install set of C. & M. oil retainers (model "T")	1.50	.60
764.	Install set of C. & M. oil retainers (model "TT")	1.50	.60
766.	Install Buffalo oil gauge	1.00	.40
767.	Install foot accelerator	.75	.30
768.	Install steering-gear lock	1.00	.40
769.	Install Yale lock on one door, catch on other door, Sedan or Coupé	2.00	.80
770.	Install Yale lock on both doors, Sedan or Coupé	2.50	1.00
771.	Install mirror	.25	.10
772.	Install rubber step mats (two)	.50	.20
773.	Install odometer	.50	.20
778.	Install carburetor control	.75	.30
777.	Install speedometer	2.50	1.00
1500.	Charge for work according to actual time spent on job.		
2000.	Special contract-price jobs.		

CLEANING ENGINE

We will now take up the usual and common work required on all engines. We will first start with cleaning and lubricating the engine and greasing a car. About every nine cars out of ten require cleaning and greasing.

Clean old oil from the engine as explained in the illustrations, Figs. 1, 2, and 3.

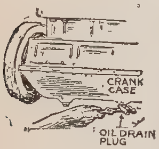

Fig. 1

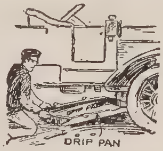

Fig. 2

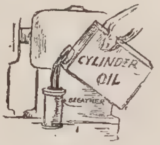

Fig. 3

Fig. 1. Remove the drain plug at bottom of oil pan and drain out the oil.

Fig. 2. Remove the oil pan and clean it thoroughly with gasoline; also clean the oil strainer.

Fig. 3. Replace the oil pan, and pour fresh cylinder oil into the engine.

It will be found that, when oil stops dripping, if the starting crank is turned a few times by hand a little more oil will flow. The best time to drain oil is after the engine has been run and heated and the oil is thinned.

When the oil has ceased to come from the crank case and the oil pan has been removed, cleaned, and replaced, the drain plug is replaced. It is not screwed tightly home, as it is soon to be removed again. Now **pour some light lubricating oil into the breather pipe** (Fig. 3) and run the engine again for about 15 seconds; then drain this out. It is better to flush out the parts with light cylinder oil in this manner, than to use kerosene, for reasons stated on page 167. Replace the drain plug and draw it tight, as well as the cap screws holding the oil pan to the crank case; also see that the gasket is replaced properly and does not leak. **Refill with good cylinder oil.** A gauge alongside of the engine is usually provided to show how much oil to place in the engine.

Note. If the engine is not in running condition, after replacing the oil pan as directed above, open the compression cocks on the cylinder and spin it rapidly by hand. The longer this is done the better, but it is an arduous task and if kept up for a minute or so it will be all that is necessary.

If the drain cock does not permit the oil to flow freely, when draining, run a wire through it to open it up.

The outside of the engine can be cleaned with gasoline. A brush dipped in gasoline to reach inaccessible places, and also an oil gun to shoot gasoline in inaccessible places, will suffice. The lighting of a match or any kind of flame, however, while cleaning should be prohibited.

A modern method for cleaning the engine is by means of a sprayer. In large shops compressed air is used quite extensively for all kinds of cleaning.

Home-Made Engine Cleaner

A gasoline or **kerosene spray,** acting under **air pressure,** will quickly remove dirt and grease from the engine or chassis. A device for forming this spray is shown in Fig. 4. It comprises a metal tank,

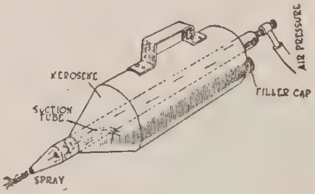

Fig. 4

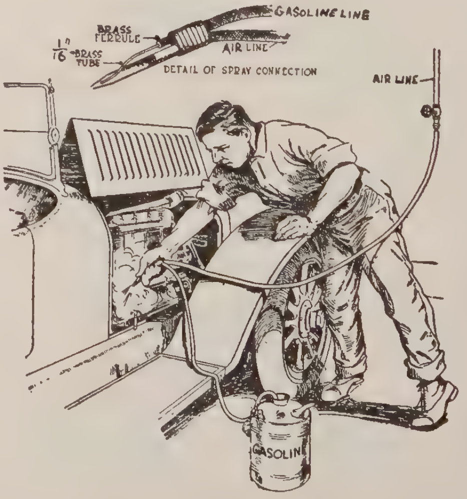

Fig. 5. Another engine cleaner. The parts may be readily cleaned by a **gasoline spray** or aspirator, actuated from the air-pressure line. This spray comprises a short length of copper tubing, about ¼″ in diameter, having a piece of 1/16″ brass tubing soldered to its side. The air line is connected to the larger tube, and the smaller tube is connected to the gasoline supply. When the air is turned on, a suction is created in the smaller tube, drawing gasoline from the can, and forcing it onto the part to be cleaned. (*Motor World.*)

holding the cleaning solution, and an aspirator for forming the spray. This aspirator is a copper pipe, passing through the center of the tank, one end being connected to the air line and the other being drawn down into a nozzle. A small copper tube connects this pipe, so that the solution is drawn from the tank and forced into a spray by the passing air. A foot pump can be used to inject air if pressure is not available.

Cleaning Engine Exhaust System

This cleaning should include the **exhaust manifold, pipe, and muffler.** The latter should be taken apart and the **parts soaked in kerosene** over night. The pipe and manifold may be cleaned by drawing through a pack of kerosene-soaked waste attached to a long wire.

Keeping Oil off the Radiator Hose

To prevent oil from rotting the inlet hose from the radiator to the engine, give the hose a **coat of shellac** and then a **couple of layers of tape** and shellac over that. This will assist in preventing leaks. The shellac keeps the oil away from the rubber and makes a good joint.

Cleaning Parts of a Car

While on the subject of cleaning an engine, we give below a few **home-made devices** which can easily be constructed for cleaning other parts of the car.

In large shops vats are provided in which engines are dipped into a potash cleaning solution, by means of a chain hoist.

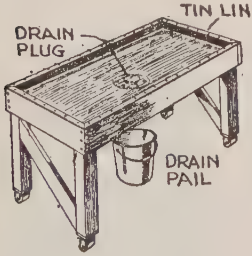

Fig. 6

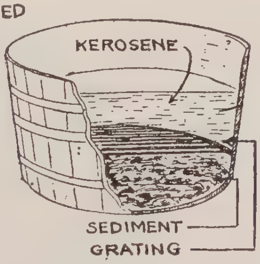

Fig. 7

Fig. 6. **A washing table for parts.** This is large enough to permit any part of the car to be cleaned. But, more important, it may be moved to the job. A wooden basin, or sink, 5 ft. long, 2 ft. wide, and 6 in. deep is mounted on legs, and lined with tin. A drain plug is placed in the center, permitting the dirty cleaning solution to be drawn off into a pail hanging beneath the stand. Gasoline may be used for cleaning parts, but kerosene is cheaper and safer.

Fig. 7. **Kerosene tub:** A large tube of kerosene will be found convenient for washing parts. The tub should have a metal grating 4″ or 5″ from the bottom, so that whatever sediment settles is not stirred up each time a part is washed. The presence of the grating insures clean liquid for a considerable length of time, for just as soon as a part is washed the grit and dirt settles below the grating, leaving the liquid clean.

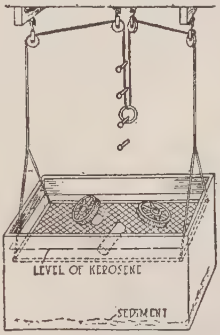

Fig. 8

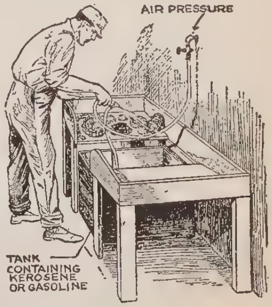
AIR PRESSURE
TANK CONTAINING KEROSENE OR GASOLINE

Fig. 9

Fig. 8. **Combination cleaning tub and drainboard** for removing the dirt from parts. It is usual to make the tub and drainboard separate, but by installing a screen in the tank whose height may be readily raised or lowered, all the advantages of a drainboard are obtained, together with considerable economy of space and some added conveniences.

Fig. 9. **Gasoline or kerosene, forced by air pressure on to the parts to be cleaned,** quickly removes all dirt and grease. A system for doing this is illustrated. The cleaning liquid is held in a metal tank placed beneath the inclined cleaning troughs in the manner shown. An injector type nozzle, connected to the air line and to the liquid, permits the liquid to be drawn from the tank and forced on to the part to be cleaned after which it drains back to the tank, to be used over and over again. During periods when the cleaning outfit is not in use the dirt settles to the bottom and may be scraped out. (*Motor Age.*)

For cleaning small brass aluminum, and metal parts, see Index.

GREASING A CAR[1]

One of the first things to do when starting to grease a car is to screw down on the grease cups, which forces out all grease therein. The cap is then unscrewed, the grease cup refilled, and the cap placed back—but do not cross-thread the caps or they will work loose and be lost.

The modern method of greasing a car is with the pressure system, such as the Alemite (page 174). If the car is not equipped with this system, a good grease gun should be provided. A type of grease gun which can be recommended is shown on page 663 (Fig. 9).

The Townsend grease gun is an excellent device for greasing such places as the shaft of a cone-type clutch (through a plug hole), the universal joint and other places on a car where a grease cup is not provided, but where grease plug holes are provided. You can grease the universal and the other such parts of the car in a few minutes' time, without removing the nuts or bolts.

Lubrication of Springs

A detail which, if attended to, conduces much to the easy running of a car, is the **oiling of those parts of the springs upon which the leaves move.** It is becoming the practice to make provision for proper lubrication at this point. This is easily done by drilling a hole through each leaf; otherwise it is not easy, when the weight of the car is on them, to introduce any oil into the interstices. Very frequently, however, rust is seen along the joints, show-

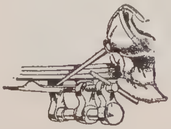

Fig. 10

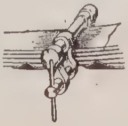

Fig. 11

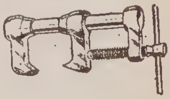

Fig. 12

Fig. 10. Lubricating the surface of the separated spring blades.

Fig. 11. The same tool used as a temporary cramp to secure a broken spring.

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[1] See Index for "Greasing rack."

ing that water can get in, at any rate, and oil will work its way in, too, if applied at the edges, but it will probably be found that this can be more easily done if the blades are separated by means of the special appliance illustrated herewith (Figs. 10, 11, 12).

Rust in the springs affects their proper movement, and causes mysterious squeaks as well. The joints of the links connecting the upper and lower portions of the springs at each end should also have a little oil applied occasionally.

If a car is overloaded much beyond its normal capacity, extra work will be thrown on the springs which may give rise to breakage when the car is being driven over bad roads. An **extra leaf added** to the springs is advisable **for overloads.** Considerable advantage to the life of the springs is obtained by having shock absorbers. See Index under "Spring repairs."

Other parts of a car to lubricate and grease are shown on pages 172 to 174.

Spring Covers[1]

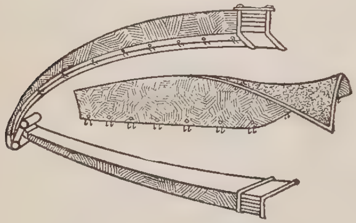

Fig. 13. **A spring cover and lubricator** which laces over the spring, preventing any danger of moisture or dirt getting between the leaves. The cover is lined with a felt wicking which is saturated with oil before the cover is put on, and will hold enough oil to lubricate the springs for 10,000 miles. The smooth gliding effect is obtained which is so noticeable in a new car with perfectly lubricated springs. (Woodworth Specialties Co., Binghampton, N.Y.)

Tightening Springs

When lubricating the springs, it is a timely opportunity for observing defects of loose nuts or broken leaves in the springs.

The nuts belonging to the **clips** which hold the spring on to the axle often display a tendency to work loose, and if this is not remedied the axle will be thrown out of line, with more or less serious consequences to tires and driving gear generally; or, if the front axle is in question, the steering may be affected, thus causing "wobbly wheels."

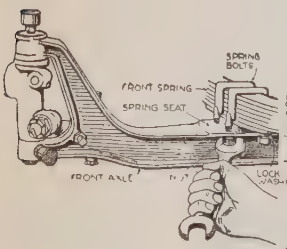

Fig. 14

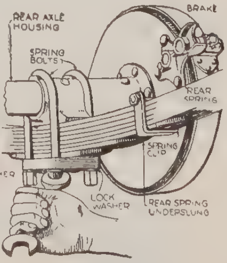

Fig. 15

The springs, like the engine bearings, have to take a sort of set before they are permanently tight. Hence it is desirable to tighten up the spring clips at the end of the first one hundred miles of running and then to inspect them occasionally until they remain tight.

A Spring Lubricant

A spring lubricant, known as "Spring-eez" is recommended. It is applied to the sides of the springs with a brush and chemically accomplishes that which by mechanical or other means, is either an arduous or impossible task, in that it **penetrates** between the leaves without the necessity of spreading; it disintegrates and eliminates rust; it deposits a lubricant, and causes the springs to perform their function properly, without squeaking about it. In the same manner its application makes the removal of "rust-frozen" nuts, bolts, screws, spark plugs, valve caps, etc., a simple matter.

Spring Shackles

Many of the makers now are putting on **adjustable** spring shackles, so that wear can easily be taken up. This is especially desirable in cars using a Hotchkiss drive, where a great deal of stress and wear is put on the shackles of the rear spring at its rear end and on the spring bolt attaching the front of the rear spring to the bracket on the frame.

With the Hotchkiss drive the rear spring supports have to take not only much of the weight of the car, but also the driving and braking strains. Hence, the better the design of the shackles and bolts at this point, the longer the life of the parts.

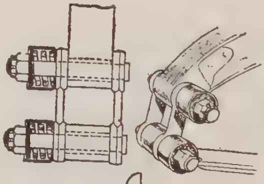

Fig. 16

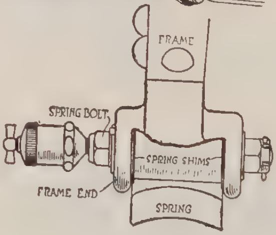

Fig. 18

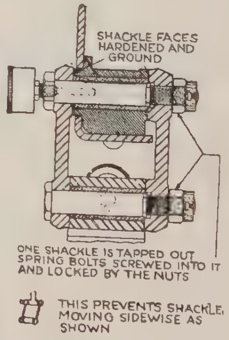
SHACKLE FACES HARDENED AND GROUND
ONE SHACKLE IS TAPPED OUT SPRING BOLTS SCREWED INTO IT AND LOCKED BY THE NUTS
THIS PREVENTS SHACKLE MOVING SIDEWISE AS SHOWN

Fig. 17

Fig. 16. The **automatic shackle bolts** on the Jordan. Note the coil springs.

Fig. 17. The **adjustable shackle bolts** used on the Hudson and Essex.

Fig. 18. Method of **taking up side play** in spring links with shims.

Among the cars using adjustable spring shackles are Jordan, Hudson, Cole, and Locomobile; the latter, by the way, has used this for some time. The Jordan shackle is shown in Fig. 16.

This shackle is of the type which automatically takes up the wear. The Hudson and Essex shackle (Fig. 17) is made so that wear can be taken up by a slight turning of the nut and locking it with a cotter pin.

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[1] See Index under "Temporary spring repairs."

REMOVING CARBON FROM CYLINDER, COMBUSTION CHAMBER AND PISTONS

Before taking up this subject, refer to pages 169, 170, and read the explanation of the **cause of carbon** and the **relation of carbon to lubricating oils.**

This is a job usually attended to before valves are re-ground. The frequency with which the job should be done depends upon the service, and quality and quantity of lubricating oil used.

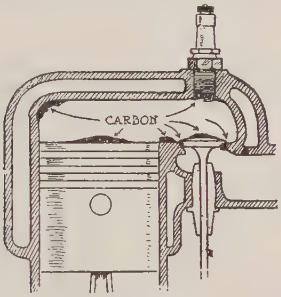

Fig. 19. Carbon usually accumulates at the points shown.

Methods of Removing Carbon

There are five methods employed in removing carbon. The most effective is that one which removes the carbon most completely—probably by hand. But to remove a piston is sometimes an expensive job, and other means are resorted to, as will be mentioned.

1. One plan is to **remove the piston** as shown in Fig. 20.
2. To **remove cylinder head** as shown in Fig. 21.
3. To **scrape with special scrapers,** as shown in Fig. 22.
4. To **chemically dissolve** the carbon.
5. To **clean by the oxygen decarbonizing** process.

This last-mentioned method is the one most generally used, and is conceded to be one of the best.

Note. **In using oxygen for carbon removal,** the piston should be placed at the extreme top of the cylinder, as the intense heat tends to roughen the cylinder walls. Both inlet and exhaust valves should be closed to prevent pitting of valve seats. The flames should not be directed so as to strike the threads of the spark-plug hole. See that the water system is kept full of water. The torch should be moved constantly, to cover as large an area as possible.

Questions Sometimes Asked Relative to Oxygen Decarbonizing Outfits

Q. **Where can oxy-decarbonizing outfits be secured?**

A. The Prest-O-Lite Co., Indianapolis, Ind., makes a good serviceable outfit, as does also the Imperial Brass Co., Chicago.

Q. **Can the Prest-O-Lite tank be used for this purpose?**

A. The oxygen tank of this company's welding outfit can be used, but lighting gas cannot.

Scraping Method

To scrape carbon fron a piston in the manner shown in Fig. 20, it is necessary to remove the piston from the cylinder.

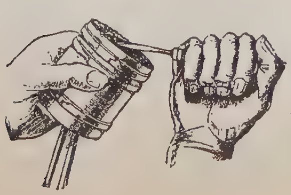

Fig. 20

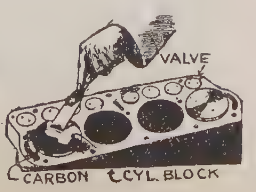

Fig. 21

Another method (Fig. 21) is to **remove the cylinder head, if it is a detachable type,** as on the Ford. Access can then be had to the tops of the pistons and to the walls of the combustion chamber in the head.

Special Scraping Tools

Scraping tools of special design (Fig. 22) are necessary for scraping the inside of a cylinder, a combustion chamber, and the head of a piston when the cylinder head is not detachable and where the pistons are not removed. The work can be done through the valve cap or plug holes.

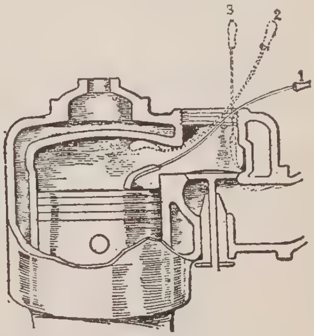

Fig. 22

Tool No. 1 is for scraping the piston head; **No. 2,** for the cylinder head, as shown by dotted lines, and **No. 3** is for the cavities over and around the valves and such other surfaces as have considerable curvature.

Scraper No. 1 should be used first, and worked back and forth with considerable pressure across the piston head until the scratching sensation disappears and the tool seems to glide over the surface. Care should be taken not to gouge grooves in the metal.

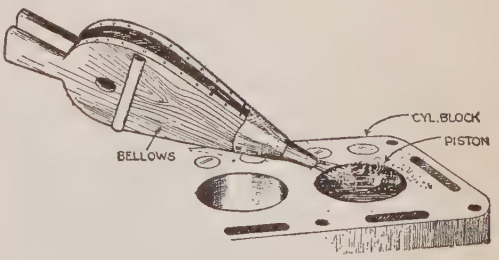

Fig. 23

After scraping, blow out the free carbon, using a hand bellows as shown in Fig. 23, if compressed air is not available. Continue scraping until the blast of air does not blow out any more carbon dust. Be sure to scrape the entire surface, for if jagged patches are left, they will become incandescent from the heat of explosion and cause pre-ignition.

It is important that none of the carbon gets into the cylinders, valves, or other parts of the engine. Therefore be sure that the valve is well seated in the cylinder you are cleaning, and be careful to blow out all carbon deposit thoroughly with an air blast.

After as much carbon as possible has been taken from the cylinders, a half-tumblerful of kerosene poured into each cylinder with the air blast applied, will often give good results. Another half-tumblerful of kerosene should be poured into the cylinders, and the engine should be turned over a few times.

The oil reservoir should then be drained and cleaned thoroughly with a clean cloth previously soaked in gasoline, and fresh oil should be put into the oil pan (after cleaning and using kerosene), as kerosene will thin the oil and cause it to lose its lubricating qualities and is liable to cause the bearings to score or cut. If any of the kerosene is left in the engine combustion chamber, it will eventually work into the crank case.

It is customary to grind the valves after having scraped carbon, and after grinding, to adjust valve clearance.

Oxygen Decarbonizing Method

The oxygen decarbonizing method is a process of cleaning the carbon from inside the cylinder and head of the piston, without removing the cylinder head, by means of an oxygen flame, as shown in Fig. 24.

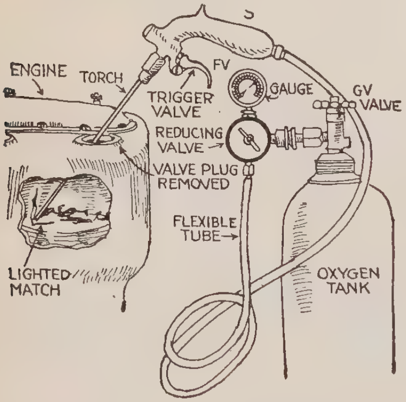

Fig. 24. Oxygen decarbonizing outfit.

The outfit (see also, page 751) consists of an oxygen tank, at an initial pressure of about 1,800 lbs. per square inch, fitted with an adjustable reducing valve that brings the pressure down to 10 to 20 pounds. The oxygen is applied through a torch or copper tube about 18″ long, with a rather fine, flexible delivery jet, communicating with the reducing valve through a flexible tube and fitted with a trigger valve (FV). The delivery jet of the torch when inserted through a valve-plug orifice, can be manipulated to reach all parts of the combustion space, if it is slightly bent and cleverly turned and twisted by the operator.

To Operate Oxygen Decarbonizer

1. **Turn off the gasoline at the tank,** and let the engine run until it uses up all the gasoline in the carburetor. If the pan is greasy, remove it, to avoid the possibility of a fire.
2. **Remove the hood and cover the air intake of the carburetor** with sheet asbestos, so that no spark can drop into it.
3. **Remove the large plugs into which the spark plugs are** screwed, and clean the cylinders, one at a time, being sure **that the piston is at its extreme height in each cylinder** and that both intake and exhaust valves are closed before starting to clean it.
4. **Start on the valve chamber,** first putting a few drops of kerosene oil or alcohol into it; ignite with a match or wax taper; insert tip of torch and direct a jet of oxygen against the carbonized surface. The jet of oxygen almost instantly consumes the carbon where it strikes, so move the tip around until the incandescence dies out, when it will be necessary to inject more kerosene or alcohol, and to repeat the operation until the chamber is thoroughly cleaned. When the burning starts the carbon will burn with a whitish flame and a shower of sparks will come out of the spark-plug hole.
5. **Clean the piston head.** When it is impossible to see portions being cleaned, continue the operation until the series of sparks stop blowing out, as sparks will cease as soon as the carbon is entirely consumed.

To clean the top and sides of the cylinder combustion chamber it is necessary to bend the flexible copper tip of the torch so as to direct the jet of oxygen upwards. To inject the kerosene or alcohol, use an oil gun or ordinary oil can with a curved nozzle.

Alcohol leaves the surfaces much lighter than kerosene, but when the oxygen strikes it there is quite a sharp report. **Kerosene** is rather more quiet than alcohol.

Some operators simply **drop in a lighted match** and then turn the jet upon it, but this method requires much more frequent igniting than when kerosene or alcohol is used.

It is important that **kerosene should not be mixed with the lubricating oil** as it will lose its lubricating qualities. The crank case should be wiped out before putting in fresh oil. When using the method described above, the flame must be handled cautiously, otherwise the parts inside of the cylinder combustion chamber will be overheated.

Chemical Method for Removing Carbon[1]

There are **several preparations** on the market for this purpose. It comes in powder form which, the makers claim, if mixed with the gasoline, will prevent carbon formation.

Another agent is known as a **liquid decarbonizer.** This chemical, the manufacturers claim, will dissolve the carbon accumulation in the combustion chamber and on the piston, and will also loosen the rings if they are gummed and stuck to one side of the piston.

When giving the engine the first dose, and where carbon is well accumulated, start the engine and run until warm; then shut down the engine and pour the decarbonizer into each cylinder, say about ⅛ pint in each, where it can act on the piston and rings. Also pour it over and around the valves. Leave the engine over night, or for at least three hours. After this time, start the engine up, and the carbon is supposed to pass off through the exhaust.

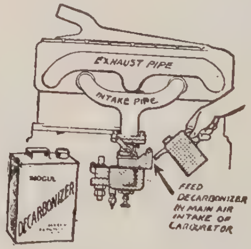

Fig. 25

After once cleaning in this manner, about once every two weeks feed the decarbonizer to the engine by placing about ⅛ pint in an ordinary oil can and let it pass in the air intake of the carburetor (see illustration), while the engine is running. The decarbonizer will suck into the engine, and will be sufficient to keep rings and valves clear and to keep carbon from forming.

Note. **It is not advisable to use liquid decarbonizing mixtures which contain kerosene,** as the kerosene tends to work its way into the oil pan, thus thinning the lubricating oil. The best plan to remove carbon is by the oxygen decarbonizing process, providing it is done properly and providing the parts inside of the cylinder combustion chamber are not overheated.

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[1] **A carbon preventive** called "Woodworth Carbon-Clear," manufactured by Woodworth Manufacturing Corp'n., Niagara Falls, N.Y., is mixed with the gasoline, one spoonful to five gallons. It is claimed that this will prevent the formation of carbon.

WHY AN ENGINE LOSES POWER

There are four main causes for this. When an engine fails to develop its usual power the cause is frequently one of the following:

(1) loss of compression;
(2) deranged valve action;
(3) faulty ignition;
(4) improper carburetion mixture.

1. **Loss of compression** means more than simply failure to compress the charge to a specific extent; it is a common name for a condition which not only means low initial compression and consequent weak explosion, but also that a smaller charge is taken into the cylinder, that a portion of the diminished charge escapes during the compression stroke without doing even a small amount of work, and that a part of the explosive force (the only source of power that an engine has) escapes through unauthorized channels —altogether a threefold loss.

Faulty compression comes from a variety of causes: Cylinders may be worn, scored or cracked; pistons may sometimes crack, or rings become gummed, worn or broken; valves need grinding when pitted or warped; their stems are sometimes bent so that the valves cannot seat perfectly, or the stems and guides considerably worn. Valve stems become gummed and the springs sometimes weaken, so that a portion of the charge escapes before the valve shuts it in.

Leaks occur around spark plugs and valve caps, but are readily found by applying a little oil, while engine is running and noting if it bubbles.

2. **Valve action** is disturbed by wear. Usually this results from the valve tappets not having been given sufficient opening, or having been set to give too much opening, or from the valves not being properly timed. Valves that do not seat come of course under the subject of loss of compression.

3. **Faulty ignition** is occasioned by insufficient or unsuitable sparks, or by a spark at the wrong time, which may result from imperfect setting of the spark, from a weak battery, or from demagnetization or some other trouble peculiar to the magneto.

The ignition timer should come under suspicion and should be carefully examined for defects which lead to irregular action. Lack of synchronism means loss of power, and it is plain that missed explosions are fatal to efficiency. It is not always easy to detect missing or weak explosions, and no doubt they pass unnoticed many times. If vibrator coils are used they probably need adjusting, or their contacts need dressing.

4. See page 117 for suggestions regarding the **carburetion mixture.**

Other Causes of Loss of Power

Air leaks around the inlet valve stems make it impossible for even the best carburetor and the most careful regulation to supply a right mixture, as the leakage fluctuates and is greatest at the very time when the volume of gas used is the smallest, because there is stronger suction when the throttle is nearly closed. This completely upsets the right proportions at all throttle openings except the one adjusted. This is true also of air leaks around the carburetor or intake connections.

Weak valve springs will also cause loss of power, as explained on page 776.

The muffler may have become clogged by soot and charred oil, thus preventing a free exhaust and consequently a full charge, besides causing back pressure and undue heating.

Gasoline passages may have become clogged.

The oiling system may fail to supply the needed amount of oil, or the oil used may not be of the former good quality.

Carbon may have accumulated in the cylinders; the air valve in the carburetor may be working badly because of dirt or wear.

Dragging brakes will consume a lot of power.

Sometimes the addition of a top, etc., is not duly allowed for, though every driver must have observed what a difference the weight of one passenger makes.

In conclusion, it is suggested that **if a car does not run with its former power,** the cause is probably not the result of any one thing, but of a number, each contributing in proportion to its importance.

MEANING OF COMPRESSION, EXPANSION, AND MEAN EFFECTIVE PRESSURE

Compression pressure is the pressure of the gas after being drawn into the cylinder and **compressed in the combustion chamber** by the up compression stroke of the piston. This varies with the quantity of gas drawn into the cylinder, the speed of the piston, the size of the combustion chamber, and the condition of the valves and rings, and the tightness of the parts. See also, page 116.

The expansion pressure (often termed explosion pressure) would be the maximum or the **greatest pressure immediately following the combustion** or burning of the gases. This pressure is many times greater than compression pressure. This expansion pressure (gas expands when ignited and heated) continues, but diminishes throughout the entire power stroke.

The explosion pressure runs from three to four times that of compression pressure. If the compression drops one-half, then the explosion pressure drops, but the loss is in more than direct proportion. It would seem that if the explosion pressure was one-half, the power developed would be one-half. But one must realize that it takes a certain amount of power merely to keep the engine moving, that is, to overcome the inertia and friction of the moving parts. This amount is constant. All power developed beyond this amount is available to run the car. If the compression and power drop to one-half, just as much power is required to run the engine, so that the available power drops in much greater degree.

Mean effective pressure (M.E.P.): During the entire cycle of a gas engine, the cylinder is subjected to many variations of pressure. We have seen that during the power stroke, the pressure decreases as the piston proceeds along its stroke. All of this pressure causes the engine to deliver power. In the same way, during compression stroke the pressure gradually **increases** as the piston travels upward. All of this pressure hinders the engine from delivering power, and should therefore be considered as a negative power.

Now, if we average up all the pressures during a cycle and subtract those which hinder the engine from those which help it (the power stroke is the only stroke which helps), we shall arrive at the M.E.P., that is, the **average or mean pressure which is effective in producing power.**

The advantages of high compression are: greater engine efficiency at high speeds and greater economy in fuel.

The disadvantages are lack of flexibility at low speeds, greater strain on bearings, and greater tendency to burn valves and plugs, as well as a tendency to over-heat.

A greater compression can be carried in an over-head-valve engine, regardless of stroke or bore; therefore larger valve openings are permissible.

Naturally this increases the heat, but as the valves are in the head, the discharge is rapid. The explosion pressure is generated directly above the piston center, which receives no side thrusts.

The spark plugs in an "L"-head type are usually over the inlet valves where the inrushing gas keeps them cool and where the fire is most certain—since they are in the most perfectly scavenged part of the cylinder, i.e., the direct path of the fresh charge.

In the overhead type, on the contrary, they are exposed to the full heat of the explosion. In a high-compression engine, therefore, only well-made plugs should be used. One method of protection is to surround the plug with a water jacket as much as possible.

Abnormal compression is prone to cause over-heating. Results however can be obtained with high-compression ratio which cannot be approached with average compression.

If a high compression is desired in an "L" or "T"-head engine, in order to take advantage of the high compression, the cylinders must be designed with a sufficiently long stroke, to enable the desired ratio to be obtained without raising the piston appreciably above the floor of the valve pockets, as at (L) in the illustration (Fig. 26).

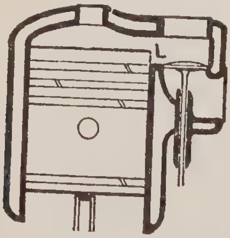

Fig. 26. This illustration shows the type of piston referred to. It will be obvious that the explosion will develop in the valve pocket (L), and that part of its expansion or pressure value is lost when the piston projects above the top of the cylinder to any great extent.

Average Compression of Engines

The usual compression pressure for touring-car engines is about 55 to 75 lbs. on four and six-cylinder engines, and 60 to 85 lbs. on eight and twelve-cylinder engines, per square inch, without the additional effects. This, when running at average road speeds, probably increases. The compression on a Hudson six-cylinder engine is approximately 70 to 75 lbs. The tendency is to decrease compression as the diameter of bore increases.

A six, eight, or twelve-cylinder engine, having a much more continuous torque than a single-cylinder engine, will obviously stand a higher ratio of compression.

The maximum compression is determined when the throttle is wide open and all pet cocks are closed. For instance, the compression in the cylinder of a Packard should show 75 to 85 lbs. pressure at cranking speed with pet cocks closed and a wide-open throttle.

Compression at the time of the explosion, at the instant when the piston is at top of stroke, is very hard to determine. Factors which would have to be taken into consideration are: character of fuel, degree of mixture, and speed of engine. In the average engine, pressure at explosion would probably be about 250 lbs. See also, page 116.

At higher speeds of the engine a slight compression leak is not so noticeable as at low-engine speed. If it is desirable to have the engine throttle down to a very slow speed, then be sure that there are no compression leaks in any part of the engine, including rings, as one leaky cylinder will affect the others.

The compression of airplane engines is somewhat greater than on automobile engines. As a rule the explosion pressure is four times the absolute compression pressure based on the assumption that the cylinder is filled with the charge to atmospheric pressure at the beginning of the compression stroke.

The compression on a motorcycle engine, as a general rule, is also rather high where speed is desired, but on the U. S. A. motorcycle engine, used during the war, the compression was slightly lower than the average. This somewhat depresses the power curve, but the engine will run better on a wide-open throttle at lower speed, enabling the machine to "hang-on" with great tenacity and to pull with power through sand, mud, etc.

An open throttle fills the cylinder with gas, which of course increases the compression pressure. Therefore an engine would pound or knock at low speeds with a wide-open throttle, as when climbing a hill slowly.

Increasing Compression in an Engine

This means that by **reducing the space in the combustion chamber** from the head of the piston to the inside top of the compression chamber of the cylinder—when the piston is in its uppermost position—the gas would be compressed tighter, therefore there is more explosive or expansion force on the piston when combustion takes place.

High compression gives more power, but it is harder on the bearings and makes the engine more liable to knock and produce heating, and is less flexible at low speeds.

It is true that different compressions affect the power of explosions, and that an uneven compression ratio in different cylinders will consequently cause an engine to jerk. If the compression is excessively high, it can keep the spark from jumping the gap in the spark plug, unless the latter is closed up slightly.

Decreasing compression. See Index.

TESTING THE ENGINE COMPRESSION[1]

The compression is much easier to test than the carburetor or ignition apparatus.

To test the compression of the engine one has but to crank it slowly (with switch off) and note the comparative resistance of each cylinder and the resistance of all in general. If the resistance of the compression of one or more cylinders is less than in the others, then this particular cylinder is leaking compression through one of the many causes previously enumerated. If the resistance of all of the cylinders is below the regular standard, then, perhaps, all are leaking compression.

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[1] See Index under "Compression tester, home-made."

A method of testing with a special gauge is shown in Fig. 27.

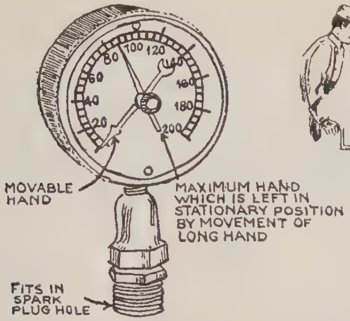
20
40
60
80
100
120
140
160
180
200
MOVABLE HAND
MAXIMUM HAND WHICH IS LEFT IN STATIONARY POSITION BY MOVEMENT OF LONG HAND
FITS IN SPARK PLUG HOLE

Fig. 27

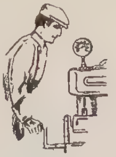

Fig. 27A

Fig. 27. A special gauge designed for testing the comparative pressure of each cylinder. It is attached to the engine cylinder by removing a spark plug and fitting the gauge, called **a compressometer**, instead. The engine should be cranked two or three times with the hand crank. (Fig. 27A).

Compression of the cylinder to which the compressometer is attached is indicated on the instrument as the maximum hand (short one) remains at the highest point so indicated. Note the two hands: the short one remains fixed at the highest point reached during the test. This test does not give the maximum pressure, as the maximum pressure is obtained only when the throttle is wide open and the cylinder is filled with gas. With this test the throttle is not opened, the idea being to see if there is a good spring resistance offered to the movement when the engine is quickly cranked.

As you test each cylinder separately, enter the reading on a slip of paper, and then compare the results. Those cylinders showing low compression are leaking, and the cause should be found and remedied.

A cylinder with good compression cranks with a springy resistance. If it cranks very freely, it may be considered an evidence of poor compression, and the cylinders should be tested for compression one at a time, as follows:

The compression relief cocks (in a six-cylinder) on five of the cylinders, say Nos. 2, 3, 4, 5, and 6, should be opened and the compression of No. 1 noted when turning the engine over. Then close relief cock No. 2, open cock No. 1, and crank again to test No. 2, and so on until the six cylinders are tested.

A leak through one or more valve seats is generally accompanied by misfiring and loss of power. A slight leak through all of the valves is accompanied by loss of power, but often without misfiring.

Grinding the valves will probably remedy this, if the leak is not due to leaky piston rings.

Leaky piston rings are often the cause of compression leaks and may be due to the rings being gummed in the grooves. A little kerosene poured into the top of the cylinder, and then cranking the engine several times may loosen the rings, as explained under "Piston rings."

Poor Compression; Effect and Cause

The subject of compression is one of the most important subjects connected with a gasoline engine. If an engine lacks power, nine times out of ten it will be traced to poor compression.

The compression space in an engine is the space between the end of the piston and the top of the inside of the cylinder at (L), Fig. 26. In drawing in a charge of gas into the cylinder, the piston travels downward, but after drawing in the gas through the intake valve, the valve closes and the piston on its up-stroke pushes the gas up into the head of the cylinder and compresses it (see page 32). If the valve leaks, or if there is a leak otherwise, then the gas will not be compressed to as high a pressure as if there was no leak.

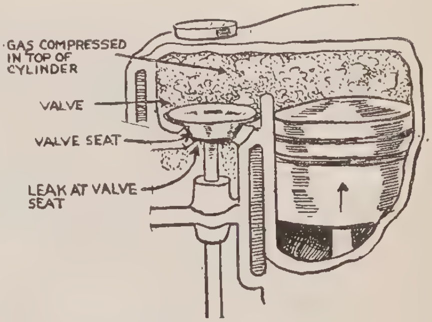

Fig. 28. If compression is poor, the probable cause is that the valves are leaking at the seat.

These joints must be tight at all times. For instance, if the cylinder-head gaskets or the small gasket in the spark plug, or the spark plug itself is not tight, gas will leak out and cause loss of compression and lack of power.

When the gas is compressed to the highest point, then the spark ignites the compressed gas and forces the piston down with great force. If the compression pressure is **low the force will be less.** If the compression power is **high the force will be greater.**

Leaks will affect the operation of the engine, by weakening the compression, diluting the fresh charge by the air that enters, by the escape of the pressure during the power stroke, and by the igniting of the mixture in the inlet pipe. Therefore **the power of an engine depends on good compression,** and good compression must be maintained.

A frequent cause of leakage is pitted valves (see page 769), which by not closing tightly, permit the pressure to escape. If the valves are in good condition, and the spark plugs and other openings in the cylinder head are tight, leaky piston rings may be causing the loss and should be examined.

The spark plug and the relief cock may be made tight by the use of copper-asbestos washers, or by a copper washer, that metal being soft enough to be forced into the rough places.

Leaky valves may be ground in as described under "Valve grinding."

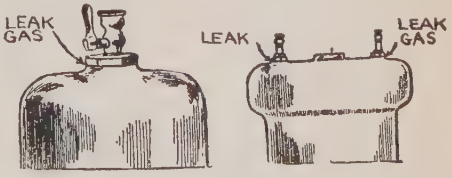

Fig. 29. Other causes of leaks may be in the spark plug, gasket, or piston rings.

There are many places where compression leaks may be looked for: through the valves not being set right, or through the **valves leaking** at the seat, through the **valve caps** not being screwed down tight, through the **spark plugs, relief cocks** and **piston rings, cylinder-head gaskets, etc.** Leaks have also been known to occur through a small sand hole in the end of the piston.

Compression leaks in valve caps, spark plugs, and priming cups (relief cocks or pet cocks) are usually due to a failure to draw them down tight in the threads.

A leak in the gasket connecting the intake pipe is a very common cause for missing at low speeds, and is best detected by allowing the engine to run at the missing speed. Take a squirt-can full of gasoline and squirt around all the intake pipe joints. If you detect any difference whatsoever in the running of the engine, there is a leak. The remedy is obvious.

Cylinder-head gaskets, if not properly tightened and fitted, will permit a compression leak, and will also admit water to the cylinder on those cylinders fitted with detachable heads.

Asbestos gaskets, when replaced, are first coated with shellac or soaked in linseed oil (not used on automobile engines). Copper gaskets are soft and give; therefore they do not require this treatment. See Index under "Gaskets."

Where cylinder-head gaskets are replaced without thoroughly cleaning them, as well as the surfaces on which they are fitted, or if they are not drawn down tight after the engine is warmed up (second tightening), a compression leak is likely to occur.

When cylinders are **not cast en-bloc,** care must be taken that gaskets are of exactly the same thickness, otherwise the cylinder with the thickest gasket will be raised higher than the others and will consequently have larger combustion space. As a result it will have lower compression. This in turn disturbs the running balance.

In two-cycle engines conditions would be even worse, for here we not only increase the combustion space and enlarge the lower space (which in two-cycle engines is an important feature), but we also change the port timing, as a little thought will prove.

If the cylinder wall, the cylinder head, or the piston head is cracked, compression will be affected.

A crack in the cylinder wall will admit water to the cylinder from the water jacket. If a hole is suspected, a test can be made on the cylinder to see if there is a leak by putting a foot-pump connection to the water jacket of the cylinder. Fill the water jacket with water and apply the air pressure, and see if bubbles of water ooze through, inside of the cylinder. If this is the case, then these holes must be made tight.

If water is found in the crank case, it results from one of three general causes: (1) water in the gasoline or lubricating oil; (2) loose cylinder-head gasket; (3) a cracked cylinder, or a sand hole in the cylinder from the water jacket. It is possible, sometimes, to stop a cylinder sand hole leak with salammoniac. See Index for this subject.

To detect a crack in the piston head, the latter must first be scraped clean of the carbon deposit and examined carefully.

Sometimes there will be a discharge back into the carburetor; this indicates a leaky intake valve, providing it is not first found to be the result of faulty carburetor adjustment, due to lack of sufficient gasoline, or to too much air, termed a "lean mixture."

Sometimes a discharge in the muffler indicates a leaky exhaust valve, but not always. It will require an experienced ear to detect the difference between an unfired charge being exploded in the muffler, due to carburetor adjustment and that of a leaky exhaust valve

Piston and Rings Cause of Leaks

When the piston rings or cylinders have been cut and scratched by long use, or running without oil, the compression leak will be into the crank case, and when the crank case heats so that it is uncomfortable to touch, it is an indication that the leak exists. The only remedy is the reboring of the cylinders, and the fitting of oversize pistons and rings, or, if the pistons are not too badly scratched, new piston rings may suffice.

When piston rings work around in their grooves so that their split ends are in line, this will often give the compression an opportunity to escape. Therefore, see that the split ends are not in line.

If the piston rings are in good condition, they will be smooth and shiny, as will also be the cylinder walls. If the rings are dull and dirty in spots and streaks, it will indicate that the flame passes between them and the walls, leaving a sooty deposit.

Badly fitting piston rings may be caused by the rings sticking in their grooves, because of gummy deposit from the lubricating oil; rings that are stuck in their grooves will not press against the cylinder walls and will cause loss of compression. Kerosene oil will cut this gum, and free the rings. If this is suspected, just a little kerosene poured into the cylinder and distributed by cranking the engine will cure it.

To test for a leak at the valve cap, spark plug, or relief cock: Pour oil over the cap on top of the cylinder block, and if bubbles occur when the piston is moving upward, it is an indication that there is a leak. It can be corrected by simply tightening, or it may be necessary to renew the gaskets. Pour water into the valve cap to detect an air leak, if the spark plug or relief cock is screwed into a valve cap with a depression in it. If there is a leak, it will bubble through the water when the engine is being cranked. This can be remedied by merely tightening up or by fitting new gaskets.

Before Grinding the Valves See if the Valves Leak

The loss of compression may be elsewhere than in the valves. To save time, therefore, first test for various other probable causes of leaks as described. A good plan is to use soap suds and apply it at all points where there is likely to be a leak, as, for example, around the cylinder head gaskets, spark plugs, priming cocks, etc. Then have someone crank the engine with the priming cocks closed and the switch off, bringing it up to compression, and hold it there for an instant. If air bubbles form there, you may know there is a leak. Test each cylinder. Remedy leaks, if any, before proceeding farther.

A compression leak between the piston and cylinder walls is rather difficult to test. Probably the best way is first to correct compression leaks as described above; then, if the compression is still poor, the leak must be between the piston and the cylinder wall. See Fig. 30 for one method of testing. The remedy for leaks past the piston rings is to put in new rings, if they are not merely gummed and cannot be loosened with a little kerosene. Usually they are worn or out of round. See also the subject "Piston rings."

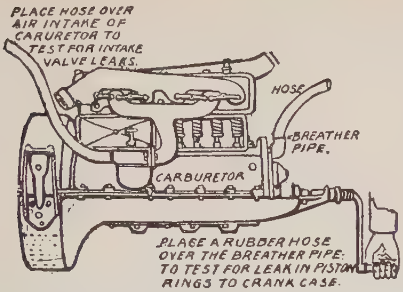
PLACE HOSE OVER AIR INTAKE OF CARURETOR TO TEST FOR INTAKE VALVE LEAKS.
HOSE
BREATHER PIPE.
CARBURETOR
PLACE A RUBBER HOSE OVER THE BREATHER PIPE: TO TEST FOR LEAK IN PISTON RINGS TO CRANK CASE.

Fig. 30. One method of testing for piston-ring and valve leaks.

To test for inlet-valve leak: Knowing that the minor leaks above referred to are corrected and that all the parts are tight, the next step is to test for leaks of the inlet valves, if any. Place a piece of garden hose over the carburetor air intake, as in Fig. 30. With throttle wide open, have someone crank the engine with switch off. Place the hose to the ear; if a hissing sound is heard when the piston is on compression stroke, the inlet valve is leaking and needs grinding.

To test for piston-ring leaks: Place the hose at the breather pipe; crank as before; if a hissing sound is heard as the piston moves up on compression, the pressure is escaping past the piston ring, down the wall of the cylinder into the crank case. In this case new rings are required, or maybe a little kerosene to loosen up the ring will suffice.

If no hissing sound is heard, and you are still losing compression, the trouble probably lies with a leaky valve. The only way to find it out in such a case is to remove the valves of this cylinder and examine them.

If you are able to hold against the compression of a cylinder for half a minute without perceptible loss of compression, the compression is good in this cylinder. Test each cylinder.

Note. A bulletin on lapping out cylinders, grinding pistons into cylinders, removing score marks, etc., is furnished free to readers of this book by the Clover Mfg. Co., Norwalk, Conn.

Spark Plugs Indicate Condition of Valves and Piston Rings

When spark plugs are constantly oily and fouling, this is an indication of oil passing from the crank case past a **leaky piston ring.**

It is also indicated by excessive lubricating-oil smoke (blue) passing out of the exhaust, as the oil works up past the rings.

The condition of the spark plugs will sometimes indicate the condition of the valves. If the end of the spark plug is **oily,** it indicates too much lubricating oil or leaky piston rings.

If **black soft soot** is present, like that which accumulates in a lamp chimney, this indicates that too much gasoline is being fed to the cylinder through the intake, causing too rich a mixture. This may come from improper carburetor adjustment or from an air leak in the intake manifold.

If the ends of the **plugs are oily and sooty,** this would indicate that the valves leak, as this permits burned gases being drawn into the mixture, with the result of poor combustion and lack of pressure in the cylinder, and also of permitting oil to pass and foul the plug.

Prussian Blue for a Valve Leak Test

To test a valve-head seat: Buy a ten-cent tube of Prussian blue at any paint store. Loosen the valve spring, and **blue the face of the valve.** Then turn it one-quarter around in the valve seat. If the seat shows a clear clean line of blue, you have a perfectly fitting valve. If there are points where the blue does not touch, you have a worn or warped valve or a faulty seat.

If, after these tests, compression is not restored, the trouble is a serious one, requiring removal of the cylinders or cylinder head. The piston rings may be broken, scored, or badly worn, or the cylinders may be scored also. To remedy such troubles as scored cylinders, where they must be reground, requires special machinery, and this sort of repair is done by those who specialize in this class of work. Such work as fitting rings and grinding valves, etc., can easily be done in any shop.

Keep in touch, so to speak, with the compression in your engine if you wish to obtain best results.

A piston may sometimes have a flaw in the casting, and a small hole will permit loss of compression. See Index under "Testing piston for a leak."

Causes of Leaky Valves

A valve and its parts, as used on engines with valves on the side, is shown in Fig. 31.

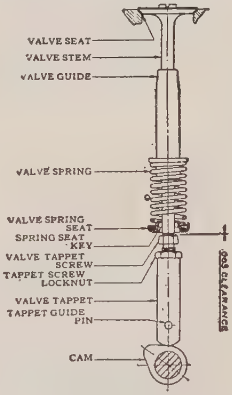

Fig. 31. A valve and its parts. The Ford valve has no tappet adjustment. When worn, new valves should be installed.

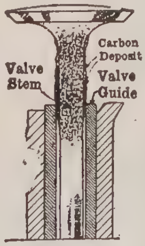

Fig. 32

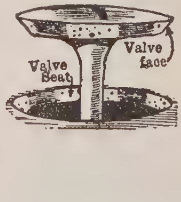

Fig. 33

Fig. 32. Note the black spots on the valve face and valve seat. This permits the escape of gas. If the valves are ground or reseated, the spots will be removed and the valve will seat tight, provided the pitting is not too deep and the valve spring is not too weak.

Fig. 33. Exhaust-valve stems often become carbon coated, and when the engine is driven at high speeds the temperature increases, causing expansion, with the result that the valve will be given a taper effect which will not permit it to seat properly. Often this is the cause of a leaky valve, and the stem should be cleaned thoroughly and sufficient clearance allowed between the valve stem and the valve guide. Clean by placing the valve in a vise, and use a strip of emery cloth.

To determine if valves need grinding or reseating: Valve grinding will ordinarily remove small pits, but if badly pitted or if the valve head is warped (caused by excessive heating), out of line with its seat, or if shoulders appear on the valve face or valve seat, they should first be re-seated with a special re-seating tool and then ground to a smooth surface.

Valve stems become worn in time and permit air to be drawn in through the valve guide when the inlet valve is open, thus admitting more air to the carburetion mixture, which sometimes causes missing. The remedy for worn valve guides is discussed on page 774.

The subject of worn valve tappets and guides is discussed on page 775.

GRINDING ENGINE VALVES

Valve grinding is necessary when either the inlet or the exhaust **valves leak.** The exhaust valve has a tendency to leak more than an inlet valve because it is more exposed to the heat.

To test whether valves need grinding, see the "Prussian blue test," explained on page 769; also try the compression. Weak compression usually results from leaky valves as well as from leaky rings; therefore be sure that the leak is in the valve and not in the rings.

To grind valves is not a difficult process. It is merely a slow and **painstaking job,** and is better done the more patient and untiring the operator is.

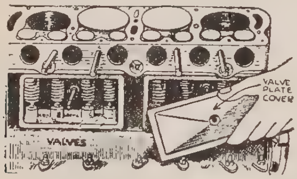

Fig. 34. Valve cover removed on an engine with valves on the side exposing the valve springs and valve stems.

To Remove Valves on Engines with Valves on the Side

First **remove the intake pipe** (if it is in the way) and then the **valve-plate cover** (Fig. 34). Remove the **valve cap or cylinder head,** if of a detachable type.

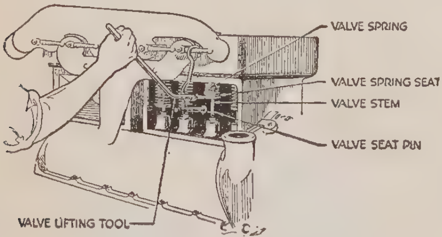

Fig. 35. Method of compressing the valve springs on a Ford to remove the valve.

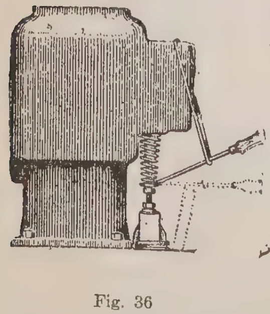

Fig. 36

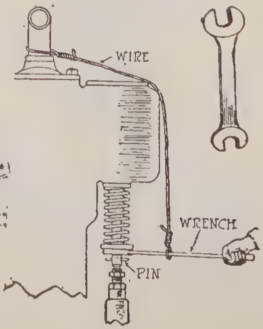

Fig. 37

Figs. 36 and 37 show two methods of releasing spring tension to remove the spring-seat key.

Remove the spring-seat key from under the spring. These springs are very stiff and will require a special spring lifter of some form which can be secured at any supply house, or you can make a serviceable tool, as explained in Figs. 36 and 37.

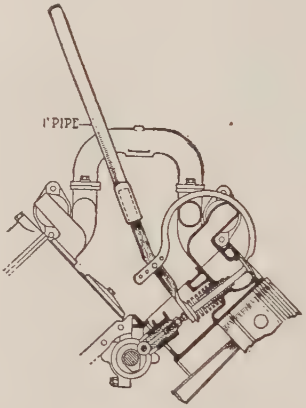

Fig. 38

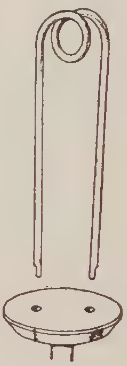

Fig. 39

Fig. 38. A method sometimes used on V-type cylinder-block engines for compressing valve springs.

Fig. 39. After the spring-seat key is removed, the valve is lifted out of its seat, which is not always as easy as it would appear. Valves may be lifted from their seats by means of a **valve lifter** made from a spring steel rod. A piece of 3/16" round rod, about 14" long, is heated and bent in the form illustrated, after which the coil is spring tempered. The points are filed down until they are a snug fit in the holes in the valve top. Valves may be readily lifted out for inspection by means of this device.

Grinding Valves on an L-Head Cylinder with Valves on the Side[1]

First, remove the valve cover, as shown in Fig. 34; then remove the valve caps or cylinder head (if detachable), and then the valve-spring key, by one of the methods shown in Figs. 35 to 38 and 40. **Next remove the valve** (Fig. 41).

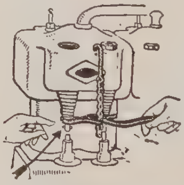

Fig. 40.

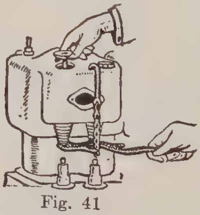

Fig. 41

Fig. 42

Fig. 40. Remove the pin in the end of the valve stem. A spring lifter will make this easy.

Fig. 41. Lift the valve out of the cylinder.

Fig. 42. Smear the valve-grinding compound around the edge of the valve.

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[1] "Clover Grinding Compound" for grinding valves, grinding pistons into cylinders, lapping out cylinders, grinding crank shafts into bearings, polishing crank shafts, etc., is manufactured by the Clover Mfg. Co., Norwalk, Conn. This concern issues a very instructive free bulletin on valve grinding.

Second, place some valve-grinding compound on the face of the valve. The usual procedure is to apply first a coat of oil on the seat, and then to distribute it with the tip of the finger; then dip the finger into the emery (flour of emery), and apply this to the seat. Put on an even coat and don't plaster it all around the surrounding metal parts. Take your time.

There are specially prepared grinding compounds which can be secured at supply houses. They usually come in three grades: No. 1, No. 2, and No. 3. The first is coarse and cuts heavily; the second does not cut so much, and the third polishes.

Third, place the valve back into its seat; then use a screwdriver or a brace with a screwdriver bit, placing the point in the recess, with which most valves are provided.

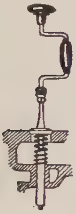
Fig. 43

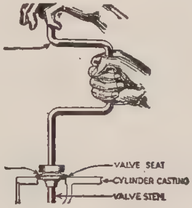

Fig. 44

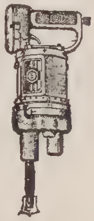
Fig. 45

Fig. 46

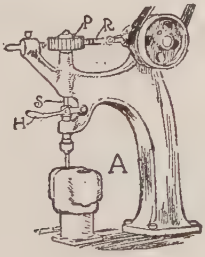

Fig. 47

There are various ways of grinding valves: with a brace and a screwdriver bit as in Fig. 43, or by hand, with a regular screwdriver as in Fig. 50, or by means of a special hand-grinding tool (Fig. 46) with a reciprocating motion, or by a specially made valve-grinding tool operated by power (Fig. 47), or with an electric valve-grinding tool (Fig. 45). There are numerous valve-grinding tools on the market.

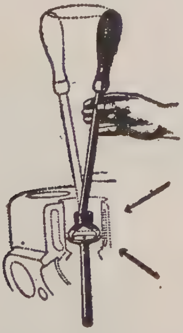
Fig. 48

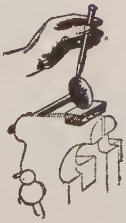
Fig. 49

Fig. 48. **"Anderson" universal valve grinder.** To use this tool it is necessary to make two light impressions or center-punch marks on the flat surface of the valve (Fig. 49), at an angle, or in the sides of the holes already there. The "pinch-ing-bug" hardened-steel jaws are then inserted, and securely held by turning down the knurled nut. Grind by rotating between the palms of the hand. The rod is fastened in such a way as to give a swivel action, permitting the rod to be held at any angle while grinding—the valve remaining true on its seat. (Stevens & Co., 375 Broadway, New York, N.Y.)

A spring should be placed under the valve as shown in Fig. 43. This will allow the valve to be raised from its seat occasionally for inspection.

Place a cloth in the opening to the cylinder to prevent the grinding powder and dirt from getting in; and be sure and take it out when through.

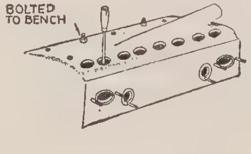

Fig. 50

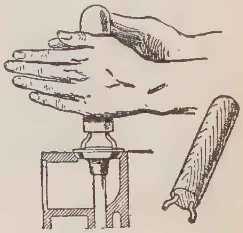
Fig. 51

Fig. 50. A plain screwdriver can be used for grinding valves and can be operated in the manner shown in Fig. 51.

Fig. 51. **A tool for grinding Ford valves** may be made from an 8″ length of broom handle and two nails. The two nails are driven into the sawed-off end of the handle, until only about one inch of the nail is left. The heads of the nails are then filed off and bent until they will fit into the drilled holes in the valve top, which are usually found either in the form of holes or of slots to take a screwdriver.

Fourth, turn the valve half a revolution back and forth in its seat, and occasionally lift it from its seat and shift it around. Don't turn it round and round. See the reason for this, as explained on page 772.

When the pits on the valve are almost removed, continue the operation with flour of emery of a finer grade, instead of the coarse grade; remove the valve oftener, applying more oil and less emery each time, until a good seat is obtained all around; then finish up by polishing the seats with oil. Kerosene is most effectively used in finishing, and the smoother the finish obtained, the less the chance for a leak. Be sure that the valve stems are free in the guides.

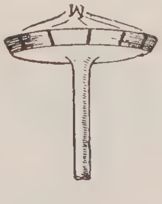

Fig. 52

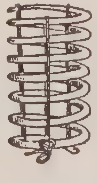
Fig. 53

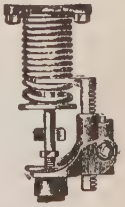
Fig. 54

Fig. 52. **To test the finish of a valve face after grinding:** mark it with a lead pencil as shown about ½ in. apart or less. If, after putting the valve in place and after oscillating it about a quarter-turn, all marks are erased, the job is satisfactory. (The marks on valve (W) are the pencil marks to be erased.)

Fig. 53. **Replacing a valve spring:** Tie the valve spring before trying to replace it. A simple method is to compress a valve spring between the jaws of a vise. While compressed, it is tied up with a loop of wire or string in two or three places. When the spring is thus tied up under tension, its replacement is easy. This is not necessary, however, if a valve-spring lifter is at hand.

Fig. 54. **"Bryant" valve-spring compressor.** The upper engaging device is inserted between the coils, thereby raising the spring away from the disk, leaving the disk and key free to be removed. The valve may be "ground in" and replaced in position without removing the spring or the lifter from their places. (Can be obtained of Stevens Co., 375 Broadway, New York, N.Y.)

Remove the valve and clean both head and seat with kerosene, and don't overlook cleaning the valve stem.

If a polished seat is desired, finish as follows: When the valve is ground to a dull, smooth surface, remove and clean the valve face thoroughly. Do not clean the valve seat, but leave upon it the compound which remains from the last grinding. Replace the valve and give it twenty or thirty turns. Remove again, clean the valve, but not the seat as before. Replace the valve, and repeat until the desired polish is obtained The polished seat may look somewhat better, but the **dull smooth seat gives much better results,** as has been proved by test.

For grinding valves, a pressure of about 3½ lbs. is sufficient. More pressure than this will cause the grinding compound to cut rings in the valve or seat.

A valve that is properly seated will bounce back when dropped into its seat. If it stops with a dull thud, either the grinding is not perfect or the valve stem is bent.

To Test Valve Seat After Grinding

Test a valve to see if it has been properly seated after grinding. As a rule, the grinding of a valve should not be carried too far. After completing the grinding operation as described above, clean the face of the valve thoroughly; place a light coating of oil on the valve face and then place the latter on the valve seat. Turn it back and forth a few times.

Then remove the valve and clean it, holding it to the light and observing if there are fine polished lines on it. These lines are the points at which the valve-head seat makes contact with the valve seat.

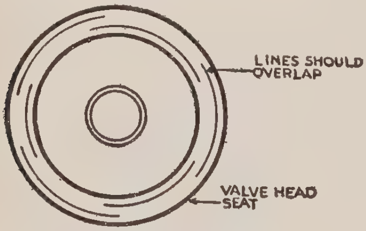

Fig. 55. Correct valve face.

It is not necessary that the lines continue all the way around the valve face or seat; in fact, this is rarely found to be the case. They are usually as shown in Fig. 55 when properly seating. Note that it is necessary that one line overlaps another line, so that there is no break all the way around the face of the valve.

If, on the other hand, there is a break at any point where one line does not overlap another, the gas will escape, and the entire operation should be repeated until the lines make a complete overlapping circle as shown in Fig. 55.

The reason why a valve should not be turned continuously in one direction when grinding, is that it is liable to result in a spiral cut in the seat which would be hard to grind out.

An ideal valve seat is a very fine, narrow edge, as it will last longer than a wide one, and, furthermore, a wide seat tends to permit carbon to collect in the seat, and thus heats the valve, while a narrow valve seat cuts the carbon, thus assisting in keeping the seat clean.

If difficulty is met with in grinding some of the valves, owing to the fact that the abrasive cuts the surface very slowly, it is because that particular engine has a very hard alloy steel Tungsten valve.

Tungsten metal valves have Tungsten heads electrically welded to nickel-steel valve stems. Valves are also made with **cast-iron heads** welded to steel stems.

The Webster laminated valve is another type of valve, the manufacturers claiming that the flexible action of the head makes it possible to use this valve without having to grind it in and that it will keep the face of the seat clean. Another feature claimed, is the smoothness and quietness of operation. This valve is made up of seven laminations, the bottom one of which is chrome-vanadium steel. The laminations are locked together on a 3½ per cent nickel steel stem by a patented method of swagging, making the stem an integral part of the valve head.

To grind valves in an engine with valves-on-the-side, with a detachable cylinder head, see also page 56.

After grinding the valves, replace the valve caps (Fig. 56), then adjust the valve clearance, and put on the valve cover (Fig. 34).

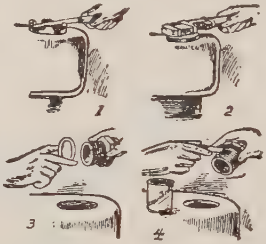

Fig. 56. **Valve caps** are placed over each valve and are finely threaded and provided with a copper gasket (3). When **replacing,** the threads should be coated with graphite or one will have difficulty in removing them the next time. (1) shows a castellated type which sometimes is sunk into the head of the cylinder and requires a special tool to remove.

Grinding Overhead Valves

The foregoing instructions are for grinding valves in an "L" or "T"-head type of cylinder.

Valves placed overhead, are either in **cages,** as shown on pages 53, 71, or in **cylinder heads which are detachable,** as in Figs. 112 to 115, page 57. The process of grinding is similar to the method of grinding valves explained on page 771 and also page 57.

Where valves are in cages, the cages are usually removed as shown by Fig. 57 below and the valves are ground in the cage. The method of grinding

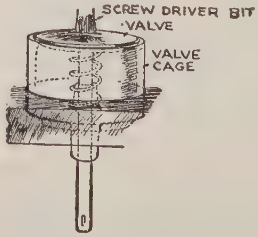

Fig. 57

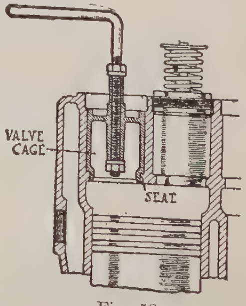

Fig. 58

Fig. 58. A simple way of **grinding a Buick valve cage** to a perfect seat is shown here. Through the center of the cage insert a round iron rod which has been threaded for a nut at the two places shown. Then tighten the nuts. With the rod as a handle, the cage can be rotated easily. See also page 71.

is similar to that of grinding valves explained on page 771.

The cage (Fig. 57) is placed in a counter-sunk hole in the bench, with a spring under the valve to raise it. In fact, it is a good idea to place springs under all types of valves when grinding, as shown in Fig. 43.

To tell when a valve is ground to a perfect seat, see Prussian blue test (pages 769, 772, and Figs. 52, 55).

REFACING VALVE-HEAD FACES AND RESEATING VALVE SEATS

When valve-head faces or valve seats are badly pitted or cut, or where shoulders appear, they will require more than mere grinding.

Valve-head faces are beveled, at either 45°, 30°, or 60°—usually 45°.

As an example of the contruction of a valve, a Ford valve will be used as shown in Figs. 59 and 60. Valves can be secured in the form of blank forgings and can be turned up on a lathe to size. Usually it is more economical to purchase valves finished.

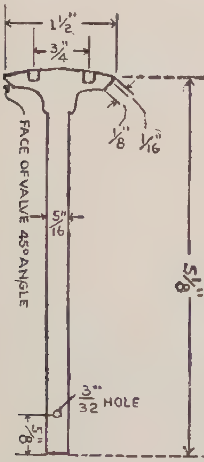

Fig. 59

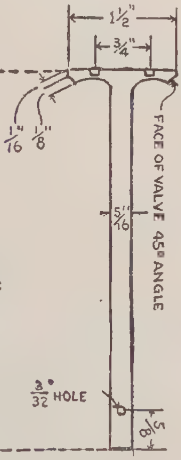

Fig. 60

Fig. 59. Dimensions of a finished Ford valve with a cast-iron head.

Fig. 60. A Tungsten valve. The Tungsten valve, of course, is much harder. Note that the face of the valve is beveled at a 45° angle. The exact dimensions of a Ford valve in thousandths of an inch are as follows: diameter of valve head, 1.422″; valve stem diameter, .311″; length of valve stem, 4.976″.

Refacing Valve-Head Faces

The valve head face is **refaced** with a special refacing tool, as shown in Figs. 61 and 62.

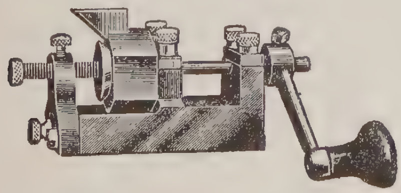

Fig. 61. The Sioux valve refacing tool; to be held in a vise. It is made with cutters for valve faces with 45°, 60°, and 30° angles.

Where Tungsten valves are used, they can be ground if a good valve-grinding compound is used for the purpose; but if they are badly pitted, they should be refaced, because the Tungsten metal is very hard, and the labor in this case is considerable. The usual practice is to place them in a lathe and emery them down with special devices for the purpose, or to use fine emery cloth on a block, while a valve is rotated at a high speed. A valve refacer designed for Tungsten or other valves is shown in Figs. 61 and 62.

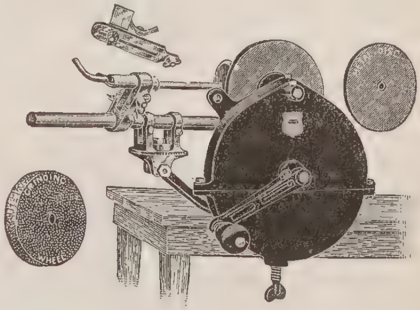

Fig. 62. **The McCullough valve grinder or valve refacer** is guaranteed to grind all makes and sizes of gasoline-engine valves with absolute accuracy and to any bevel desired. It will grind with ease, and perfectly, the hardest tungsten valves without affecting the temper. The hardest valve can be cut to shape in a few minutes, and it does not require a skilled mechanic to accomplish it. When not being used as a valve grinder this machine can be quickly converted into a tool and drill grinder, thus making it a most necessary tool in any auto repair shop. Manufactured by B. L. Fry Mfg. Co., St. Louis, Mo.

Reseating Valve Seats

Truing up a valve seat in the cylinder is usually done with standard sizes of valve reseating cutters or valve seat reamers, as they are usually termed. One type is shown in Fig. 63.

When reseating valve seats, the novice must be careful not to cut too deep into the seat and thereby lower the valve stem. In fact, it is advisable to adjust the valve clearance after either grinding or reseating valves. **After reseating, always grind the valve in order to make a good tight seating.**

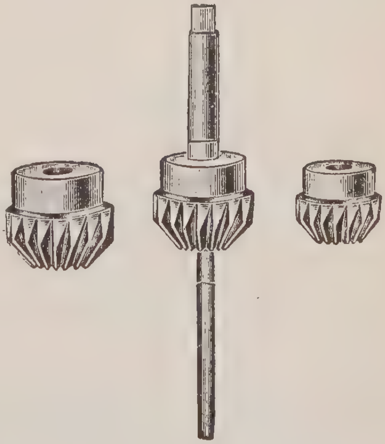

Fig. 63. The Sioux valve-seat reamer for refacing valve seats.

A perfect seat is assured when a white line extends clear around both the valve and the seat, when giving the Prussian blue test. The width of the line is immaterial, but the narrower the line, the better the compression will be, because there is less area for the pressure of the valve spring to act on. However, it is not well to have the ring less than ⅛″ wide.

A valve seat should have a bevel of not less than 45°. With less than this the valve will stick. Another good angle is 60°.

Q.: I have a ——— model car. Valve seats have been ground till the valves drop a ¼″ into seat and the valve head is not level with the combustion chamber till the piston has descended one-half of the suction stroke. Valves are 2¼ ins. Cylinder bore 4¼, stroke 6 ins. Is it advisable to reseat and use slightly larger valves?

Ans.: Yes. Leave the seat narrow so it will last longer. 1/16 to ⅛ inch is wide enough for the seat in the cylinder. You can secure the valve blanks at most any auto supply house.

It will be noticed that some valve stems seem to wear very much on one side. This may be caused by one or more things, viz.: (1) the hole is not concentric with the valve seat—which can be remedied by reseating in a radial drill press; (2) the top of the valve lifter is not at right angles with the valve stem, wedging it off to one side; or (3) the same may be true of the valve head on the stem of the valve. These two latter troubles can be remedied by the judicious use of the file.

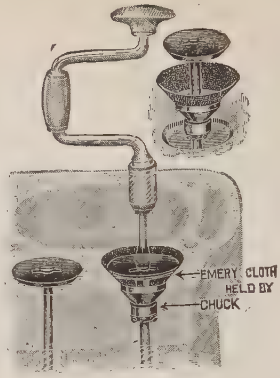

Fig. 64. **The McCullough valve reseating tool** consists of a carborundum cloth cone held to the face of the valve as shown. The valve is used just the same as a reamer, the cloth cutting the seat in the valve seat of cylinder at exactly the same bevel as that of the valve face. No reamers are required. There is nothing to replace but the carborundum cloth. Emery cloth or sand paper will do quite as well, but will not last as long. Manufactured by B. L. Fry Mfg. Co., St. Louis, Mo.

VALVE-STEM GUIDES, OVERSIZE VALVE STEMS, AND VALVE TAPPET GUIDES

When valve stems become badly worn, it is almost a certainty that the **valve stem guide,** or hole through which the valve stem passes, is worn out of round. This permits air to be drawn through the inlet valves when they are open, which causes an **imperfect mixture,** resulting in bad starting as well as noise.

Sticking valves are also sometimes caused by worn valve guides, causing the valve stem to stick at the top and bottom of the guide, with the result that air is drawn into the cylinder, causing missing.

On some engines there are valve-stem guide bushings which can be renewed when worn by putting on a new bushing and reaming out the guide for a new valve, which is fitted at the same time, and by then grinding the valve to a seat.

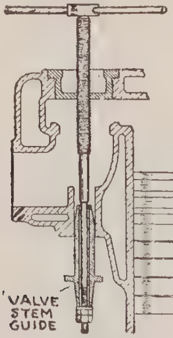

Fig. 65

Replacing valve guides: Where engine cylinders are fitted with removable valve guides, the old valve guides may be driven from the cylinder casting. The fitting of new guides must then be done with more care, however, as a slight distortion of the guide will cause the valve to stick. The puller illustrated in Fig. 65 is ideal for this work, as it applies a steady, even pull to the guide in a manner that cannot spring it out of shape. This tool can be made by taking an old cylinder cap and drilling and tapping it to carry the threaded rod, which may be made on the lathe in a few minutes. The valve guide, it will be noticed, is drawn in from the bottom.

Many valve guides are not bushed, but are simply drilled passages in the metal of the engine, as, for example, on the Ford.

In this construction, the **guide is reamed larger, and an oversize valve is put in.**

Ford valve guides (as well as those on many other engines) are a part of the cylinder casting, and cannot be renewed. Reaming and fitting oversize valves is a better method than to ream the guide large enough to put in a bushing. Unless a great deal of metal is removed, the bushing would be so thin that it would not last long.

A reamer 29/64″ is used to ream the push rod or tappet holes 1/64″ oversize, and a 21/64″ reamer for reaming the valve stem guides 1/16″ oversize on the Ford.

Oversize Valve Stems

Oversize valve stems are necessary when worn valve guides are reamed out. The standard oversize valve stem is $\frac{1}{64}$″ (or, in other words, the valve guide is reamed that much larger). If the standard valve stem was $\frac{5}{16}$″ in diameter, it would be $\frac{1}{64}$″ larger, or $\frac{21}{64}$″ in diameter.

If valve guides are badly worn, it will be necessary to ream larger and to fit larger oversize valves.

On older models (Dodge cars), the valve guide was integral with the cylinder, and a 35/64″ drill bored out the worn guide. Then a .556″ reamer is run through. Then a finishing cut is taken with a 9/16″ reamer.

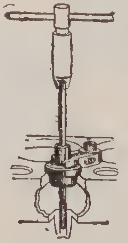

Fig. 66

Fig. 67

Fig. 66. **A valve-guide reamer.** When reaming the valve guides it is necessary to ream true; therefore a guide is necessary. The guide is shown clamped to the cylinder head. The reamer is then passed through the guide and turned by a hand tap-wrench.

Fig. 67. **An oversize valve stem which must be fitted when** a valve guide is reamed.

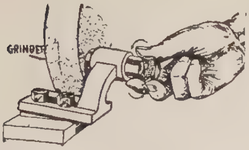

Fig. 68

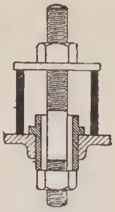

Fig. 69

Fig. 68. **The method of truing valve tappets, when worn,** is shown in this illustration.

Fig. 69. **Valve-tappet guide puller** is made of a short section of 2″ iron pipe, or any size larger in diameter than the guide. A washer is then placed over the top of the pipe. A bolt which will go through the guide hole, and two nuts, will complete the puller.

Noisy Valve Action

Noisy valve action: Difficulty is frequently experienced in locating noises in and about the engine, probably because there are so many of them that it is difficult to determine where to begin.

There are **three points** in connection with valve operation where a clicking noise may occur, as follows:

1. Worn valve tappet guides.
2. Too great a clearance between valve stem and valve tappet.
3. Valve springs too strong.

The best way, perhaps, is to go about it in a systematic manner, starting with the most likely sources, as, for instance, in the valve tappets.

Worn Valve Tappets and Guides

Valve tappet guides usually wear out of round, as a result of the cam striking the lower end of the valve tappet in one direction. Thus in time the wear will be such that each time the cam strikes the tappet to raise it, the tappet is thrust to one side of its guide, and a clicking noise will result.

The remedy is either to put in new valve tappet guides and tappets, or to ream out the tappet guide and to fit oversize tappets.

On the Ford, the tappet holes can be reamed to 1/64″ oversize with a 29/64″ reamer, and oversize tappets can be fitted.

VALVE-STEM CLEARANCE

This subject is fully dealt with on pages 58 and 73, therefore only the resultant effects produced by improper valve clearance will be dealt with here.

Proper adjustment of the valve tappets will help in reducing the noise which invariably occurs when there is any wear, as a result of the increased space between the valve stem and the valve tappet.

The proper space between the ends of the push rods and valve stems is as explained on pages 58 and 59. The smaller the space, the less the noise; but sufficient space must be allowed to provide for expansion when the engine is warm and for irregularities in the shape of the cam or roller.

Sometimes only one or two valves may need adjustment, while others may be in good shape; in such cases there will be a clicking sound at regular intervals.

The repairman can generally find a tappet that is badly out of adjustment in a very short time by simply working the tappets of each cylinder up against the valve stems and down again, with his fingers, while the pistons of the respective cylinders are on their compression strokes.

Another plan is to place a thin piece of metal as a thickness gauge under a suspected valve stem, as shown in Fig. 72, and when the noisy one is found, the insertion of the tool will cause the clicking to cease abruptly and the valve will remain quiet until the tool is removed.

Valve-Clearance Adjusting

Adjustable valve clearance is where there is a valve-tappet adjusting screw (Fig. 2, and Fig.1, page 58).

To test valve clearance, the best plan is to use a thickness gauge and follow instructions given on page 59.

In the absence of a thickness gauge for regulating the valve space, many repairmen use a piece of paper as shown at (C) Fig. 71. It is folded once and slipped between the ends of the stem and tappet; the lock nut (N) is loosened, and the stud (S) is screwed up or outward until it just begins to pinch the paper and prevents it from sliding about as readily as at first. The paper is then removed and the lock nut is tightened.

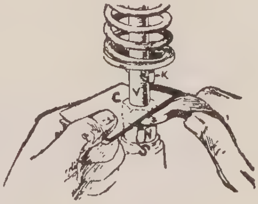

Fig. 71

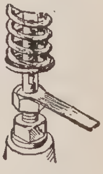

Fig. 72

Fig. 71. Valve adjusting.

Fig. 72. Thickness gauge inserted between valve stem and tappet to find out the existing valve clearance.

When both the inlet and exhaust valves have been adjusted in this manner, each one should be individually tested with a single thickness (a thickness gauge is best; see page 73 and see also, page 58 for the adjustment or gap necessary for leading engines), to see if the valves remain tightly closed throughout their required period.

This is best done by sliding the single thickness of paper back and forth as the engine is being turned slowly from the closing to the opening points of each valve. The marks on the fly wheel may be used to advantage in this operation if accessible, but they are not necessary. One can slide the paper under a stem and turn the engine over until the paper is seized, which indicates the valve opening. Then turn it a little farther until it is free again, which marks the closing of the valve. Now, if the paper is turned still farther, and is continually slid about, if it is not seized before the regular time for the valve to open (according to either the position of the piston or the crank handle), the adjustment is about right, but if the paper is prematurely seized the space is insufficient. The valve in each cylinder should be adjusted in the same manner.

When adjusting valve clearance, remember that if no space at all is left between the valve and the plunger, the valve will not seat properly; therefore, it is important to get the distance exact.

Non-adjustable valve clearance is where no adjustment nuts are provided, as on the Ford. Therefore when the clearance is too great, new valve stems and often tappets also must be installed, or valve adjusters can be used as explained below.

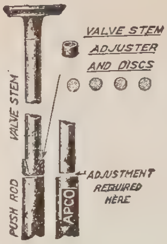

Fig. 73

Fig. 73. **Valve-clearance adjusters.** When the space between the end of the push rod and the end of the valve stem is more than 1/32", then a clicking noise is the result. As the Ford valve has no means of adjustment it is remedied by either installing new valves and 1/64" oversize push rods (tappets), or by using adjusters, as shown in this illustration, which are made of steel lined with fiber. These can be secured of supply houses. The clearance on a Ford valve should be .022" to .028". See Index under "Valve clearance, Ford."

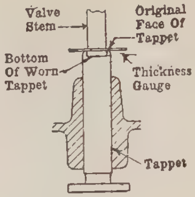

Fig. 74

Fig. 74. **If a valve tappet becomes worn with a depression** in the end of the tappet, this would throw the valve out of time if clearance was measured with thickness on the top or sides of the depression. **Install a new tappet, and also a new valve stem.**

VALVE SPRINGS

If the springs of the exhaust valves become weak from use or heat, the pistons will draw burned gases into the cylinders, past the valves with the incoming gasoline charge, **giving an improper mixture.**

The valve springs should be tested when overhauling, to see if they are full strength (see Fig. 76). They are usually made of chrome-vanadium steel. The average strength of a valve spring is about 30 lbs., but varies. On the Franklin series "9B" engine, when supporting a weight of 25 to 28 lbs., the springs should have just enough tension to seat the valves properly. A 1/32" washer under the spring will increase the spring tension by 1 lb.

Exhaust valve springs are stronger than the inlet spring, and at high engine speed the exhaust valves nearly always permit some leakage.

The reason why an explosion from a weak exhaust spring misses is, that when the throttle is closed, the piston cannot get much of a charge, and consequently it sucks the exhaust valve open and draws back some of the burned gases, which spoils the small charge in the cylinder, causing mis-fire.

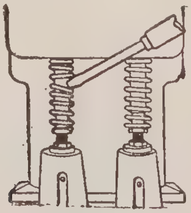

Fig. 75

To test for a weak exhaust spring, insert a screwdriver between the coils (Fig. 75), thereby increasing the tension. If missing stops, then remove the spring and stretch it about an inch, or put in a new one.

Valve springs that are too stiff are to be avoided, because they may close the valves with so much force as to break the stems at the key, or the heads from the stems, and it is a certainty that the seats will be pounded out of shape, even if the valves do manage to stand the constant hammering action. An **excessively stiff** spring consumes power which might be used to a better advantage, and there is also considerable **noise.**

A weak inlet valve spring also makes itself evident by the mixture back-firing into the carburetor. Springs too weak to hold the valves on the cams will also produce clattering noises, owing to belated seating of the valves.

To increase the tension of a weak valve spring, stretch the spring a mere trifle by slightly opening up the coils with a screwdriver (Fig. 75), or by securing one end coil of the spring in a vise and tying a cord or the like to the other end, so as to get a grip. Then stretch it a little in the ordinary way.

Another way to increase the tension is to place a couple of **washers under the lower end of the spring.**

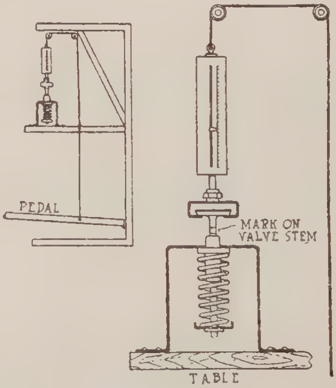

Fig. 76. When the engine is overhauled, the **old valve springs can be tested** to see that they have not weakened, and whenever a new spring is put in, it can also be tested. The illustration shows a simple means of determining whether a spring is in good condition or not.

The apparatus consists of a bracket in which is mounted a valve guide, valve, spring, spring seat, and retaining key. Two marks are placed on the valve stem, one indicating when the compression of the spring is zero, and the other when it has been compressed a certain amount, say ½". The number of pounds required to compress the spring ½" may be ascertained by testing a new spring known to be of the proper tension; then compare the test of the good spring with the old one. The pedal is depressed and the valve is raised until the lower mark on the valve stem is on a level with the top of the valve guide, at which time the pull as registered by the spring scales should be that of a good spring tested previously in the same manner.

One of the most important features necessary to obtain increased power is good valve action. Valve springs are cheap, and it pays to install a new set of valve springs occasionally, even if the old ones do not seem to be worn out. Lively springs close the valves promptly, and this is especially necessary if the engine is to be run at high speeds. If it is to be used for racing and the last ounce of power is desired, it may be advisable to use special valve springs that are stronger than the regular type, but such springs are more prone to break the valves and are more noisy.

ENGINE KNOCKS[1]

Knocks are usually caused by the following parts being loose or worn, or otherwise in poor condition:

1. Lower connecting-rod bearings.
2. Upper connecting-rod bearing or wrist pin.
3. Cam-shaft bearings.
4. Main crank-shaft bearings.
5. A loose piston which produces a piston slap.
6. Timing gears.
7. Cam shaft.
8. Fly wheel.
9. Carburetion adjustment not correct.
10. Running too far advanced on the spark.
11. Worn valve stems and valve guides.
12. Pre-ignition.
13. Badly worn or broken piston rings.
14. Too great a compression.

Troubles which commonly cause a knock that develops on a hill, and that is not perceptible on level ground are as follows:

1. Lean mixture.
2. Magneto set too early.
3. Valves seat poorly.
4. Carbon in cylinders.
5. Poor valve adjustment.
6. Loose wrist pin bushing.
7. Loose magneto shaft coupling and sticking valves.

The cures for these may be taken up in order. They are as follows:

Lean mixture can be cured by opening the needle valve slightly, or by closing the air valve. The former is preferable, as it is easier to make a correct fuel adjustment than an exact air adjustment. This adjustment should be made on the road. Take the car out on a hill and run it up in its present condition. Return to the bottom of the hill and make a change in the mixture, by turning the fuel adjustment. When this is done run the car up the hill again and note if there is any decrease in the knock. If there is none, or the change is only slight, it is time to pass to the next cause.

Climbing a hill with spark too far advanced will always cause a knock. See Index under "Ignition knock."

Loose cylinder nuts will cause a knock and vibration, and in some cases a knock has been caused by the engine being loose on the frame.

Timing gears: Lack of proper lubrication causes most of the worn-out knocks which are heard, while many come from natural wear. The timing gears, for example, run in a bath of oil, and yet, in time, the teeth become worn and, with the excessive backlash or play, a rattling and sometimes a knocking is heard.

Knocks are frequently caused by connnecting rods being slightly bent or out of alignment, which sometimes happens when fitting the cylinders down over the pistons. This will also cause a "piston slap."

Locating Engine Knocks

Minor causes: Before making tests, first determine if the cause of the knock is not one of several minor causes, which are easy to locate:

1. See if the cylinder is free from carbon, and if the knock is not caused by pre-ignition (see pages 170, 780).
2. Find out if the knock is due to running with the spark lever too far advanced.
3. See if carburetion is properly adjusted.
4. Ascertain whether valve clearance is correct, and if the valve tappets are not badly worn.

After determining that the minor causes enumerated above are not producing the knocks, then test from the outside of the engine with a sounding bar, so that the **location** of the knock will be determined or at least that its approximate position may be learned.

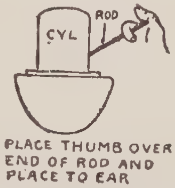

Fig. 77

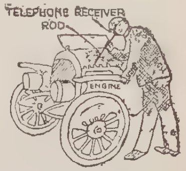

Fig. 78

Fig. 77. **A sounding rod** (of iron or steel) can be made useful to locate the source of knocks. Place the thumb over the end of the bar and then place the ear close to the thumb. The closer you get to the noise, the louder it will be.

Fig. 78. Detecting noises in the engine by sound, with a **Sonoscope,** on the same principle as the sounding rod above shown in Fig. 77. (Made by American Elect. Co., Chicago, Ill.)

It is particularly important to learn at just what point in the engine the trouble exists, and what the cause is likely to be. With this information to start with, no unnecessary parts need be removed, and much time will be saved. Aside from this, it is well known that an engine is always more or less marred by tearing down, and this unnecessary expense should be avoided as much as possible.

We have often seen good automobile mechanics stand around a knocking engine, and have heard each one name a different cause for the trouble. Taking an engine apart is a costly piece of work, and often much labor and expense could be saved **if the cause could be accurately located before the parts are disturbed;** in fact, the knock is not always in the engine itself, although it may sound as if this is the case. It may be found in some of its attachments or fittings, and could perhaps be easily remedied by the operator if only he had the means of locating it. For this reason, the use of the sounding bar is recommended.

First examine the valves: Noises from worn valve stems, push rods, or guides are usually caused by too much space between the end of the valves and the push rods; these conditions, too, are usually the cause of most clicking noises. They can easily be detected by "testing for noisy valves," as explained on page 775.

Wrist-pin knocks can be tested as follows: While the engine is running, short-circuit the spark plugs, one cylinder at a time, to cause it to miss, with the engine running slow or idle. While this is being done, if the piston pin is loose there will be a noticeable knock. The surest method is to remove the piston and connecting rod, and to test on the bench by "feeling" for the looseness.

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[1] See also Index

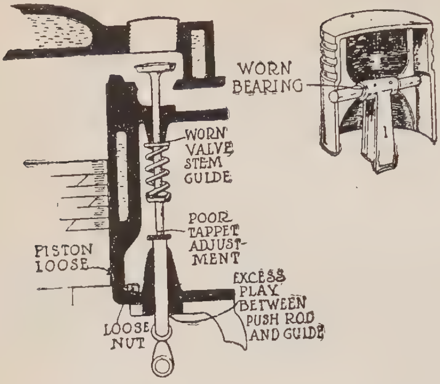

Fig. 79. **Although not all are shown above, most of the common engine noises and knocks** are caused either by poor tappet adjustment, by a worn valve-stem guide, by play in the push-rod guide, by a loose piston or a worn cylinder or loose cylinder nuts. Any of these will cause the engine to knock, and they should be remedied immediately to prevent further complications.

To test for loose pistons: Remove the spark plugs and put ⅛ pint of heavy oil in each cylinder; crank by hand slowly until the oil works to the piston rings. Replace the spark plugs and start the engine; see if the same noise occurs. If it does not, the heavy oil has cushioned the piston from the cylinder and has stopped the knock temporarily. The oil will soon get hot and run from the rings and piston, and the knock will occur again.

If the piston is loose, or if the connecting rod is bent, it has a tendency to cause the piston to strike the cylinder wall at an angle, causing a "piston slap." The rings may be tight, yet if the piston itself is loose, this knock is very likely to occur.

The cam shaft and timing gears can easily be detected with the sounding rod. The timing gears will have a sound or growl that is entirely different from a knock.

To test for loose fly wheel: Allow the engine to run idle at about 500 r.p.m.; then throw off the switch and wait till it slows down to about 75 or 100 r.p.m., after which throw the switch on with spark slightly advanced. Repeat this a few times, and if the fly wheel is loose there will be one distinct knock each time the switch is thrown on.

Another method of testing for a fly-wheel knock is to rock it (remember that the fly wheel may be entirely all right, but some other part attached to it may be loose).

A connecting-rod lower bearing knock can be definitely determined by removing the hand plate at the bottom of the crank case, placing your finger on one edge of the bearing, and cranking the shaft. Have someone rock the fly wheel or starting crank gradually one way and the other (switch off). If it is loose, you will feel it.

Main bearings can be tested in the same manner. A main-bearing knock can also be determined when running the car, by suddenly throwing it into high speed or when pulling a stiff grade. If the main bearings are loose, a distinct knock can be heard.

How to Locate a Knock by the Sound Produced

To locate the cause, first drive the car until the engine becomes warm or reaches its average temperature; second, select a run of about half a mile, running into a grade of about 8 to 12 per cent, of whatever length may be had.

Drive the car at from 10 to 15 miles per hour on the level road, and maintain this speed up the grade if possible. At this speed the engine should run quietly.

But, if, on the other hand, **a slight but distinct metallic rap is heard,** whether it be one, two, three, or four times to a revolution of the crank, the **push rod** or rods will be found to have too much play.

Should it be a slight knock, which slightly increases as the car mounts the hill, mark it first as resulting from **worn piston rings,** which for the fraction of a moment stand still in the cylinders at the beginning of the power stroke, while the piston travels its first 1/64″, or whatever distance the wear may permit. Or it may result from **worn pistons** which are being driven against the cylinder walls at the beginning of the power stroke.

This knock may, on the other hand, have a distinct metallic sound which occurs once to every explosion and greatly increases as the throttle is opened or more gas is admitted into the cylinders. If this be the case, mark it **carbon deposit** in the combustion chambers and on the piston heads, which becomes very hot and ignites the gas, causing pre-ignition.

Should the knock be either heavy or light but with a muffled sound, occurring either one, two, three, or four times to two revolutions, this can be marked **connecting rod or rods,** which may be loose on the crank shaft, or the piston pins or bushings themselves may be worn. The one or more which are causing the knock may be located by holding down on the coil vibrator, or in any other manner that will discontinue the spark at the plugs separately. For example, if by preventing cylinder No. 1 from firing, the knock ceases or is one less in two revolutions, then the trouble lies in connecting rod No. 1.

Should the engine pound, having the sound of a block of wood striking the ground, which will occur once to every explosion, but may be heavier at the explosion of any one cylinder, mark this **crank-shaft main bearing.** In very bad cases this pound can be felt by the driver.

Again, a fly wheel that is loose on the shaft will cause the same kind of a pound (this, however, is very rare). But if the driver will listen very closely he will discover that a crank-shaft bearing has a double pound with the knocks occurring very close together, so close that when first heard it will sound like one pound.

A spark knock can be more readily felt than heard, because the power of the engine is being held back by its own ignition.

A spark knock is due to advancing the spark lever too far, causing combustion to take place before the piston reaches top.

A gas knock is due to an excess of gas, resulting, for instance, from suddenly opening the throttle wide open. This knock also results from too rapid combustion, but the gasoline we have today does not burn so rapidly as to cause a knock (see Index under "Gasoline)." For "carbon knock," see page 170.

A compression knock may result from anything which decreases the space between the head of the piston and the combustion chamber.

Detecting Location of Knocks in an Engine with an Air Pump

A device known as the "Chapman Trouble Finder"[1] is illustrated below. This device will indicate knocks and leaks.

Principle: It is equipped with the necessary connections to enable one to apply it to any make of car, and is a process consisting of alternately raising and lowering the air pressure within a cylinder causing all loose parts to rise and fall. Thus, in doing so, they produce a knock.

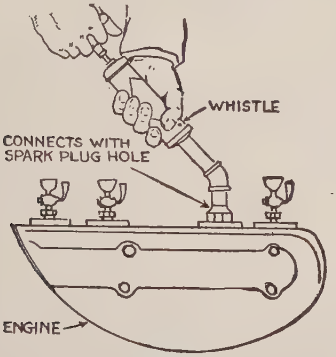

Fig. 80

How it is connected: It is to be used only when the engine is not running.

Remove all spark plugs, screw the device in place of a spark plug, and turn the engine with the starting crank until air escapes through a small whistle near the bottom of the device. Then turn slowly, giving the whistle a chance to operate.

When the whistle stops blowing for a short period, the piston is at top dead center of the compression stroke. Stop cranking the engine; push the handle of the finder down full length; grasp the finder with the hand so that the thumb or finger covers the hole in the whistle, and with the other hand on the handle of the finder you are ready for a test of leaky valves and rings, loose pistons, piston pins, connecting rods, and main bearings.

Procedure of Tests

Connecting rod: Bring the piston to top of the compression stroke. By the rapid movement of the handle all loose parts are caused to rise and fall, and can be plainly heard. By forcing the starting crank in against the end of the shaft, the jar can be plainly felt. This indicates a loose connecting rod, but if the noise is heard and no jar is felt, it is a loose piston pin. If two knocks are heard, it indicates that both are loose.

Piston side slap: If no knocks are heard or felt, turn the starting crank about six or eight inches, bringing the piston off center. Then move the handle rapidly up and down. If a clattering noise is heard it indicates a side slap, as pistons slap one wall and then the other.

Leaky valves: To locate leaky valves, bring the piston to top of compression stroke and move the handle rapidly up and down with a full stroke, which causes the air to escape through the part that leaks. By listening at the breathing tube, if you hear a wheezing sound, it indicates a leaky piston. Wheezing at the exhaust valves indicates a leaky exhaust valve.

Main bearings: To detect a loose main bearing, give the handle longer but equally rapid strokes up and down, placing your free hand on the crank or nub end of the shaft or upon the part nearest the main bearing. If the main bearing is loose you can feel a distinct rise and fall of the shaft.

If directions are carefully followed and none of the troubles described above are located, the trouble may be a carbon knock or advanced ignition, or a loose part not pertaining to the interior of the engine.

Piston Slap

The usual cause of knocks has been discussed in the foregoing pages. Another knock (which is caused by loose-fitting pistons or by connecting rods out of alignment) is explained in the illustration (Fig. 81), and is called **"piston slap."**

This is a knock that is very difficult to locate. About the only means of locating it is with the sounding rod and to have someone short-circuit the spark plugs at each cylinder while the engine is running, in order to determine in which cylinder the knock is. If the knock ceases when one cylinder is cut out by short-circuiting the spark plugs, then the cylinder in which the knock is occurring has been located.

The only remedy is to remove the pistons and to try them in the cylinder and to "feel" for looseness, or caliper the piston and cylinder wall to see what the clearance is. It is also well to see if the connecting rod and the piston are in perfect alignment. See Index under "Piston and connecting-rod alignment."

Bear in mind that a piston may slap when the engine is first started, but after it has warmed up and it expands, the knock may cease. Alignment of the piston and the connecting rod is an important factor also.

Oversize pistons and proper alignment of the piston and connecting rod is the remedy for piston slap. It will thus be apparent that this kind of knock can occur even though the piston rings fit tight.

Piston slap is the result of the piston striking first one side of the cylinder, then the other. The looser the piston is, the greater the slap. If the piston is a good fit, the slap is negligible, which is the case in the ordinary engine. The slap may be due to **worn cylinders,** to the connecting rod being out of alignment, or, in the case of **aluminum alloy pistons,** or slightly loose cast iron pistons, it may appear only when the engine is **cold,** when the pistons are contracted and are much looser than when they are hot.

There may be two or more distinctive piston slaps during the cycle. However, it is likely that the only one that can be heard is the one that occurs when the piston shifts from one side of the cylinder to the other at upper dead center just as the explosion is taking place, as shown in Fig. 81.

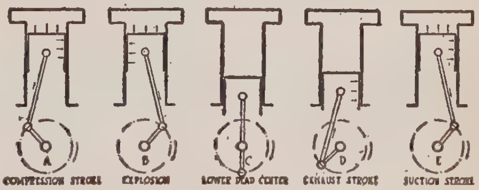

Fig. 81. **Piston slap** is a very common trouble with aluminum pistons, which, when cold, contract and leave a space between the cylinder wall and the piston. After the engine is warmed up the pistons expand and the noise ceases. Aluminum expands twice as much as cast iron. The Franklin car overcomes this by cutting three slots in the skirt of the piston with a spring ring placed in the bottom which holds the lower part of the piston to the walls. As the expansion increases, the ring tension gives accordingly. See also Index under "Pistons."

When the piston is on the compression stroke (A) (Fig. 81), it is in contact with the right side of the cylinder. As the crank pin swings by dead center, the inclination of the connecting rod is changed from right to left, thus forcing the piston to the other side. Under the full explosion pressure (B) the piston will strike a very heavy blow when it makes the change.

The piston remains in contact with this cylinder wall throughout the stroke, and when lower dead center (C) is reached, the pressure on it is entirely relieved, so that it is quite likely that the piston is then more or less able to float between both walls.

On the exhaust stroke (D) the piston is thrown gently to the right side of the cylinder, owing to the downward pressure of the inertia, as well as to the slight exhaust pressure. It is very doubtful that this ever causes an audible slap.

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[1] Can be secured of A. L. Dyke, Electrical Department, Granite Bldg., St. Louis, Mo., Price $7.50.

The piston remains in contact with this wall throughout the suction stroke (E); then the downward pulling force of the connecting-rod is resisted by the suction on the piston as well as the inertia.

At very high speeds inertia may change some of the details of this explanation, but these can hardly be of interest or importance.

Pre-Ignition: Cause of Knocks

Sometimes it happens that the mixture is ignited before the ignition ignites it. This is termed "pre-ignition."

A rich mixture, or the burning of the lubricating oil, will leave a **deposit of carbon** on the piston head and combustion chamber. The intense heat of the explosions after long-continued runs, will heat the carbon which remains red hot, thus igniting the mixture before the proper time. This causes knock.

If the **points of the spark plug are too thin** and of poor material, they will get hot enough to glow in the same manner, and in such a case spark plugs with heavier points should be used.

Small points of metal, the result of rough castings or other causes, should be filed down, by using a fine file.

If the **water circulation stops,** or if the air cooling is not effective, the cylinder walls will get hot enough to ignite the charge, in which case the engine will continue to run after the ignition has been cut off. The remedy for this, of course, is to make sure that the engine is properly cooled, otherwise a "seized piston" will result. See Index.

Eliminating Compression Knock by Adding a Gasket

A knock caused by too high compression sounds like a carbon or advanced spark knock (see Index). The compression may be reduced by placing a thick gasket between the cylinders and the crank case. (This is seldom necessary on engines of modern construction.)

This is sometimes desirable when the car is equipped with a heavy closed body. In such cases a better job may be done by making the thick gasket of cast iron. It is made in a similar manner, but must be planed or milled to a uniform thickness and with a smooth finish. Otherwise the cylinders will be thrown out of alignment or the joints will not be tight. **Another method would be to use special pistons to decrease compression.**

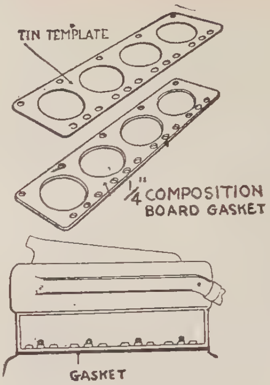

Fig. 82

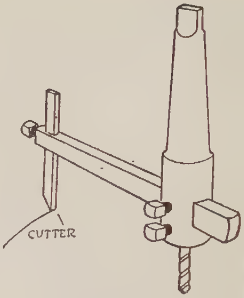

Fig. 83

Fig. 82. Tin template, and finished gasket. Lower cut shows gasket in position.

Fig. 83. Gasket-cutting tool.

Procedure of fitting a gasket: (1) Remove the cylinders. (2) Place the cylinders on a bench, and clean both the cylinder flange and engine base thoroughly. (3) From a sheet of tin, make a template (Fig. 82) which is an exact reproduction of the base of the cylinders, except that all the openings, such as piston and bolt holes, are about ⅛″ larger than those in the cylinders. The template is used as a pattern for marking out and forming the cylinder-raising gasket, and permits the gasket to be made without going to the cylinder each time to see if it is being done right. A copper asbestos gasket does not have sufficient clearance to be used as a pattern. (4) Procure a sheet of red composition board ¼″ thick. (5) Using the template as a pattern, scribe out the cylinder and bolt the holes and the outside form to the red composition board. (6) Using a gasket-cutting tool, as shown in Fig. 83, and a drill press, carefully cut out the piston holes. Make these ⅛″ larger than the cylinder bore. (7) Drill the bolt holes slightly larger than the diameter of the bolts. (8) With a band saw, or key-hole saw, cut the composition board to the outside shape of the pattern. (9) Remove all burred edges with a file. (10) Place the composition board on the engine base, and bolt the cylinders in place, as shown in Fig. 82. Shellac should be used sparingly to prevent leaks.

As a result of this the cylinders have been raised, giving a larger compression space and less compression. The result is that the compression knock disappears and the engine will pull much better on low speeds.

Note. It will be necessary to readjust the valve rods after the cylinders have been bolted down securely. (*Motor World.*)

Unless the compression is the same in all cylinders, the engine will not be in good balance and loss of power will result. The power lost when one cylinder does not fire is far more than one-fourth, and this is largely the result of a loss of balance.

To increase compression pressure: See Index.

INSTRUCTION No. 69

ENGINE BEARINGS: Main Bearing Adjustments; Fitting Bearings; Scraping, Burning-In, Boring, Reaming, Lapping, Etc.; Crank-shaft Alignment; Cam-shaft Adjustments; Connecting Rod and Piston-Pin Bearings and Alignment; Relation of Vibration to Balance

ENGINE BEARINGS[1]

With the exception of lubrication, the most important factor in the operation of an automobile is the condition of the bearings.

The most important bearings in an engine may be classed in four divisions:

1. Crank-shaft main bearings.
2. Lower connecting-rod bearings.
3. Upper connecting-rod bearings.
4. Cam-shaft bearings.

There are three different kinds of bearings: ball bearings, roller bearings and plain bearings. The last-mentioned is the type in general use. The ball bearings have been used to a limited extent on the racing type of engines, and the roller bearing is seldom used at all.

Ball bearings are sometimes used for main crank-shaft bearings, but very seldom.

To insure success, they should be large. On the Stutz racing engine the balls are over 1″ in diameter. It must be remembered that the surface contact of a ball with its race is practically a mathematical point. For this reason they are not found to be successful for connecting-rod lower-end bearings, for the impact is too great for such a small surface.

Where there is a whip, even of small degree, ordinary ball bearings should never be used unless they are of very great size. In a short, stiff shaft with a center bearing, ordinary sizes and types are satisfactory, but otherwise double-row bearings of the self-aligning order are used.

Where a crank shaft is fitted with ball bearings, the crank shaft must either be a two-bearing crank shaft, as, for instance, the Autocar truck engine, which is fitted with a crank shaft of very large diameter, so that the bearings can be fitted at each end of the shaft, or, if more than two bearings are used, then the crank shaft must be of the built-up-type, as it would otherwise be impossible to place the ball bearings over the center bearings of the crank shaft.

Roller bearings are likewise seldom used. These have, of course, a very much greater contact area than ball bearings, and have been used in the connecting-rod lower end, but not as a general practice.

Plain Bearings

The plain bearing: This is the type most used. Formerly, hard steel and phosphor-bronze bushings were regarded as the best combination, but in modern practice, where large bearing surfaces can be used, white metal or babbitt bushings are usually employed in preference.

In the case of small bearings which must sustain a heavy shock—such as, for example, the big, or lower ends of the connecting rods—white metal is scarcely hard enough to resist the spreading action of the impact. Phosphor-bronze, or a composition metal, is therefore necessary here; but where sufficient surface can be obtained to insure against this tendency, white metal—owing to its anti-frictional properties—is generally considered preferable. Since it is composed largely of lead, the result of a failure in lubrication from any cause is merely to melt it out without harming the shaft, which would probably occur if a tough metal like phosphor-bronze were used.

The secret, therefore, of a successful white-metal bearing, or indeed of a bearing of any kind, is a true and highly polished surface on the journal. The white-metal bearing can then be fitted comparatively tight, and will rapidly accommodate its surface to that of the steel, and long life will be insured if the lubrication is correct.

The essential requirements to be considered in a bearing bushing are that it should have anti-friction properties, so as to withstand the heavy impact or pressure against it during the hard pulls and high-compression impulses and at high speeds, without heating; it should be hard enough not to give, crack, or break under severe shocks and blows, and must be of such a construction as to be easily renewed when worn.

There are two kinds of bearing metals, (1) those which contain a greater percentage of copper and a small amount of softer metals, which are known as hard metals, such as brass or bronze; (2) those which contain a large proportion of tin or lead and a small percentage of copper, known as soft metals, as babbitt metal, anti-friction metal, and white metal.

The soft metal is generally used because the bearing can be renewed more easily. The soft-metal bearing does not have sufficient strength, alone, to sustain the weight and impact of the rotating parts; consequently it is usually used as a liner in a bearing and bearing cap, and is thus termed a "bushing."

The soft-metal bushing, or **babbitt,** can be run in a molten state into the bearing shell or cap, which is composed of tougher and harder metals.

White-metal bushings are usually die cast, and are placed into the bearings.

The bearings which are most dealt with on an engine are the crank-shaft main bearings, the upper and lower connecting-rod bearings, and the piston-pin bearings.

Crank-Shaft Main Bearings

The main bearings of an engine in which the crank shaft revolves are usually constructed as shown in Fig. 1.

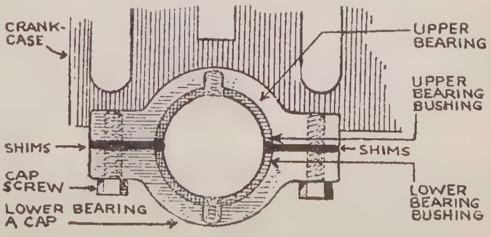

Fig. 1

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[1] See Index under "Tractor and truck engine bearings."

The upper part of the bearing is a circular depression cast in the lower part of the crank case, into which is fitted an upper bearing bushing.

The lower part of the bearing, which bears the weight of the crank shaft and the thrust of the impact of explosions, is in the form of a cap, termed a lower main bearing cap, which is fitted with a lower main bearing-cap bushing. This cap is held securely around the crank-shaft bearing by being bolted to the upper half of the bearing by cap screws. It is made of steel or brass, or bronze.

Bearing Bushings

The upper bearing and lower bearing cap are lined, or bushed, with soft metal, such as babbitt or white metal.

There are two kinds of bushings: the **solid bushing** which is not removable, and the **die-cast bushing** which is removable.

The solid babbitt bushings are those where babbitt metal in a molten state, is poured, or run, into the upper bearing and the lower bearing cap, and thus they are lined with a stationary babbitt lining which cannot be readily removed.

When bearings which are lined with babbitt metal become worn, the bearing cap can be drawn up by filing; or, if shims are used, they can be removed and the cap can be drawn up as the wear increases; or, if they are too badly worn, new babbitt bushings are run into the upper bearing and lower cap.

The babbitt metal bushings as used on the Ford engine, for example, are of the solid type. In this case, the old babbitt is removed and the surface on which the babbitt is to be poured is tinned and the molten babbitt metal is run in around a mandril smaller than the shaft. A true bore slightly less than the shaft is then made with a boring tool and is reamed with a clearance for an oil film, after which the necessary oil channels are cut in the surface of the bushing.

Die-cast bearing bushings are removable. They are cast in separate dies, with either steel, bronze, or brass backs lined with white metal or anti-frictional metal alloy, similar to babbitt. These bushings are fastened to the bearings and the bearing caps by means of rivets and pins, or screwed with countersunk screws—usually the latter.

The split removable die-cast bushing just referred to is shown in Fig. 2. Another type of split removable bushing is shown in Fig. 3, known as the Ryerson reinforced bearing bushing, and consisting of a bronze or steel skeleton used in combination with babbitt or other bearing metals.

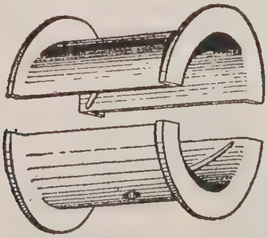


Fig. 2. **The die-cast split removable bushing.** The part above fits into the upper bearing and the part below fits into the lower bearing cap.

Die-cast bearings are usually constructed of a composition metal, die cast in a steel or bronze shell under pressure, then soldered and locked at both ends, thus eliminating the possibility of the babbitt coming loose from the shells. The bushings are also sometimes all die-cast babbitt, without the bronze or steel back.

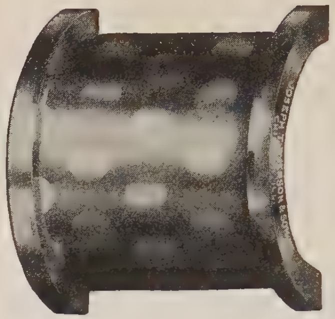


Fig. 3. The Ryerson bearing bushing—a die-cast split removable bushing.

When bearings which are fitted with die-cast bushings become worn, the bearing cap can be drawn up by removing the shims between the bearing and the bearing cap, or, if shims are not used, by dressing down the sides of the bearing caps.

If badly worn or burned, the old bushings can be removed and new ones can be substituted, or old ones may be scraped without removing. Usually all that is necessary is to remove the shims and tighten up the lower bearing cap.

Bearing Clearance

The space between the bearing bushing and crank-shaft main bearing pin, when the bearing cap is drawn tight, is about .002″, this space being divided on both sides of the crank pin, making a clearance of .001″ all around the circumference of the crank pin, which space is **occupied by a film of oil.** While this condition exists, and if the metal of the bushing remains hard without giving under the constant pounding of the power impulse and vibration, this oil film remains unbroken and the bearing remains in perfect condition. But the softer metal will, in time, give way to the pounding and vibration, with the result that the bushing will wear oval-shaped, because the weight of the crank shaft and the thrust of the power impulses will all concentrate on the lower bearing bushing. Most of the wear is thus at the bottom. In fact, practically all of the weight and most of the wear is on the lower part of the bearing, called the lower bearing cap. For this reason there is not much wear on the top. The 1910 Ford engine did not have a bushing in the top of the crank-shaft bearing at all.

If the bearing bushing is hard, or if a hard spot should develop in the bushing, the **crank pin** itself will wear flat on the pressure side.

Whenever a bushing in the crank-shaft main bearing has become worn until the inner surface is no longer absolutely round, it makes itself known by a peculiar **knock,** perhaps more like a heavy rumble, or vibration, than a sharp distinct knock. This rumble is usually more noticeable at speeds of 35 to 40 miles per hour.

On examination it will be found that the fit is loose and that the shaft has an excessive amount of "play" or lost motion; in the case of a main bearing, the shaft then is out of alignment.

The cause of bearing knocks: An article in the *American Automobile Digest* covers this point very clearly, and is as follows:

"As soon as the clearance between the bearing and the shaft exceeds the natural thickness of the film, the rod will begin to knock. The **oil film** thickness varies with the grade of oil used and the pressure on the bearing. Common usage and design allow from one to two one-thousandths of an inch to be taken up by the thickness of the oil film. Bearings should not be allowed to run loose for any length of time; when the knocking or pounding is first noticed, time should be taken to make a proper job of bearing fitting and replacement or adjustment, as the case may be. If the bearing is allowed to pound, it will wear the crankpin oval, making it impossible to fit a new bearing perfectly without removing the crank shaft and having the pin reground to the proper size."

Oil grooves in bearing bushings are treated on page 171. Do not forget, when taking up on bearings, to examine the oil grooves. They may be worn thin, and should be opened up.

MAIN BEARING ADJUSTMENT METHODS

Where main crank-shaft bearing bushings are only slightly out of round, or worn, the bearing cap can be drawn tighter by adjusting the lower bearing cap.

There are two methods for adjusting or taking up on a lower bearing cap so that it will be tighter on the shaft: (1) by removing the shims; (2) by dressing down the sides of the bearing cap.

Usually, the rear main bearing, owing to the increased weight of the fly wheel, is the one which wears first, and usually the bushing in the lower bearing cap wears most.

Adjusting a Bearing by Removing the Shims

Taking up main bearings: First, take down the oil pan. To do this remove all the bolts underneath, and all bolts at each end of pan. Then remove the lower oil pan. The bearings on most engines are fitted with brass or other forms of separators of a standard thickness, made up of thin shims in various gauges, .001" to .005" thick.

Shims: On modern bearings there are usually three shims of different thickness, under each side of the bearing cap, the thinnest shim being at bottom.

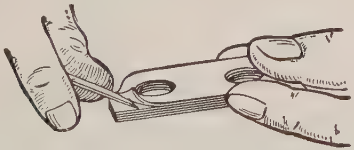


Fig. 4. **The laminum shim:** Note the **laminated layers of metal** similar to thin brass. In the illustration, the top layer is being started with a knife blade, enough to get a hold, then it can be peeled off. (Laminated Shim Co., 533 Canal St., New York.)

The type of shim generally used is the laminated shim shown in Fig. 4. It is made of thin layers (.001" to .005" in thickness) of laminum, which can be peeled off as desired. This type of shim can be used in the main crank-shaft bearings and also in the connecting-rod lower bearings.

To make proper adjustment, simply remove one or more thin shims from each side of the bearings.

The bearing cap, usually referred to as the lower bearing, must be drawn up tight, not against the shaft, but against the shim or spacing sleeve. If drawn tight against the shaft, it will burn out, and if left loose, it will pound and perhaps strip nuts off the cap screws. A really good mechanical job cannot be made without shims or their equivalent.

Adjustment of Reo Main Bearings; Removing Shims

As an example of a main bearing adjustment, the main bearings on the Reo models "T6" and "U6" are shown in Fig. 5.

The main bearings are adjusted as follows: Having removed the underpan from the chassis frame, unscrew the three small cap screws which fasten the cam-gear housing cover to the oil pan and the 18 cap screws which fasten the oil pan to the crank case. If care is exercised, the oil pan may be dropped down without necessitating the draining of the oil or previous disconnecting of the oil pump.

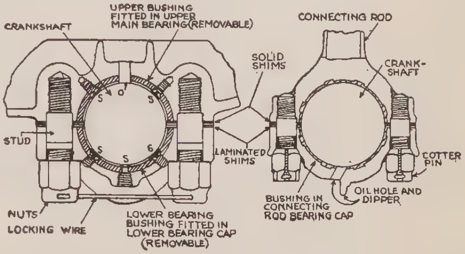

UPPER BUSHING FITTED IN UPPER MAIN BEARING (REMOVABLE)
CRANKSHAFT
CONNECTING ROD
SOLID SHIMS
CRANK-SHAFT
S
O
S
STUD
S
S
6
LAMINATED SHIMS
COTTER PIN
OIL HOLE AND DIPPER
BUSHING IN CONNECTING ROD BEARING CAP
NUTS
LOCKING WIRE
LOWER BEARING BUSHING FITTED IN LOWER BEARING CAP (REMOVABLE)

Fig. 5

Now remove the locking wires which anchor the nuts. Turning these nuts off their studs will permit the bearing cap to be taken off.

Remove one lamination from each of the metal spacing shims provided; replace the cap; tighten the nuts, and if the crank shaft still turns easily, repeat the operation **until a slight tightness can be detected.** It is good practice to adjust each bearing separately.

For example, let us suppose that with the spark plugs removed (thereby eliminating compression) the crank shaft can be turned over very easily. Commence with the first main bearing and adjust it properly, following the directions as given above. Were we to allow this bearing to remain properly adjusted, some difficulty would undoubtedly be experienced in detecting the exact tightness of the second bearing. Therefore, in order to ascertain this point, slack off on the first bearing just a trifle.

When the second bearing has been correctly adjusted, slack off on the nuts a trifle, and adjust the third bearing.

After the fourth bearing has been adjusted, the other main bearings should be drawn up snugly and the **locking wires** replaced.

Testing after adjusting: If the main bearings have been properly adjusted, no difficulty should be experienced in turning the engine over with the hand starting crank.

When testing the bearing, keep in mind that while it should have no appreciable amount of looseness, this does not mean that the drag on the shaft should prevent its free rotation, or so that you can spin the crank shaft with the hand crank, with the spark plugs removed. When all main bearings are properly adjusted and the caps are bolted in place, the crank shaft should be just loose enough in the bearing to permit revolving it by hand or turning it readily with the fly wheel, and without the assistance of a bar or pry.

Remember, there is a possibility of getting the bearings too tight, and under such conditions the babbitt alloy in the bushing is likely to cut out quickly unless precaution is taken to run the engine **slowly** for the first few days, with plenty of oil.

When bearings have been taken up, replace the oil pan, being careful not to damage the gasket, and do not forget to see that **all nuts** are securely tightened and that the cotter pins are inserted.

Note the Reo method of replacing the oil pan: Care must be taken in replacing the oil pan, as there is danger of damaging the gasket for the cam-gear housing cover and causing oil to leak from the front end of the engine. A thin strip of tin placed over the gasket will serve as a guide for the oil pan, and prevent damage to the gasket. Before fastening the pan in place, withdraw the tin strip. Best results can be obtained by fastening up the pan on the left side of the engine first. In this manner it is possible for one person to guide the pump plunger into its barrel while raising the right side of the pan in place. Before replacing the underpan, be sure that all cap screws are tightened securely.

If the bearings of an engine are not fitted with shims, which is unusual, then it will be necessary to dress the sides of the bearing so that it will make a closer fit.

Adjusting a Bearing by Dressing the Bearing Cap

Where there are no shims between a bearing cap and the upper bearing by which adjustment can be made, as previously explained, the bearing cap must be dressed down so that it can be drawn tighter around the shaft pin.

The bearing cap can be dressed off on the sides by filing (termed "draw filing") or by dressing the sides down on a sheet of emery paper. This work requires careful and painstaking effort, and frequent inspection or checking while dressing down.

When removing a bearing cap, always inspect the bushing to see if the babbitt is damaged to such an extent as to need scraping, or if the bushing is burned out or worn so thin that the bushings should be replaced. Usually the bushing in the lower cap wears most. If it is a solid babbitted bushing, a new cap with bushing in it can be used to replace the damaged one, or if it is a removable bushing, the bushings can be replaced. Usually, however, when this is the case, it will be found that all bearings must be replaced and properly lined up by scraping, or burning-in, or reaming, as will be explained farther on.

If the engine is on the bench, it is also advisable to **inspect the crank-shaft pins** and see if they are smooth and are not scored or cut, or worn oval or flat, or out of round, for if they are, then the attempt at adjustment will be time lost.

In this case, the crank shaft should be removed and tested (explained farther on), and bushings properly fitted.

If the crank-shaft pins are in good condition, and the babbitt bushings have not been damaged, the cap can be dressed down by draw-filing with a large mill file, as shown in Fig. 6. The repairman must exercise great care to hold the file squarely on the cap (see Index under "Draw filing").

When the cap has been dressed down sufficiently, try the surface of the cap for high spots, by holding a scale across it at several points and angles, as shown in **Fig. 7**, or try it on a surface plate (a smooth steel slab) by tapping the cap lightly with the fingers at several points to note any slight variation in the surface. If the cap is rubbed lightly over the surface plate and dark spots appear on the surface, these are the high spots and they should be dressed off with the file until they are distributed evenly over the surface of the cap.

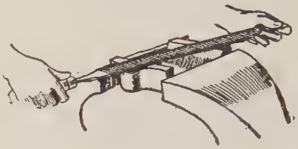


Fig. 6

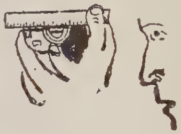


Fig. 7

Another method for dressing a bearing cap down on the sides, especially where one is not an expert with a file, is to cut the edges or sides of the cap down on a sheet of emery cloth glued to a perfectly flat hardwood block, a sheet of glass, or a steel surface plate. Any workman can perform the job successfully this way.

Unless filing is carefully done, the edges of the work are practically certain to be filed out of line, resulting in twisting when the cap is pulled down.

To test after adjusting: The bearings should not be fitted too tight or too loose. Follow the plan for testing the resistance of the crank shaft in the bearings after adjusting, as given on page 786.

Note: When removing bearing caps, be sure to **mark them** so that they can be replaced, and always put oil on the bushings when replacing a cap.

On most engines the main bearing caps, as well as the connecting-rod caps, can be taken up or adjusted by removing the oil pan and **without removing the engine from the frame,** or the crank shaft from the engine. On the Ford, the front and center main bearings can be adjusted without removing the engine; but in order to do any work on the rear main bearing, it is necessary to remove the engine.

Renewing Damaged Bearing Bushings

Where a bushing is damaged by being burned, scored, or worn thin, it must be renewed either by fitting new bushings, if of the removable type, **or** by rebabbitting, if of the solid babbitted type.

Crank-Shaft Alignment

When doing this work, the important point to bear in mind is that **the crank-shaft main bearing pins must be in perfect alignment with the bearings.** If one bearing bushing surface is lower or higher than the others, this will cause great vibration as well as wear. Thus the purpose of fitting the bearings is to align the bearing surfaces to the crank-shaft main bearing pins.

Inspect the crank-shaft bearing pins before fitting bearings: Before fitting the main bearings or connecting-rod bearings to a crank shaft, it is necessary to test the crank shaft to find out if it is out of alignment itself, by being bent or sprung, or if the bearing pins are worn flat or oval, or if they are scored, cut, or rough (explained farther on).

METHODS OF FITTING AND ALIGNING BEARINGS TO THE CRANK SHAFT

There are several methods of fitting and aligning bearings to the crank-shaft main bearing pins:

1. By "spotting-in" and scraping.
2. By boring, then reaming, then "spotting-in" and scraping, then "running-in" in oil.
3. By boring, reaming, and burning-in, which might be termed "melting-in"; then "running-in" in oil.
4. By boring, then reaming, then "running-in" in oil.

Either of these processes can be used, and all are intended to accomplish the same purpose, that is, to give a good bearing surface and to align the bearings with each other and to the crank-shaft main bearing pins.

Spotting-in and Scraping a Main Bearing (1)

Usually, for all ordinary wear, the adjustment of bearings is all that is necessary (for removing shims or dressing the sides of the bearing caps as the wear increases; more often by removing shims), and the removal of the oil pan is usually all that will be required.

Where bearings are spotted-in and scraped, it is necessary to remove the engine from the frame of the car.

To scrape and spot-in bearings: Remove the engine from the frame by means of a hoist or otherwise; remove the pistons; remove the oil pan and cylinders, or the cylinder head, if of a detachable type.

Mark each part when removed: Before disassembling the bearing caps to remove the crank shaft, the timing gears should first be carefully marked, as also the pistons, etc., that were removed, so that they can be assembled later on in their proper place. Usually, the connecting rods and caps are marked as shown on page 800.

Turn the crank case on its side, preparatory to removing the crank shaft. The crank case will then look something like that shown in the illustration (Fig. 8).

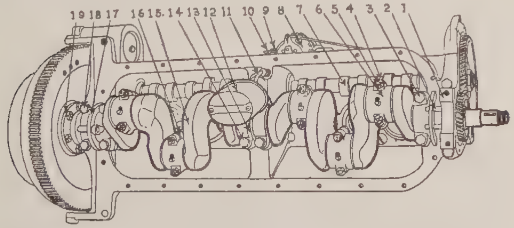


Fig. 8. Crank case with crank shaft in place (Nash "six," series 681 engine): (1) front bearing cap; (2) oil ducts to carry oil back in crank case; (3) crank-shaft front bearing screw; (4) connecting-rod lock nut; (5) connecting-rod bolt; (6) connecting-rod cap; (7) cam; (8) ignition distributor (Delco); (9) and (10) set screws for distributor; (11) oil pipe from pump to distributing tube; (12) oil-pump screen; (13) center bearing cap; (14) center-bearing lock screw; (15) crank shaft; (16) connecting-rod shims; (17) rear-bearing cap; (18) rear-bearing lock screw; (19) crank-shaft fly-wheel flange.

The oil-pump screen (12) is removed, as well as the fly wheel, by disconnecting it at the crank-shaft fly-wheel flange (19). Mark the fly-wheel bolt holes.

The connecting-rod caps are then removed and marked, as are also the connecting rods themselves.

The crank case is then turned up-side-down, and the main bearing caps (1, 13, and 17) are removed. Be sure to mark each one carefully.

The crank shaft is then removed and the work of spotting-in and scraping will be done on all of the upper bearings first, in order to have the crank shaft align with them.

Before proceeding further, **the crank shaft should be inspected for alignment,** etc., as outlined on page 792, and as will be explained farther on.

After determining that the crank shaft is in perfect condition, the next procedure is to "spot-in" and scrape the upper bearings.

Spotting-In and Scraping the Upper Main Bearings

Clean the crank-shaft main bearing pins and upper bearings with a soft cloth and wipe perfectly dry.

Then give the crank-shaft main bearing pins a very light coating of blue, or marking compound.

The marking compound is Prussian blue which can be secured at any supply house, and comes ready mixed (lamp black is also sometimes used). A little **dab** on the fingers is sufficient to wipe on the **shaft,** as a very light coat is required. If too much is given, it will run all over the bearing, and spots will show which should not be scraped.

Put the crank shaft in place, and revolve it several times in the upper bearings by hand.

Remove the crank shaft and note in what manner the blue has spotted the upper main bearings. The "high spots" inside the **bearing** will be found marked in blue, showing that at these points the crank touched; but the part which is white was not touched by the crank. Therefore the problem is to get the high spots down until the bearing will mark, or have a blue surface, all over.

This is accomplished by scraping the high spots down, as in Fig. 9, with the scraping tools shown in Fig. 10, which can be secured at any supply house or can be made of old files. This is a slow, tedious job, for if too much metal is removed it cannot be replaced.

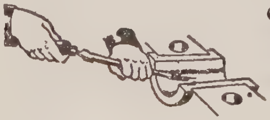


Fig. 9

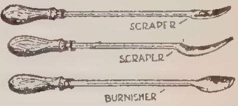


Fig. 10

This marking, or "spotting-in" and scraping process is repeated from time to time till the whole surface is marked, as shown in **(D)** (Fig. 11). In practice, it is not possible to get every white mark off the bearing; therefore continue the scraping and spotting-in until at least three-fourths of the total surface is blue, and the rest will wear in.

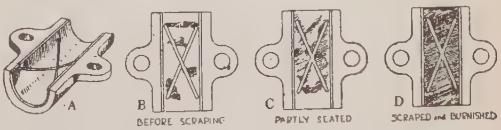


Fig. 11. Showing appearance of markings as the scraping proceeds.

After the scraping is done, the **burnisher** shown in Fig. 10 may be run over the entire surface of the bearing to shine it up and smooth the surface.

If, when first placing the crank shaft in the upper bearings, it is noticed that the end bearings are colored and the center one is not, it is an indication that the center bearing has received more wear than the end ones, and that the end bearings must be reduced in height to bring them down to a perfect line with the center one.

If the center bearing and only one of the end bearings is colored, it indicates that one of the end bearings has worn more than the other two, or that the center bearing has not received as much wear as both end bearings.

Whichever may be the case, the remedy is to scrape the babbitt bearing metal at the required points until the three (or whatever number of bearings there may be) **are in perfect alignment with the crank shaft.**

While marking or "spotting-in" these bearings, the weight of the crank shaft is sufficient. Do not put on the caps at all, as they would force or spring the shaft down and mark the low part of the bearings.

Spotting-In and Scraping the Lower Main Bearing Caps

After the upper main bearings are completed, the lower main bearing caps are treated in a similar manner, being scraped down to a perfect marking.

A very important point is to "spot-in" and fit the rear cap first and to test it for stiffness; then loosen it, then "spot-in" and test the next, and loosen it, and the other likewise. After doing this, tighten down on all. Otherwise, if each bearing is tightened as you proceed, the bearing being fitted could not be properly tested for clearance.

Clearance: After spotting-in and scraping the main bearing caps, the caps are tightened down and "run-in" by belt power, using plenty of oil. The caps are then removed, the bearing surface is examined, then replaced, and proper clearance is given by removing a shim, if necessary.

Adjusting and testing: When the lower caps are fitted and the nuts are drawn up tight, the shaft should turn with some resistance. Some repairmen judge the amount of resistance by being able to move the crank shaft with one hand as shown in Fig. 12. The bearings must not be so tight that they will overheat and seize.

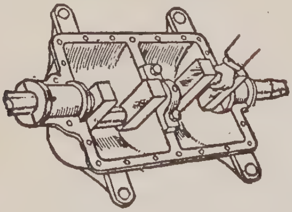


Fig. 12. Testing tightness of main bearings.

Care should be taken in setting up a scraped bearing not to have it as tight as a new bearing, as the metal in the old bearing has been compressed and will not seat itself and wear down, as in the case of a new one. The bearings should not be set up so tight that the crank shaft cannot be readily turned by the hand.

If the shaft turns too hard, do not think that loosening up the nuts is the remedy. In such a case an extra thickness of shim brass will have to be put in, so that the nut can set down tight and still allow the shaft to turn.

If the bushing or metal babbitt lining in a cap is worn badly or is very thin, then new bushings or a new babbitted cap will be necessary. The fitting process will be necessary just the same, however.

Bearing Pointers

After fitting the bearings, run the engine at moderate speed for the first 500 miles, using plenty of good oil to work the bearings in.

Before marking and after scraping, dust all the metal chips out with a small paint brush.

See that the oil grooves are not clogged, and are deep enough.

Wash all parts off with gasoline or kerosene.

Have the scrapers sharp, and never try to scrape with nicked scrapers.

In renewing bearing bushings, care must be taken to see that they are of about the same thickness of metal as the original ones. If too thick, the pistons will be pushed higher into the cylinder and will alter the compression and cause vibration. On two-cycle engines it would change the port timing.

If the crank shaft and timing gears do not mesh deep enough, after scraping the bearings, they will be noisy. Therefore this must be observed, and the upper half must be scraped more to permit a deeper mesh, if necessary.

After fitting bearings, never turn the car over to the owner with the bearings so tight that it is difficult to start the engine with the starting motor, otherwise he will run the battery down in cranking the engine. It is best to have them moderately tight, and then, after the car is driven for about 1,000 miles with plenty of oil, to examine the bearings and see if the cap should be adjusted.

End Play in Main Bearings

End play in main bearings is caused by wear, and the usual remedy is to put in new bearing bushings. Nevertheless, a fairly good repair can be made on the old bearings by building up babbitt at the ends with a soldering iron and some special solder.

The solder is made in the proportions of pure block tin, 1 lb., to half-and-half solder, ¾ lb. These are melted together and poured into sticks. Muriatic acid with zinc (see Index under "Soldering acid") is used to clean the surface, and the soldering is done with a well-tinned iron. After the end of the bearing has been built up, it is then scraped to fit.

On some engines the crank-shaft gear can be removed, and a large washer is placed between the end of the bearing and the gear.

Boring, Reaming, Spotting-in, and Scraping Main Bearings (2)

This is another process for aligning the bearings with each other and with the crank-shaft main bearing pins, which is similar to the scraping process, except that two other operations are added.

The main bearing caps are fitted in place (the crank shaft removed), and then the bearings are bored out on a **boring machine** designed for the purpose. They are then **reamed** with a special reamer, similar to that shown in Fig. 21, page 790, to about .001" larger than the crank shaft.

The crank shaft is then put into place, and Prussian blue is used for **spotting-in** the high spots, which are scraped down as previously explained.

After these processes are completed, the crank shaft is run-in by belt power, using plenty of oil, until the crank shaft can easily be turned by hand.

Boring, Reaming, Burning-in, and Running-in Main Bearings (3)

The burning-in process is supposed to take the place of scraping. By this process, the bearings are aligned with each other and to the crank-shaft pins.

The theory underlying the process of burning-in bearings is that if a very thin skin of the bearing metal next to the shaft is heated almost to the melting point while the shaft is revolving, it will form itself to a 100 per cent running fit. Such perfection is, of course, impossible of attainment. However, the process approaches it closely enough for all practical purposes.

There is some difference in the procedure, depending upon whether the bearing is die cast or of the plain babbitt cast.

In the first case, it is best to remove any gears meshing with the crank-shaft gear, for the reason that so much bearing metal may be shifted that the gears will not bind. If, after burning-in, gears mesh too deeply, the trouble can be easily remedied by placing shims under the upper bearing bushings.

If the bearing bushings are badly worn or thin or loose, then new bushings must first be fitted, either by installing removable bushings or casting the plain babbitt bushings.

If only the lower bearing is worn and it is a babbitt bearing, as on the Ford, a new cap with a babbitt lining can be secured. Usually the upper bearing can be used without rebabbitting.

The die-cast bearing bushings are of the removable type, with either brass or steel backs. They are fitted into the engine cylinder block bearing and cap. This type is most commonly used, as such bushings can be very easily replaced.

The other type is the solid babbitted bearing, which is stationary, being babbitted into the cylinder-block main bearing and cap.

Main bearings may be burned-in instead of replaced if the bushings are not loose or worn too thin, as the burning-in operation removes the worn surface of the bearing and refinishes it as good as new.

As an example, the process of fitting bearings to a Ford engine will be explained.

Babbitting: The first process is to rebabbitt the bearings if necessary. Usually, it is not necessary.

Boring: The main bearing caps are first fitted in place; then the bearings are bored out on a boring machine, as illustrated in Fig. 20, page 789.

Reaming: After the bearings have been bored out, they are then align-reamed to 1.249″ which is .001″ larger than the crank shaft (the crank shaft is 1.250″ in diameter). See also page 714, Fig. 76, for another type of an aligning reamer.

Fitting and testing crank-shaft and bearing caps: After the main bearings have been properly reamed with a bearing-aligning reamer, or roughly hand scraped, as the case may be, the crank shaft is installed by removing the bearing caps. Before installing the crank shaft, test it, as explained on pages 791, 792, 793.

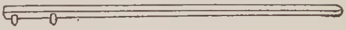
Fit No. 1 bearing very tightly by shimming, leaving a "rock" of from .004″ to .006″, that is, in such a manner that, with the shims in place, it will be impossible to push the bearing cap down to them by hand. The proper distance can be measured with a feeler gage. For instance, a distance of .005″ on one side with the cap pulled down to the shims on the opposite side is equal to .0025″ on each side when the bearing is exactly centered on the shaft. Should it be impossible to fit closely enough by shimming, the bearings may be dressed off on the sides.

After fitting No. 1 bearing, loosen it, and proceed with the remaining ones, loosening each as it is finished.

Sometimes a small high spot in the bearing will deceive one into the belief that the hole is tight. This condition must be guarded against. If such a condition is suspected, the surfaces should be coated lightly with Prussian blue or lamp black and tried by installing the part, pulling it down lightly, and turning the shaft.

High spots should, of course, be removed with the reamer or by hand scraping. Errors had best be made on the side of looseness until experience is gained, as with all bearings pulled down tight, the shaft is subjected to a tremendous strain, which may spring it.

The bearing caps are then drawn down tight on the crank shaft, one at a time, and are then tested out with the turning bar or lever, approximately three feet long, which has two pins in it and fits into the flange of the crank shaft.



Burning-in the main bearings: Each bearing should be shimmed up to the same amount of tightness, and should then be put in the burning-in machine (Fig. 13), connected with coupling (**D**), then clamped tight with clamp rods (**CC**).

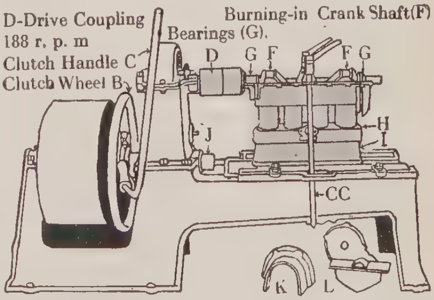


Fig. 13. **Fairbanks burning-in machine.** Burning-in the main crank-shaft bearings on a Ford engine. A belt drives the fly wheel. The power is then transmitted through a clutch to the gearing, thence to coupling (**D**), which drives the crank shaft (**F**) at 188 r.p.m. The same operation is used for burning-in the lower connecting rod bearings. The base (**I**) permits the pistons to pass the cylinder block slightly when burning-in the connecting-rod bearings. (Manufactured by the Fairbanks Co., Service Station Equipment Division, 3701 South Ashland Ave., Chicago, Ill.)

The machine is then started by means of the hand lever (**C**) which operates the clutch, and the crank shaft is revolved at 188 r.p.m., by belt power, for about 30 to 40 seconds, until the bearings begin to burn and smoke.

The hand wheel (**B**) (Fig. 13) is for the purpose of testing the bearings to see if the burning-in operation is completed. When this wheel can easily be turned by hand, the bearings are finished.

Usually, the main bearings are burned-in for about 30 or 40 seconds, then oil is poured on the bearings, and after about 30 seconds more, oil is again poured on the bearings. After about 2 to 5 minutes the clutch lever (C) is thrown out, and the bearings are then tested by means of the hand wheel (B). If the crank shaft cannot be turned by one hand, then the operation of burning-in is repeated for a few seconds.

If one bearing should not get as hot as the others, the operation should be stopped and either shims should be removed or the cap should be draw-filed to tighten on the bearing, thus insuring its being burned-in the same as the others.

After the burning-in of the main bearings, the engine is removed from the machine, all surplus metal is scraped out of the oil grooves of the bearings, and the caps are replaced and lubricated.

Burning-In Connecting-Rod Lower Bearings

The main and connecting-rod bearings had best be burned-in separately, the former first.

In order that no time need be wasted, the connecting rods should have been fitted to and aligned with the pistons and the whole assembly prepared in advance of the foregoing operation.

After the main bearings have been burned-in and lubricated, the pistons and connecting rods are assembled to the engine, after the pistons and connecting rods have been tested on the alignment device, as will be explained farther on. The engine is then returned to the machine; mounted on the same base (I) (Fig. 13), which permits the pistons to pass cylinder head block slightly. The operation is then the same as the burning-in operation on the main bearings just explained.

It is well to relieve the tension on the main bearing caps slightly while burning-in the connecting-rod bearings. When burning-in the connecting rods, it is important that, though the pistons and cylinders and main bearings are flooded with oil, the connecting-rod bearings should be kept dry until the running-in in oil process is reached. Should they get even a few drops of oil, they will remain tight and not burn.

Test with the hand wheel (B) to see if the work is completed, and when the hand wheel (B) can be turned over freely by hand, the connecting-rod cap is removed, the oil groove is scraped out, and the job is reassembled.

The engine is now ready for running-in in oil, or burnishing. The main bearing caps are tightened.

Running-in in Oil or Burnishing, Main and Connecting-Rod Bearings

The engine is returned to the machine in an upright position, and instead of base (I) being used, the upper half of the crank case is bolted to the oil sump on the machine at (M). The oil sump is filled with oil to the oil level (Fig. 14).

The engine is run at 550 r.p.m. until it is limbered up to the extent that it is possible to turn over the crank shaft by the hand wheel.

After this operation is completed, the engine is ready for complete assembly and for adjusting, testing, and inspection, before installing it in the car.

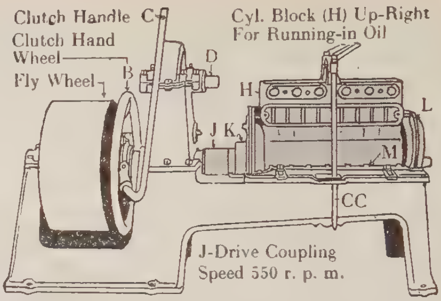

Clutch Handle C
Clutch Hand Wheel
B
Fly Wheel
D
Cyl. Block (H) Up-Right For Running-in Oil
H
L
J K
M
CC
J-Drive Coupling Speed 550 r. p. m.

Fig. 14. Fairbanks burning-in machine being used for **running-in the engine bearings in oil.** The main and connecting-rod bearings, and the piston and piston rings are also run-in. Note that the lower coupling (J), which turns the crank shaft at 550 r.p.m. is used in this instance.

Testing, Adjusting, and Inspecting Engine on Machine

The next operation is to **test the engine under its own power on the machine,** as illustrated in Fig. 15.

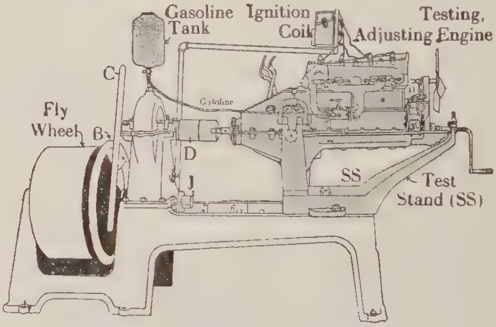


Fig. 15. Fairbanks machine being used for **testing, adjusting and inspecting engine under its own power,** before installing in car. Note that the stand (SS) has been attached to the machine for this purpose.

After the engine has been completely assembled, it is then connected to the machine with the fixture (SS), as shown in Fig. 15; it is then connected with the gasoline tank, which is furnished with the stand. The ignition system is then connected with the battery, and hose connections may be made for running water through the cylinder blocks for cooling. The exhaust should be piped out-of-doors to eliminate fumes.

After the engine is ready for this operation on the machine, the clutch (C) is thrown in and the engine is run until it starts under its own power. The machine is then shut off and the transmission of the engine is set at neutral point and the engine is run until freed up to the point of being able to crank easily by hand.

After all adjustments for oil leaks, ignition, valves, etc., are made, the engine is ready to be placed in the car. It is far better to exercise the several tests described, rather than to have to tear it out again for some trivial reason which could not be detected until the engine had been replaced.

As previously stated, the Ford crank-shaft bearing pins are 1.250″ in diameter. When the aligning reamer is run through the bearings, they are reamed to 1.249″ in diameter. When the burning-in operation is completed, the final clearance will be changed from 1.249″ in diameter to about 1.252″ in diameter, thus giving a clearance between the bearings and crank-shaft pins of about .002″, or approximately the amount which was melted down in the burning-in process. Thus a clearance is gained for the film of oil which is necessary to lubricate the bearings.

A Home-Made Running-in Machine

A very good home-made outfit can be made by using an old transmission to take the place of the clutch. The three forward speeds can be used to give different ratios of speed.

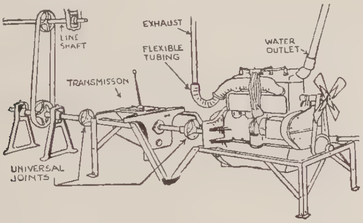


Fig. 16. Home-made running-in machine.

The outfit is shown in Fig. 16. The frame is constructed of heavy structural steel, riveted and welded together as shown. Universal joints of the flexible type are used. Two line-shaft hangers are bolted to the floor to serve as bearings for the driven pulley and shaft. The shop line-shaft is used to drive the device, and pulleys can be fitted to give the necessary speed of about 400 r.p.m.

The engine can be tested on the same stand, and if there is not too much line-shafting connected to the drive pulley, the engine can drive the shop machinery so as to assist further in testing it out under load.

Another simple method for running-in an engine after it is overhauled is to connect the front end of the crank shaft to a shaft driven by belt from the line-shafting. This coupling may be of the starter-crank type.

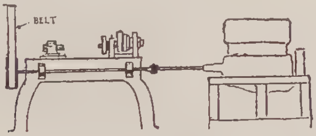


Fig. 17. Simple method for running-in an engine.

The engine should be supported on a low stand and the driving shaft should be provided with a universal joint. The shaft is mounted by bolting it to the legs of a lathe or planer, as illustrated (Fig. 17), and the shaft is driven directly from a pulley on the line-shafting.

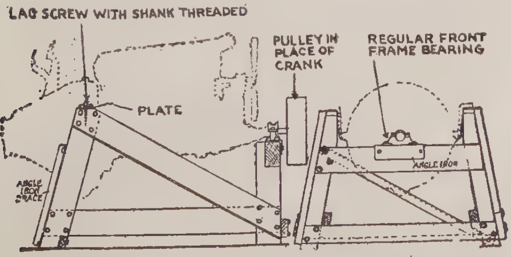


Fig. 18. Home-made Ford engine stand.

Another method for running-in a Ford engine is to construct an engine stand of heavy wood (Fig. 18). A regular front bearing-bracket of the Ford is attached to the stand to form the support for the front end.

Boring, Reaming, and Running-in Main Bearings (4)

In order to fit main bearings properly on a Ford without using the burning-in process, the K. R. Wilson method may be used to advantage.

Mr. Wilson has spent considerable time in research on this particular subject, and in doing so, has developed a combination machine that is well adapted for shops doing Ford work.

If we expect the same results from a rebuilt engine as we do from a new one, the following are essential: (1) new bearings and wearing surfaces; (2) perfect mechanical alignment. To make it possible to do this work quickly and accurately the appropriate machine tool equipment is necessary.

The K. R. Wilson process consists of boring out and then align-reaming the bearings to .001″ larger than the diameter of the crank shaft.

The fallacy of tight bearings: The common mistake of most mechanics is their desire to see a bearing "spot-in" all over even though it shall be so tight that it cannot be turned without a long lever. That idea is wrong owing to two considerations:

1. Expansion which results from the heating up of the motor after it is started.
2. Clearance must be allowed for the oil film.

A tight bearing means metal-to-metal contact. This, in turn, means that there is no room for oil, and the resulting friction will cause the bearing to wear until a .002½″ to .003″ clearance is created.

To prove this, fit up a set of bearings tightly by any known process, whether hand scraping, burning-in, or reaming. Put the motor in a car and run 200 miles. Pull the motor down for inspection; remove any bearing cap; lay a .003″ feeler-gauge on the crank shaft; replace the bearing cap, and tighten it down to its original position. Then see how easily you can turn the shaft by hand by grasping at the crank pins, without any increased leverage. The result proves that the time spent in trying to get a tight, perfect fit was wasted.

Procedure: We will first consider the method of fitting bearings to a new crank shaft. The case of a worn crank shaft will be taken up later.

Re-babbitting: The old babbitt is impregnated with grit and metal particles—so-called abrasives—and if "just tightened up," as in ordinary practice, will soon cut themselves out again and become loose. Therefore the bearings should be ruffed up with emery cloth and re-babbitted as shown in Fig. 19. The same treatment should be applied to the bearing caps if old ones are used. However, it is better always to buy new caps.

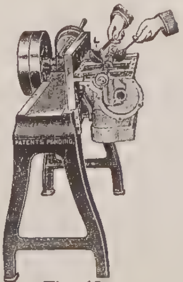


Fig. 19

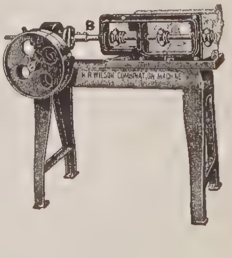


Fig. 20

Fig. 19. The Wilson combination machine being used to babbitt the upper main bearings on a Ford engine.

Fig. 20. The same machine boring out the babbitted main bearings, with caps in position.

Babbitt contains 86 per cent tin, 7 per cent copper, and 7 per cent antimony. The metal is usually heated to at least 800°, while the tin melts at a very low temperature of 450°. It will start to oxidize and to form a dross on top of the metal: a great many repair men think this is dirt, but it is tin. Consequently, each time you skim it, you are reducing the percentage of tin, and the babbitt becomes harder and harder.

Boring the bearings: After babbitting, place your bearing caps in position, bolt down tight, and bore them out **together with the upper half of the bearings.** This operation insures perfect alignment and correct cam-shaft gear centers. The boring is done with three fly cutters, as shown in Fig. 20.

The object of this operation is to prepare the bearings for align-reaming. To do this, the fly cutters are adjusted to bore the bearings so that they will fit the pilots of the reamer.

The main thing to remember in this operation is that the bearings should be bored so that with the pilots of the **main bearing reamer** in the bearings, and the caps on and pulled down, you should be able to turn the reamer by hand. It is also important that they be not too loose. The correct size is 1.244″.

Align-reaming: The boring of the fly cutters is dependent on the hardness of the babbitt. We have already seen that we change this hardness by skimming; therefore we cannot depend on fly cutters for accuracy.

It is therefore necessary to provide **some other means for properly finishing the bearings and bearing caps after they have been rough bored.** To do this a power-operated **aligning reamer** .001″ larger than the crank-shaft bearings is used (Fig. 21). The Ford crank shaft is 1.248″; the reamer is 1.249″. It is equipped with pilots ahead of each cutter.

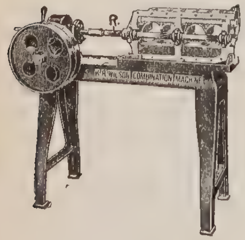


Fig. 21

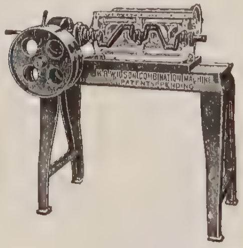


Fig. 22

Fig. 21. Alignment of bearings by reaming the bearings with caps in position.

Fig. 22. Running-in the bearings with the crank shaft in place.

Place the reamer in position; replace the bearing caps that automatically line themselves up; then **align-ream.**

When the reamer is removed and the fillets on all three bearings are touched up with a hand scraper, and the crank shaft is placed in position, draw down the caps tight, and you will have a perfect mechanical fit, .001″ larger than the crank shaft. One reason for running in the extra .001½″ required for an oil film, instead of reaming it, is to permit the bearing to conform to the shape and alignment of the crank shaft. The fit is snug, but not tight. **You should be able to turn the crank shaft with your two hands** without the aid of increased leverage.

In connection with the use of this reamer, it is well to remember that it should be kept well oiled because it will produce much better jobs and the life of the reamer will be increased.

Another point to bear in mind is that the maximum cut which can be made with a reamer is approximately .007″.

Running-in: The reaming process gave us a clearance of .001″; this is not sufficient. Oil the crank shaft (castor oil is preferable). Then the engine should be "run-in" with the Wilson machine (Fig. 22).

A half hour's running-in at normal speed creates the proper oil clearance, but does not destroy the babbitt or spring the crank shaft. With 20 to 1 worm gear and 3½ to 1 belt reduction, the total ratio is 70, and the machine may be driven with a 1 h.p. motor or a line shaft.

Worn crank shaft: In the case of a worn crank shaft, the very first thing to do is to take your micrometer to determine the exact size of the front crank-pin bearing. If you find it worn more than .006″ under size (or 1.242″), it is a good plan to measure at points 90° apart, and if you find it out of round more than .002½″, you might just as well discard it and save any possible trouble.

If it is not worn more than .006″ on the crank-pin bearing, it will never be worn more than .001″ to .003″ on the main bearing, and usually only around .001″ to .001½″ at the most, as the main bearings do not interfere in proportion to the crank-pin bearings.

Therefore bore out main bearings with your fly-cutter boring bar and jig, and, previous to reaming, **place shims underneath the bearing caps to raise them up equivalent to the amount of undersize of that particular bearing.** Proceed with placing the caps in position and draw them tight, then ream. After they have been reamed, **remove the shims,** replace the crank shaft, and draw the bearing caps down tight. You will then have a mechanical fit similar to that described for a new crank shaft.

Conclusion: Use plenty of good oil on the bearings while they are limbering up. Following this process, after the car is run for 300 to 500 miles, instead of a recurrence of the familiar thump, you will have a quiet motor and can be positive of having perfect, long-lasting bearings.

This operation of boring out the bearings and bearing caps simultaneously (Fig. 20) and then align-reaming (Fig. 21), as stated by Mr. Wilson, is the same method used by the Ford Motor Co. and many other manufacturers of automobile engines in the United States. The fact that their motors built by this process stand up is proof that the process is right in principle. It saves two to three hours over the common practice of boring out the upper half of the main bearing and then "hand-scraping" the caps into position.

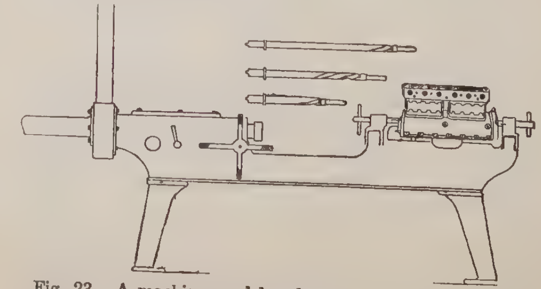


Fig. 23. **A machine used by the Ford Co. for boring and align-reaming bearings with caps in position. The top tool is the boring bar for the front bearing; the center tool is for the center bearing, and the lower tool for the rear bearing.**

A LAPPING COMPOUND FOR BEARINGS

Lapping the main and connecting-rod bearings instead of scraping or burning-in has not been the general practice, owing to the tendency of the hard abrasive to stick to the bearing material and thus to continue to cut the bearing or shaft after the lapping process has been completed.

A compound, known as **"Timesaver,"** can, it is claimed by its manufacturer, be used with perfect safety as it breaks down after it has been in use for a short time. It is composed of large and small crystals, the cutting surface being the large crystal and the small crystal being a neutralizing substance. When the large crystal has been worn down so that the short crystals are in contact with the rubbing surfaces, these are broken up and, owing to their neutralizing action, destroy the cutting qualities of the entire compound. This action generally requires about 10 min.

This product does not contain any form of emery, carborundum, or glass. It is stated that an 80 or 90 per cent bearing can be secured with it in about one-fourth of the time required to scrape the usual bearing. "Timesaver" is soluble in oil, or it can be removed with gasoline or distillate after the lapping operation is completed. It cannot be used for grinding valves, or lapping in pistons and rings, as it does not work on iron or steel.

The method of using this compound is to bore or cast the solid bearings or bushings to a light driving fit on the shaft and grind in with "Timesaver." This is applied very thinly and with plenty of oil. It is ground or lapped with a twisting and turning motion as of a coarse screw or thread. After a few twists have been given, the shaft is cleaned and fresh compound is applied.

A number of other methods can be utilized. Fig. 24 shows the car with the engine in place and the bottom half of the crank case removed. The connecting rods being fitted to the crank shaft are in the reverse position, that is, hanging down.

One shim is removed and the connecting rod is bolted up, just snug, with bearing compound and oil in the bearing, and is rocked back and forth a few minutes, tightening the nuts as the babbitt grinds out. If one application does not produce the desired surface, repeat the operation. A few minutes will generally produce the desired results.

All connecting-rod bearings can be fitted with the engine in one place, at one time, by removing the caps, taking out one shim, applying the bearing compound. Then assemble snug but not tight, rotate the engine by hand, by outside applied power, or by its own power at low speed for about two or three minutes. This will usually finish a set of old bearings, but possibly two or three applications will be necessary on new bearings.

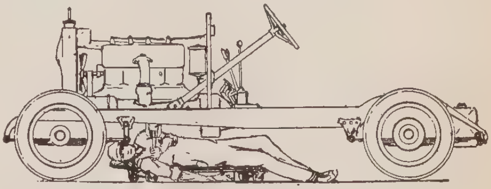


Fig. 24. Showing how the connecting-rod bearings of an engine can be lapped with the "Timesaver" compound.

The main bearings can be treated in a similar manner, and the engine crank case can be inverted and placed on a stand or block. A very good makeshift to turn the crank shaft over in its bearings is to drop the cone belt from the drill press and to use it to drive the crank shaft, using the foot clutch to start and stop the power.

It is claimed that bearings produced in this manner do not have to be assembled as tightly as a scraped bearing, as there are no high spots to wear off and the bearing, if properly done, is a finished job. This product is being marketed by the M. T. K. Products Co., of Seattle, Wash.

Another lapping compound is known as **"Kwik-ak-Shun,"** sold by Edward A. Cassidy Co., 23 W. 43 St., New York. It will eliminate scraping and works with bronze, babbitt, or brass.

The Clover Mfg. Co., Norwalk, Conn., also manufactures grinding compounds.

CRANK-SHAFT INSPECTION AND REPAIR

Before the main bearings, or the connecting-rod bearings are fitted, the crank shaft should be inspected. Some of the **disalignments of crank shafts** can be enumerated as follows:

1. Crank-pin bearings scored or cut.
2. Crank-pin bearings worn oval or flat.
3. Crank shaft bent.
4. Crank-shaft throws out of line with each other; that is, those throws which are supposed to be in line.

Scored Crank Pin

If the crank-pin bearing is **scored or cut** by ridges or rings on it (Fig. 25), it will cut the bearing, causing it to run hot and thus ruin the bearing. Fitting of bearings under such conditions will be a waste of time.

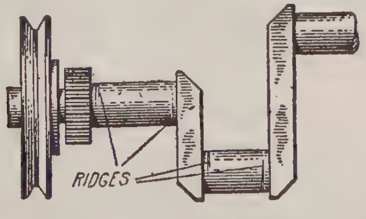


Fig. 25. Scored crank-shaft bearing pin. Note the ridges. This is only a slight score.

Where the crank pin is only slightly scored, the deep ridges or high spots can be removed with a fine Swiss file, and the rough surfaces can be polished off by encircling the shaft with fine emery cloth saturated in oil and making a steady, even motion up and down, as shown in Fig. 26, before lapping.

The strips of emery cloth should be about 1½" wide and well oiled. Emery tape is better, if obtainable. Unless the method shown in Fig. 26 is used, there would be a tendency to make the shaft oval.

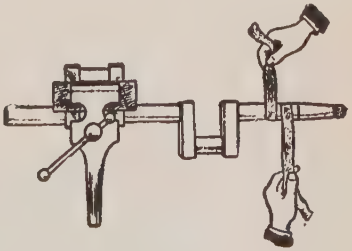


Fig. 26. Cleaning roughened surfaces of crank-shaft bearing pins with emery strips.

Another method is to lap the crank-shaft bearing pin, using a lapping compound and specially made clamps.

Lapping a Crank-shaft Pin

Lapping: Figs. 27, 28 show a form of hand lapper. This consists of a pair of hinged members with a

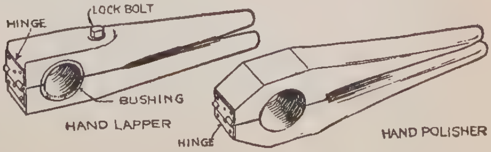


Fig. 27 Fig. 28

Figs. 27, 28. Form of hand-lapping device for crank-shaft pins.

central hole large enough to admit various-sized bushings to conform to the various sizes of shafts. A bolt is provided to hold the two halves together, and the flanges on the bushing prevent the bushing from slipping out the side of the frame.

The lapping is done by applying a fine emery grinding compound[1] and oil to the pin, and clamping the lapping tool to the work. The long handles serve as a lever for the work.

The pins are polished in practically the same way by a pair of long wooden clamps (Fig. 28) constructed on somewhat the same principle as the lapping tool.

The throws on the crank shaft can be lapped in the lathe by setting up the shaft between two centers for the main bearings, and with the use of a special flange for the connecting rod pins. It consists of a special fixture made from a large casting with a base to fasten to the face plate and a long extension arm having a split end for attaching and detaching to encircle the throw to be lapped. (*Motor Age*, by Mr. T. P. Bowman.)

If a crank shaft is badly scored, it will be necessary to put it in a lathe and true it up, or send it to a concern that has special crank-shaft grinding machines.

Crank Pin Worn Oval or Flat

If a crank pin is found out of true, that is, is not circular, by testing with micrometer calipers, and is more than .0015″ out of round, the best plan is to have it trued up on a lathe or ground true on a special grinding machine by a concern that specializes on this work.

If a crank shaft is worn more than .010″, it is usually discarded.

Where a crank pin is only slightly worn out of true and a grinding machine is not available, then file up the untrue part with a fine Swiss file to as accurately a circular shape as possible, testing frequently with the micrometer calipers. The crank pin is then lapped, as previously explained.

The cause of a crank-pin being out of true (where the lower part of the connecting rod fits) is often attributable to a flat spot, due to explosion pressure occurring constantly at one point. The result of this is that the connecting-rod bearing will not fit true and will bind, even though properly fitted. The only remedy is to have the crank shaft ground on a special crank-shaft grinding machine. (H. & H. Machine Co., St. Louis, Mo., grinds crank shafts.)

If a crank shaft (or a cam shaft) is out of true, it will cause the bearings to wear out of round in a very short time and create a knock; therefore, before assembling the crank shaft (or cam shaft) in an engine, they should be tested for concentricity. A machine especially adapted for this purpose is shown in Fig. 29.

To test a crank shaft (or any other shaft) for concentricity, the shaft is placed in the adjustable center posts (**CP**). The needle of the dial indicator is permitted to touch the crank shaft lightly (as at **B**) at various points, while the crank shaft is slowly turned by hand.

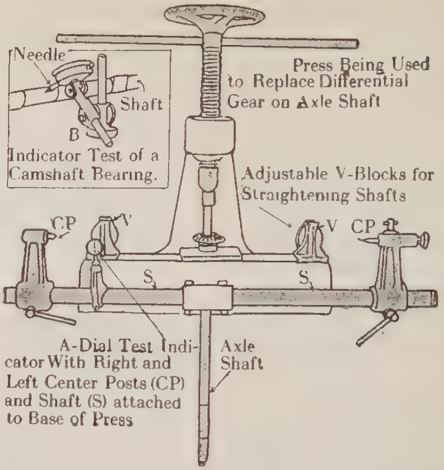

Needle
Shaft
B
Indicator Test of a Camshaft Bearing.
Press Being Used to Replace Differential Gear on Axle Shaft
Adjustable V-Blocks for Straightening Shafts
CP
V
V
CP
S
S
A-Dial Test Indicator With Right and Left Center Posts (CP) and Shaft (S) attached to Base of Press
Axle Shaft

Fig. 29. **Fairbanks Universal shaft-testing and straightening device** and arbor press in one unit. (**A**) shows the dial indicator on shaft (**S**); (**B**) gives an idea how the needle point of the dial indicator is used to test the concentricity of a shaft. The arbor press is shown in use.

The **dial indicator** will measure from zero to one quarter of an inch, and will indicate it in half-thousandths.

The centers (**CP**), may also be used for testing the concentricity of armature shafts on starting motors, generators, etc.

This device is also used for pressing bushings and shafts out of gears, for straightening axles and propeller shafts, etc.

The concentricity of the crank-shaft main bearing pins could be tested as shown in (**B**) on the machine shown in Fig. 29, but the test of the connecting-rod bearing pins on the crank shaft, which are eccentric to the main bearing pins, would necessitate special dogs or jigs for holding it.

If a shaft is found out of true, it is put in the "V" blocks (**V**) (Fig. 29), under the press screw and straightened, then tested again in centers (**CP**) with the dial indicator.

Crank Shaft Bent; Alignment of

A crank shaft may be as much as .020″ out of alignment, yet, notwithstanding, if the three main bearings are perfectly true and straight, after a few revolutions of the crank shaft in the bearings, they will pull the crank shaft within .002″. But of course, this is hard on the bearings. Where a crank shaft is bent, it should be straightened on a straightening press. For instance, it may be placed in the centers (**CP**) (Fig. 29) and the press used on it. Another shaft-straightening press is shown in Fig. 30.

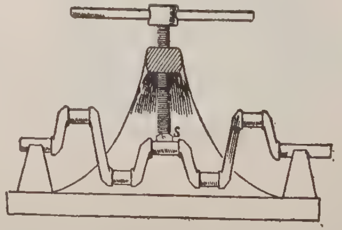


Fig. 30. **A shaft-straightening press.** Care should be taken not to apply too much pressure in the first attempt to straighten the shaft, as it may be bent in the opposite direction. A new test should be made after each attempt of straightening.

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[1] The Clover Mfg. Co., Norwalk, Conn., supplies lapping compound for this purpose.

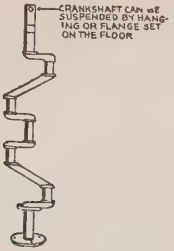

CRANKSHAFT CAN BE SUSPENDED BY HANGING OR FLANGE SET ON THE FLOOR

Fig. 31. When **storing crank shafts** it is advisable either to suspend them as shown, or to set the flange on the floor so that the crank will be straight. It is not generally known that a crank shaft will sag out of line when allowed to lean against the wall, but such is the case. Crank shafts have sagged as much as .002″ or more in this way.

Simple Method of Testing Crank Pin

The crank case may be used with little difficulty as a fixture for testing the alignment of the main bearings of the crank shaft. The case is placed on the bench in the position shown; a strip of pasteboard about 1 in. wide and 1/64 in. thick is placed beneath the front and rear bearings of the crank shaft. By these the shaft is raised from the center bearing and side play is prevented.

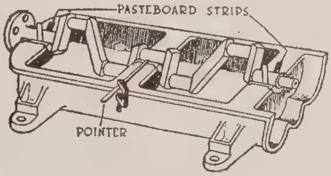


Fig. 32

A pointer is then clamped on to the side of the case at the center bearing, and by turning the shaft the amount it is out of true is determined. This method is not only better but quicker than testing in a lathe.

One Method of Testing for a Loose Bearing

Run the car over a pit, if possible, although the bare floor will do.

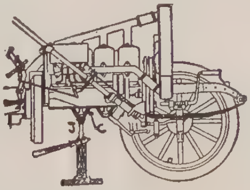


Fig. 33

Raise the car by means of a jack to suit the conditions for testing. If the rod bearings are to be tried, run a jack head against the lower half of the connecting-rod bearing and work the jack handle up and down. The smallest amount of play can be detected in this way, especially on the main bearings, where the pressure of the jack is applied on the crank shaft against the weight of the car and "play." This method is not exactly according to engineering practice, but with a sensitive jack and a sense of "feel," the amount of looseness can be determined to a certain extent.

To test for a bent crank shaft, place it in center blocks, as shown in Fig. 34. A gauge is used or indicator to locate the direction of the bend, if there is any; that is, in relation to the main bearing pins (**MP**), but as the connecting rod pins (CP) are out of line with the main bearing pins, this would require special jigs.

If the shaft is bent, there will be one point of the main bearing pin which will make a contact with the gauge, and as it is revolved the shaft will leave the gauge. This point which makes a contact should be marked with chalk, so that you will know where to apply the pressure to straighten it,

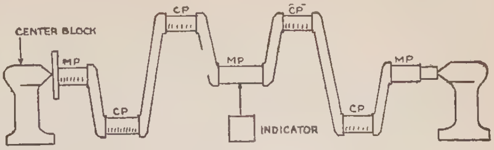


Fig. 34. Method of testing a crank shaft for a bent place. (**MP**) are crank-shaft main bearing pins; (**CP**) are crank-shaft connecting-rod pins.

In testing for a bent crank shaft, one should not be misled by a bearing surface of the shaft that is probably worn out of round; the test should be made at the side of the bearing where little or no wear is liable to take place.

There are few repair men who will undertake to straighten a bent crank shaft, and by many it is claimed to be impossible to make a lasting repair to a shaft which is out of true. However, as the repair man is occasionally called upon to "fix it up," and a straightening press is not at hand, one means employed is shown.

One method of straightening a slightly bent crank shaft is shown. This shaft is bent as indicated by the dotted line (**A**) (Fig. 36), only to a very much less extent, the bend not being visible to the naked eye except when the shaft is revolving in a lathe with a tool or other object held stationary, close to the center bearing surface or crank pin.

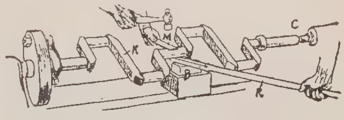


Fig. 35

The shaft (**K**) (Fig. 35) is fixed between the centers (**C**) of the lathe, blocks (**B**) are placed upon the lathe-bed for a fulcrum, and a bar of iron (**R**) or preferably of wood, is used as a lever. If an iron bar is employed, a piece of brass, wood, or lead should be placed between it and the bearing surface of the shaft for protection.

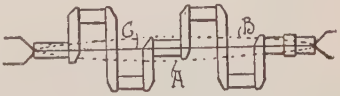


Fig. 36. Bent crank shaft.

Assuming that the shaft is bent as indicated by the dotted line (**A**) (Fig. 36), it is pried up with the bar till it assumes the position indicated by the dotted line (**B**), and while held in this position, an assistant holding a piece of brass (**M**) on the bearing surface with one hand, and with a hammer in the other, strikes the shaft a sharp light blow.

The bar and blocks are then removed, the lathe started, and the shaft tested again for results. This treatment is repeated again and again until the shaft is straight as indicated by the line (**C**). It is generally a long and tedious job, depending greatly upon chance and the ability of the operator of the bar to guess the proper amount of pressure to apply and the proper place at which to apply it.

Crank-Shaft Throws Out of Line

The crank-shaft "throws" are the parts (CP) to (MP). On a four-cylinder engine, the four throws (CP) should be in exactly the same plane or line. When out of line the crank shaft is sprung or twisted.

Such a condition will cause vibration, and may also throw the timing and the firing impulses out of line. In such a case, the valve events and spark would not occur in the correct relation to the piston positions.

One method of checking would be to learn the position in inches in which the piston is supposed to be from the top of the cylinder at the time of the opening and closing points of the valves and to see if it checks properly. On the Ford, these positions are shown on an illustration referring to valve timing. See Index.

CAM SHAFT ADJUSTMENTS

The cam shaft on some engines is a case-hardened drop forging of low carbon steel. It is usually mounted in die-cast bearing bushings.

The usual troubles are worn bushings which produce knocks and end play, and it thus often becomes necessary to replace the bushings.

If the front cam-shaft bearing has worked loose in its bearing, or is worn, the timing gears would be noisy.

If the wear is not too great, the bearing can be tightened by means of an adjustment screw which is provided on some engines, or by removing and copper plating the bearing to compensate for the wear, or by replacing the bearing bushings.

On the Continental engine (see Index) the end thrust, or end play is taken up by regulating an adjusting screw in the timing-gear case cover.

To replace cam-shaft bushings: First, it will be necessary to remove the radiator, then the gear-case cover. Be sure to note the marks on the gears, and if they are not marked, be sure to mark them. Remove the cam gear; remove oil pan; remove the springs and valves; remove the cam shaft, and also remove the carburetor assembly. Put in new bushings and ream them to a fit.

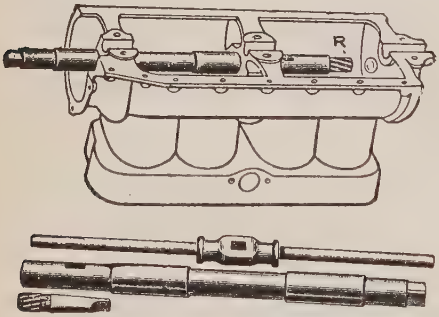


Fig. 37. A cam-shaft aligning reamer.

To prevent cam-shaft knocking, the rear cam-shaft bearings should be reamed in **perfect alignment** with the front and center bearings. An ordinary reamer is useless because the bushing is driven in and usually battered. A good form of cam-shaft reamer is shown in Fig. 37. It is manufactured by K. R. Wilson, Buffalo, N.Y. After the cam shaft is in place and the gears in position, check the valve timing.

If a cam shaft is sprung, it is necessary to remove and straighten it or to replace it with a new shaft.

On the Ford, the front and center cam-shaft bearings are held in place by set screws located in the right hand side of the cylinder-block in line with the cam shaft. The set screws should be removed from the cylinder in order to insure clearance for the cam shaft. The cam shaft is then withdrawn by means of a cam-shaft puller.

The front and center bearings are of the split-bearing type. They are held to the shaft by means of circular springs. These springs are removed by inserting a screwdriver under them, and forcing them off. The cam shaft may then be tried on the centers as shown in Fig. 29 at (B), page 792.

The cam shaft should not run out any more than .0015″. If bent, straighten it on the straightening press.

It is not good practice to remove cam-shaft gear from the cam shaft unless absolutely necessary. If it must be removed, the best plan is to remove the cam shaft and gear to an arbor press and to press the gear off.

Removing a Cam Shaft

(Dodge as an Example)

To remove the cam shaft, the radiator must be taken off and then the front gear-case cover. The cam shaft may then be pulled out after the valve push-rods are tied up, so as not to catch the cams as they slide by, and after the cam-shaft retaining pin (which will be found on the right side of the motor directly back of the ignition unit) has been removed. This pin fits in a deep groove in the center journal. In the first 40,000 or 50,000 cars the pin was held in place by a set screw, but the newer cars have a spring.

Oldsmobile (Model 45B) Cam-Shaft Bearings and Cam Shaft

Cam-shaft bearings: Several thousandths of an inch is left in the bearings which must be removed from the bore of cam-shaft bearings. It is advisable to leave a few thousandths for final reaming. They should be line-reamed when in place.

Cam-shaft bearing adjustments: It is rarely the case that the cam-shaft bearings require attention, because they are exceptionally large. The following is a method to determine **whether this attention is necessary.**

At idling speeds, play in the front bearing, or end play in the cam shaft, causes a dull rumbling noise which may be relieved by pressing against the vertical distributor-drive shaft with a screwdriver. This transmits pressure to the distributor-shaft drive gear and cam shaft, and temporarily removes the looseness causing the noise.

To replace the front cam-shaft bearings proceed as follows:

1. Remove the radiator, fan belt, and hose connection from the water pump to the cylinder blocks.

2. Loosen the retaining clip on the lower edge of the distributor-drive shaft and withdraw the splined shaft and gear from mesh with the cam shaft.

3. Remove the two front engine bolts and jack up the front of the engine about 3 inches.

4. Remove the cap screws from the gear housing, and remove the housing complete.

5. The cam-shaft gear may be removed by means of a special gear puller attached to two tapped holes in the face of the cam-shaft gear.

6. The cam-shaft bearing is thereby exposed to view. It is held in place by an offset lug and retaining screw, removal of which will allow the entire bearing to be extracted.

The new bearings provided are full in length, and may be filed on the end until of a length that permits no end play in the cam shaft. With the new bearing in position the cam shaft should be pulled forward so that its forward shoulder is firmly pressed against the inner end of the bearing, and the outer end should be level with the shoulder against which the cam-shaft gear locks. It should be understood that these cam-shaft bearings are not adjustable, and when looseness occurs, new bearings should be installed and fitted in the manner described above.

If it is desired to remove the cam shaft for examination, this may be done very easily. To do this proceed as follows:

1. Remove the push-rod assemblies carrying the push rods that rest on the cam shaft. These assemblies are located by dowels and bolted in position, hence are easily removable.

2. Draw the cam shaft out through the front, complete with the front bearing.

In assembling, one point is to be observed to obtain correct timing, and that is to crank the engine over until No. 1 piston is at the top of the compression stroke. In this position the fly-wheel marking will be 1-4 U-D-C, and the prick-punch mark on the crank-shaft gear will be at the top. Then if the cam-shaft gear markings be made to coincide with the crank-shaft markings, the valve timing will be correct.

Timing gears-45-B: These gears are matched up in sets to give a clearance of .008″ between the cam and crank gear when fitted, and will have slightly less clearance than this after some use.

These gears are marked "O" for standard, "1-L" for .001″ large, and "1-U" for .001″ undersize. The letters "L" and "U" always appear, but the figure will depend on the number of thousandths of an inch that the gear is over or undersize.

Questions and Answers on Crank- and Cam Shafts

The following questions pertain to the Continental engine (see Index), but are applicable to many other engines:

Question 1: How can the end thrust or end play be taken up on the crank shaft?

Answer: The end thrust of the crank shaft is taken against the front bearing. To adjust this end thrust shims are provided between the crank-shaft gear and the thrust surface of the crank-shaft front bearing. End play is taken up by removing one or more of these shims.

Question 2: How can the end thrust or end play be taken up on the cam shaft and timing gears?

Answer: End thrust is taken up by regulating the adjusting screws in the timing-gear case cover. These adjustments should not be disturbed unless it is plainly evident that they demand attention. To check the end thrust, release the lock nut and turn the screw in until it touches against the end of the shaft. When this contact is felt, the screw should be backed off one turn and the lock nut re-tightened.

Question 3. Can the piston and connecting rod be taken out from below without removing the crank shaft, and is that the best plan?

Answer: Piston and connecting rod assemblies can be removed from below without disturbing the crank shaft. This is decidedly the best arrangement. Not only can the pistons be pulled, but every bearing of a Continental engine can be got at readily by removing the oil pan. Engines are assembled and inspected in this manner during the process of manufacture in the Continental factories.

CONNECTING-ROD AND PISTON-PIN BEARINGS

There are two types of connecting rods in general use, as follows: (1) the connecting rod using a **stationary** piston pin (Fig. 38); (2) the connecting rod using an **oscillating** piston pin (Fig. 39).

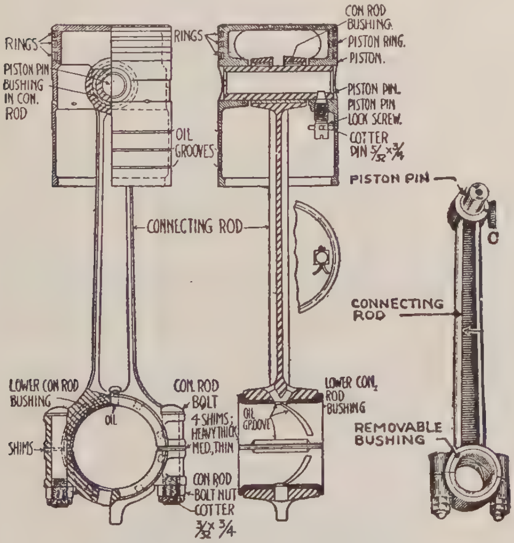


Fig. 38

Fig. 39

Connecting rods are usually made of I-section drop forgings of nickel steel. Bearings are usually die cast of special metal. Bearing-cap studs are nickel steel.

Connecting-Rod Upper End

The piston pin or wrist pin is the pin on which the upper part of the connecting rod swings. It is sometimes made of solid steel, but usually of hollow case-hardened steel tubing. It is also called a "gudgeon" pin. It is non-adjustable, and therefore, when worn, the piston pin or bushings must be renewed.

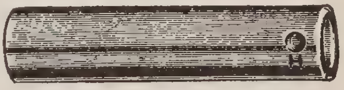


Fig. 40. Piston pin showing hole (H) where the lock screw (Fig. 38) holds the pin stationary.

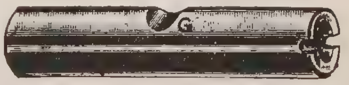


Fig. 41. Piston pin showing groove (G) where clamping bolt (C) (Fig. 39) is clamped tight to the piston pin.

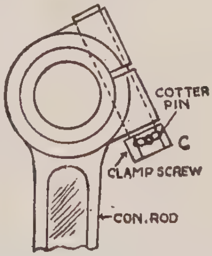


Fig. 42. Showing clamping screw which clamps the connecting rod to the piston pin. Oil holes are provided in the pins to lubricate the pin and bushing.

The stationary piston pin (Figs. 38 and 40) is used where there is one bronze bushing in the end of the connecting rod, which oscillates on the piston pin. The pin is held tight by a set screw at hole (H) (Fig. 40).

The oscillating piston pin (Figs. 39 and 41) is where the piston pin is clamped to the upper end of the connecting rod, as shown in (C) (Fig. 39) and more clearly shown in Fig. 42. The bronze bushings in this instance are pressed into bosses in the piston, and the piston pin oscillates in the bronze bushings.

The first bearings of an engine to manifest the effect of wear, in normal service, are the connecting-rod bearings. They are next to the piston and rings in importance.

Connecting-Rod Bearing Knocks

A method for determining a loose connecting rod is explained and illustrated in the *American Automobile Digest* as follows:

"After continued use they become worn, producing a dull thud or pound, especially noticeable when the engine is suddenly accelerated or speeded up. This is due to the fact that the bearing becomes elongated, as shown in Fig. 43, since the pressure is in one direction only. For this reason the knock is dull and is usually worse when the engine is idling.

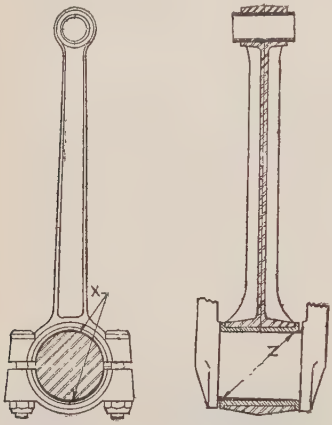


Fig. 43. This illustrates how the crank-pin bearing wears. At (X) is shown natural wear, while at (Z) is shown the wear caused by a bent or twisted rod.

"The best method of **locating a worn connecting-rod bearing** which has started to knock is by short-circuiting the spark plug, when two knocks will be noticeable, since the explosion pressure is eliminated. In addition to being caused by a worn bearing, the knock can also be caused by a twisted connecting rod, scored bearing, burned out bearing, or end play. In the case of a seized bearing or one that has been burned out, due to a lack of oil, the motor will also groan when starting cold.

"**A worn piston-pin bearing** can easily be distinguished by a sharp metallic knock occurring twice when the spark plug is short circuited. The knock will appear regularly, and is very sharp when the engine is pulling hard."

Removing Pistons and Connecting Rods from Engine

It is necessary to remove the pistons when working on the wrist pin.

The method of removing the piston (Overland, for example) is to take off the bottom half of the crank case and then remove the connecting-rod bearing cap from the rod attached to the cylinder which it is desired to remove. The bearing cap is held by two bolts fastened by castellated nuts. When these are removed the rod can be swung to one side out of the way of the crank shaft and the entire assembly can be withdrawn from the cylinder in the manner illustrated (Fig. 44). The piston pin can then be driven out with a punch, after which the bushing can be removed.

This method cannot be applied to all engines. Such work as this is usually done by removing the engine from the frame, and when engine is disassembled.

Be sure to mark all parts when removing them, so that they can be assembled in their respective locations, as before disassembling.

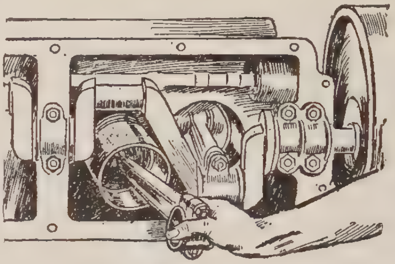


Fig. 44. Method of withdrawing piston and connecting-rod assembly after the bottom half of the crank case has been removed.

Removing Piston Pins and Bushings

To remove the piston pin of the stationary type, the cotter pin and lock screw (Fig. 38) is removed with a cotter-pin puller and a special socket wrench which will fit into the space.

The piston pin is then pressed out, which is not always an easy task. One method of removing a piston pin is shown in Fig. 45, and can be resorted to if the piston pin is hollow, so that the shaft can be run through it.

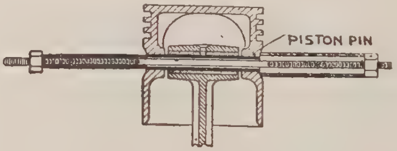


Fig. 45. **For removing piston pin or bushings,** a rod is turned to slide freely through the bushing and is then threaded S.A.E. standard. The pulling bushing is made slightly smaller than the hole in the piston.

To remove a piston pin of the oscillating type, loosen the lock screw (C) (Fig. 42) with a special wrench; then press the piston pin out of piston bushings.

Sometimes a tight piston pin can be more readily removed by plunging the piston in boiling water. This will tend to loosen the grip of the piston on the pin and will then permit it to slide out.

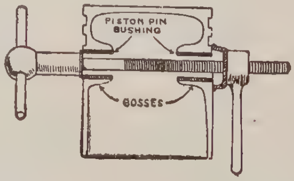


Fig. 46. Method of removing the two bushings from the piston bosses where the piston pin oscillates.

For removing the two bushings from the piston where an oscillating piston pin is used, refer to Fig. 46.

For removing the one bushing from a connecting rod (upper end), where the stationary piston pin is used, see Figs. 47, 48, 49.

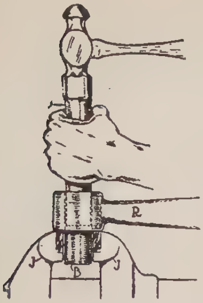
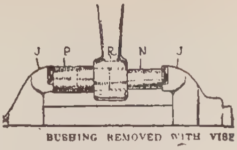


Fig. 47



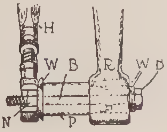


Fig. 48 (upper)

Fig. 49 (lower)

Fig. 47. **One common way to remove an upper connecting-rod bushing.** Jaws (J) of the vise are opened far enough so that the end of rod (R) rests upon them and at the same time gives sufficient clearance for the bushing to pass between, as it is driven out. To drive out bushing (B), a drift (D) (usually a bar of steel) and a hammer are required.

Fig. 48. **A better way:** Jaws (J) of the vise are opened wide; a piece of pipe (P), large enough to clear the bushing, is placed against the inner surface of one jaw; the rod is carefully adjusted and pressed against it to hold it in place until the drift or solid pin (N) is adjusted into place. Then draw the vise together to squeeze the bushing out of rod (R) into pipe (P). If no vise is at hand with a large enough opening, recourse can be had to the method shown in Fig. 49.

Fig. 49. **Another plan:** A bolt (B), some washers (W), a piece of pipe (P), a nut end, and a wrench (H) may be employed as shown. By this method, a bushing may be removed without danger of springing or burring up the connecting-rod end.

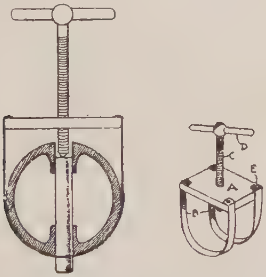


Fig. 50. **A piston-pin remover.** (A) is flat iron tapped to take screw (C). Flat iron bands are attached so that they can be placed around the piston, then the screw is forced against the wrist pin (piston pin).

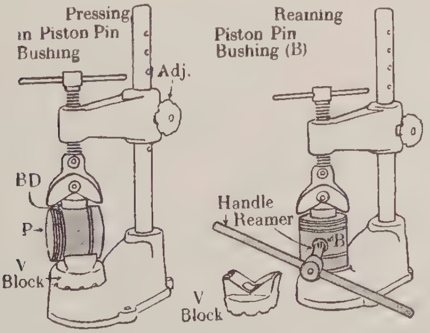

Pressing in Piston Pin Bushing
Adj.
BD
P
V Block
Reaming Piston Pin Bushing (B)
Handle
Reamer
B
V Block

Fig. 51. **Fairbanks Universal piston vise and press,** designed especially for removing piston pins and bushings.

If oversize reaming is necessary for bushings, the same device can be used to hold the piston for the operation. This device will also hold the piston while fitting rings to the piston, or for scraping carbon from the piston, or while the top, or upper part of the connecting rod is being clamped to the piston pin.

This vertical vise can be used for many other jobs, as the "V" jaws have a babbitted lined surface which will not injure the finish of the piston.

Fitting Piston-Pin Bushing[1]

Where the oscillating type of piston pin is used, the bushings are fitted in the piston bosses after the old ones have been driven out. Very often, instead of pressing out the old bushings, they are reamed oversize, and an oversize piston pin, usually .0025″ or .005″ oversize, is substituted.

To check the play between the piston pin and the piston bushings (Ford piston, as an example), hold the piston with the piston pin perpendicular to the bench with the left hand (Fig. 52), while with the right hand the connecting rod is forced up and down in such a way as to cause the pin to be forced against one side of the bushing and then the other. If there is any play, a new pin should be fitted and, if necessary, the piston bushings should be replaced.

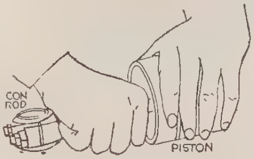


Fig. 52

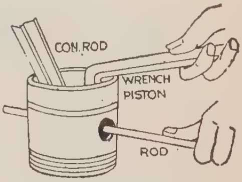


Fig. 53

The pin is removed by running out the connecting-rod clamp screw, after which the pin may be pushed out. Every repair shop should be equipped with a piston clamp, or vise.

If no clamp is available, the piston may be held by means of a rod (Fig. 53) through the piston pin while loosening or tightening the rod. The practice of holding the rod in a vise invariably results in a twisted rod and a scored cylinder.

The piston pin, when properly fitted, will wear very slowly, but when carelessly fitted, it will wear the bushing in a very short time, causing a noisy engine and excessive wear on the crank-shaft bearing.

The piston pins are usually fitted in the bushings by **selective fit.** A pin is tried in the bushing. If it turns freely, another pin is selected until one is found which requires a fair amount of effort to force it in and turn it. Since the piston pin is harder than the bushings, it is usually necessary to renew the bushings to insure a properly fitted pin.

The bushing is removed through the inside of the piston. The piston is then turned over, and the other bushing is forced out in the same manner. When pressing in the new bushings, it is important to have them line up properly with the hole in the piston, as a cocked bushing requires considerably more pressure to force it in, throwing the piston out of round.

The bushing should be pressed in until about 1/16″ of the bushing shows on the inside of the piston, or until it is 1/32″ inside the oustide diameter of the piston. When the bushings are in place, they should be line-reamed to size with a Ford pilot-type reamer "28Z-20," which may be purchased from the nearest branch.

Reaming the piston-pin bushings: If a reamer is used which has no pilot, only one of the bushings should be removed at a time, and the reamer should

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[1] Piston pins, bushings, etc., oversize and standard, can be secured of the H. & H. Machine Co., St. Louis, Mo.

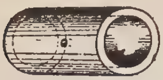

Fig. 54

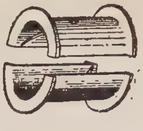

Fig. 55

Fig. 54. Bushings for the upper end of the connecting rod to go in the piston bosses, or in the upper end of the connecting rod if the piston pin is of the stationary type.

Fig. 55. Die-cast removable bushings for the lower end of the connecting rod and cap. Where the bushings are babbitted in the lower end of the connecting rod and in the cap, they are not removable.

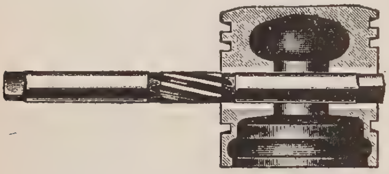

Fig. 56. **A self-aligning piston-bushing reamer with pilots** on each end to insure perfect alignment and a perfect fit the first time through. The spiral is fluted with steel blades. This type of reamer is furnished by K. R. Wilson, Buffalo, N.Y., for Ford, Chevrolet, Oakland, Oldsmobile, or Scripps-Booth cars.

be inserted through the old bushing to act as a guide in reaming the new one. The old bushing is then replaced and the reamer is inserted through the reamed bushing as a guide in reaming this one.

If there is no piston clamp (shown on page 797) available, the reamer should be held in a vise and the piston turned by hand, as shown in Fig. 58.

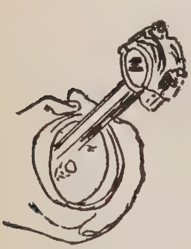

Fig. 57

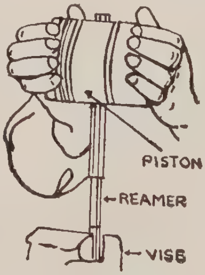

Fig. 58

When the new pin has been fitted, as described, it is removed and oiled. It is well to rub a little oil in the bushings as well. Hold the rod in the piston and force the pin into place. Turn the pin until the groove (G) (Fig. 41) lines up with the connecting-rod clamp-screw hole, and insert the clamp screw.

Run the clamp screw down with a socket wrench; remove the piston from the clamp, and press the rod from one side of the piston to the other to see that the pin does not extend outside the diameter of the piston. If it does, remove the rod and pin and press the bushing on that side in a little farther. If it does not, set the piston in the clamp and tighten down the cap screw with a "3-Z647" Ford wrench, and insert the cotter pin.

To test: The assembly may now be tried by holding the piston as shown in Fig. 57. The rod should hardly be able to turn of its own weight, but should drop gradually as the piston is jarred.

Where the stationary type of piston pin is used, the bushings are not fitted in the piston. The one piston pin bushing is fitted in the upper end of the connecting rod, as shown in Fig. 38, page 795, and the piston pin (Fig. 40, page 795) is held tight in the piston bosses by a set screw.

The same principle of removing, reaming, fitting, etc., to fit the piston pin is employed, as explained in the preceding paragraphs.

The piston pin may also be worn: therefore examine and replace it when renewing the bushings, if worn. As a rule, the wrist pin and connecting-rod bearings are prone to wear sooner than the main bearings.

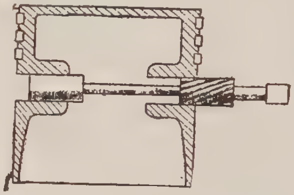

Fig. 59

Another reamer: The reamer is placed at one end of the tool there being a pilot at the other which slips into the opposite piston boss and thus guides the tool. When one boss is reamed the tool is reversed and the other one is done. Since the pilot is smaller than the finished hole, a bushing must be used to guide the pilot in the second half of the job.

Piston Pins

While the standard pins can usually be secured from stock in .003″, .005″, or .010″ oversize, it sometimes is necessary to order special ones. That there may be no confusion in ordering special sizes, be sure to give the oversize above standard, the make of car, model, motor, diameter and length, slot or set-screw hole, width and depth of slot, diameter of set-screw hole, distance from center of set-screw hole to end of pin; and also state if the pin has oil holes or oil grooves.

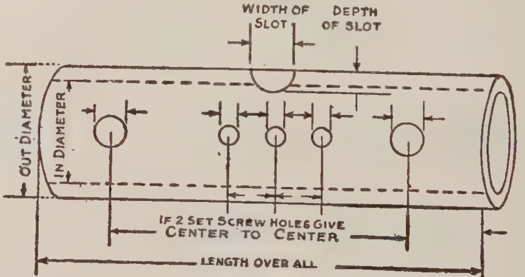

Fig. 60. A handy diagram to copy and fill in what is needed when ordering special piston pins. (By courtesy Heald Machine Co., manufacturer of cylinder grinding machines, Worcester, Mass. Copyrighted.)

Oversize Identifications

The practice of **painting the ends different colors** has been generally adopted by oversize piston-pin manufacturers, in order to identify them, so that they can be readily distinguished from one another. For instance, standard, no color; .003″ oversize, red; .005″ oversize, yellow; .008″ oversize, white.

Fitting Piston Pins

Use an accurate reamer, and be very careful not to remove too much metal. Remember that the clearance between the pin and the bearing should be .0005″ to .001″. A loose-fitting piston-pin with too much clearance will cause a piston-pin knock which will eventually mean that the whole motor will have to be pulled down and new pins inserted.

On the other hand, if it is a ringing fit, it will also cause trouble, because there must be room for a film of oil on the pin. A well-fitted pin will last for years.

Fitting Connecting-Rod Lower End

As in the case of the main bearings, there are caps fitted to the lower part of the crank-shaft bearing pins (see Fig. 38, page 795), which in this instance have removable **die-cast split bushings** in both the connecting-rod bearing above the crank shaft and in the cap below the crank shaft. This is the type generally used, with shims placed between.

On some connecting rods, the lower part of the connecting rod and the bearing cap are **babbitted,** and when the lower part of the rod is worn or burned, a new connecting rod is necessary (on the Ford); a new bearing cap also can be secured.

What has been said concerning the main engine bearings also holds good for the connecting-rod bearings. The two bearing halves may be brought closer together by the removal of some of the "shims" between them, or dressed down with a file, if shims are not provided. It is policy to take off enough metal to allow for a few shims, so that when taking up is again required, it will only be necessary to take out one or two shims.

In the majority of engines the removal of the lower half of the crank case gives access to the connecting rods.

Adjusting Connecting-Rod Lower Bearings

Loose connecting-rod bearings are detected by a kind of metallic sound or knock when the engine is running at idling speed.

To test, in order to determine which rod is loose, a good method is to run the engine at idling speed and to disconnect one spark plug after another. The knock will either cease or will sound as if there are two knocks, when the cylinder is found in which the rod is loose.

After determining that a connecting rod is loose, remove the oil pan. Turn the crank shaft (first remove the spark plugs to relieve the compression) so as to place the rod bearing in a convenient position for inspection. Take hold of the rod and, by a vigorous push up and down, ascertain whether there is end play. If so, the looseness can be felt.

Do not, however, mistake the side play for looseness, as there should be an appreciable amount of **side play.** At the same time, too much, or an excess of side play indicates wear on the sides.

If the bearings are found to be loose, pull the two cotter pins out and remove the nuts. The cap can then be removed.

Next, examine the bearing bushing and see if it is cracked, worn thin, or scored. If so, it will require new bushings and refitting by scraping or burning-in.

Note. It is not always necessary to scrape or burn-in on replacing die-cast bushings. Some repairmen shim them up and then run-in by not tightening too tight, and later on readjust again. It is best, however, to scrape them in to a fit. If new babbitted bearings are fitted, it is necessary.

At the same time that the bushing is being examined, examine also the crank-shaft bearing pin to see if it is scored or cut. If so, it will cut the bearings, and the crank shaft should be removed and the pin dressed down.

If the bearings are only worn and have a clean polished surface otherwise, then remove one layer of shims on each side and try the cap for tightness.

Replace the cap and tighten the nuts and then crank the engine by hand with the spark plugs removed (to relieve the compression), and test for tightness.

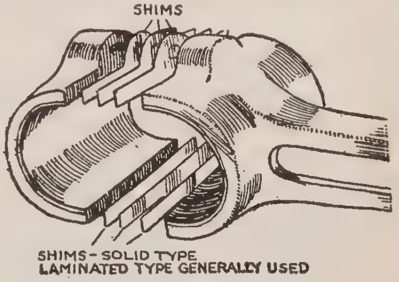

Fig. 61. **Connecting-rod lower bearing end** with cap removed to show shims placed between the upper bearing and cap. By removing a shim the cap is drawn closer to the upper bearing, and hence it would be tighter on the crank pin. The shims shown above are not the laminated type. The laminated type of shims is universally used, however.

When testing the bearing, keep in mind that while it should have no appreciable amount of looseness, this does not mean that the drag on the shaft should prevent its free rotation. Follow the same rule as given for the main bearing adjustment.

After adjusting and testing one rod, loosen up slightly on the nuts of the bearing adjusted, so that it will have no binding effect on the next one to be adjusted.

Adjust and test each rod accordingly, and after all are adjusted, tighten up on all nuts and replace cotter pins and spread the points.

It is a good plan, after about 1,200 miles of running, to **inspect and readjust the bearings again,** as they will then be set.

When replacing the oil pan, be sure the gasket is not damaged, and that the cap screws holding the oil pan to the crank case are tight, otherwise oil will leak.

If the connecting-rod bearings are not fitted with shims, then the bearing cap must be dressed down, as explained on page 784.

Note. **When removing caps and connecting rods, mark them.** Also be sure that the connecting-rod bearing caps are placed with the oil holes facing the direction in which the engine runs. This is important, especially with an engine using splash lubrication, because oil is forced into these holes when the engine is running.

Fitting Connecting-Rod Lower Bearings[1]

When the bushings in the lower end of the connecting rod and cap are badly worn, or cracked, or are loose, it will be necessary to install new bearing bushings if they are of the removable die-cast type.

If of the plain solid babbitted type, a new connecting rod and cap will be necessary, or they will have to be re-babbitted.

In either case, it is necessary to fit the bushings to the crank-shaft connecting-rod bearing pins.

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[1] See also Index under "Fitting bearings on a truck engine."

In many instances, this work can be done under the car, by removing the oil pan, disconnecting the connecting-rod caps, and removing the rod and pistons from the engine.

The new bushings are then installed in the cap, and if it projects above the cap, it is dressed down.

There are various methods for fitting the connecting rod to the crank pin, which is similar to the main bearings: (1) by spotting-in and scraping; (2) by burning-in; (3) by lapping with a grinding compound. These methods were explained under "Fitting main bearings," and the process here is the same.

Where the work is done under the car, the connecting rod can be worked as shown in Fig. 62. It is best, however, to do this work with the crank shaft removed, because at that time the crank shaft can be tested for alignment and the crank pins can be examined more freely and the work will be done better.

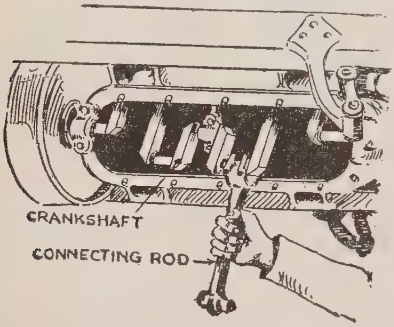


Fig. 62

Two methods are shown (Figs. 64, 65), for supporting crank shaft while fitting the connecting rods. The crank case can also be turned upside down and the work can be done while working on the main bearings and while the engine is on the bench and after the main bearings have been fitted.

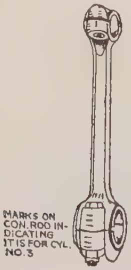


Fig. 63. Rod and cap should be marked.

When removing a connecting rod or cap, remember the position of the cap and examine it immediately for file marks. If the rod and cap are not marked, they should be, before the positions are forgotten. See also page 801.

Spotting-In Connecting-Rod Bearings

After sufficient shims have been removed from between the cap and rod, so that the bearing fits tight on the shaft, the rod nuts are taken off and the shaft bearing surface is given a very light coating of "marking" compound (Prussian blue or lamp black).

Put the connecting rod in place, and put on the cap and draw it up tight. Be sure that caps are fitted on according to the punch marks on the cap, and that the rod is on the right side forward. Then rock back and forth, or if the engine is removed, swing it around the shaft twice.

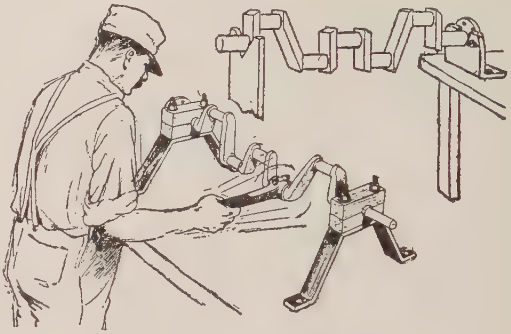


Fig. 64 Fig. 65

Fig. 64. A wooden crank-shaft support for fitting connecting-rod bearings to the crank shaft when removed from the engine.

Fig. 65. Another method.

Next remove the nuts and bearing. The "high spots" inside the bearing will be found marked in blue, showing that at these points the crank touched; the part which is white the crank did not touch. The problem is, therefore, to get the high spots down by scraping, until the bearing will mark for about three-fourths over its surface.

This marking or "spotting-in" process is repeated from time to time till the whole surface is marked as shown at (**D**) (Fig. 11, page 785). The upper part of the rod is scraped first, then the lower bearing cap.

Adjustment: When scraping is completed and all nuts are down, the connecting rod should be just **stiff enough to turn by hand,** and if placed in a horizontal position it should not fall by its own weight, but should move when pushed by hand. If fitted too tight, seizure will result.

After scraping is done, the burnisher shown in Fig. 10, page 785, may be run over the entire surface of the bearing to shine it up and smooth the surface.

Another method: When the rod shows a good bearing of about 30 per cent, tighten it to the shaft so that it will be hard to turn. When the engine is assembled (leave the oil pan off), run it for about 30 seconds; then remove it and examine the bearing. If it shows a good bearing, replace the cap. If not, remove the cap and repeat the operation.

When fitting a new connecting rod to an old shaft, the crank pin is usually undersize and it is not only necessary to remove the shims, but also to file off the sides (face) of the cap.

If a crank-pin bearing is badly under size, it is necessary to file the face of both the cap and the rod.

If, as already suggested, the shaft is badly undersize, and all connecting rods require replacing, it is usually less expensive to install a new crank shaft (on a Ford).

Oil grooves: Do not overlook the oil grooves when fitting the connecting-rod bearings. Remember that oil grooves wear thin in a worn bearing. See page 171: "Oil grooves in bearings."

How a Connecting-Rod Is Babbitted

Connecting-rod bearings are, as a rule, made from babbitt metal die-cast to size and shape, and in some cases these are backed by bronze shells, while in other designs the babbitt is cast directly into the rod and cap, the object of this being to reduce the weight of the reciprocating parts.

Babbitt as a bearing metal is very desirable, as it is soft and will not score the shaft in case the bearing should seize. It wears more rapidly than bronze, and consequently needs to be adjusted oftener. In order to prevent overheating and to allow for slight irregularities in connecting-rod alignment, these bearings must have a slight amount of end play.

Re-babbitting: In some of the older models and on some of the modern popular-priced cars, the bearing metal is cast in place, and is not in the form of removable bushings. In cases of this kind it is always best to have the rods re-babbitted at the factory or service station. Some makers even exchange the rods in order to facilitate service.

To pour and bore these bearings requires some skill, and it is a difficult job to set up. A simple method is depicted in Fig. 66, in which a machine table, such as that of a shaper or milling machine, is used, as these have T-slots to fasten the work to. To get the new bearing in line with the piston-pin bearing is not easy, but if the ends of the piston-pin hub are in good shape, one of these can be blocked up and bolted down on the machine table. Then with the babbitting mandril held vertically and located from the center of the piston pin, the bearing will line up within scraping distance, the setting being obtained by measurements.

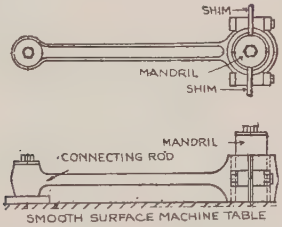


Fig. 66. A simple method of holding the connecting rod for re-babbitting the large end.

The babbitting mandril can be made of wood, which will leave a fairly smooth babbitt surface. It must be bolted down to prevent shifting when pouring the babbitt.

To form the two halves, a liner is inserted on each side that touches the mandril, both halves being run at the same pouring.

The babbitt can be heated in a ladle, using a slow heat and stirring frequently. For best results the babbitt should be poured at the proper temperature, which is that at which it will char a pine chip, but will not ignite it. When the metal has reached the pouring temperature, the rod should be heated somewhat. This prevents sponginess and blisters in the babbitt. Pour it slowly, and avoid the scum which forms in the ladle, or remove it before pouring.

After the bearing has cooled, the oil holes can be drilled, and then the final operation of scraping and fitting can proceed. It will be necessary to cut new oil grooves, which can be accomplished with a hammer and cape chisel, as shown in Fig. 67. (*American Automobile Digest.*)

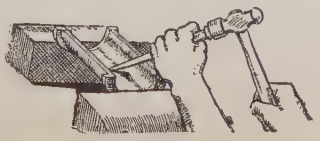


Fig. 67. Method of grooving re-babbitted bearings.

Pointers on Connecting-Rod Bearings as Usually Found on Tractor Engines[1]

Rods and caps should be marked: Before removing any of the connecting rods they should be examined for identification marks (Fig. 68). The marks referred to are placed on the connecting rod and cap, so that they may be reassembled in their original positions.

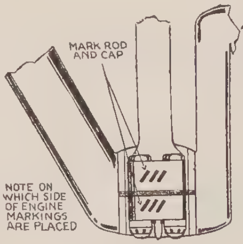


Fig. 68

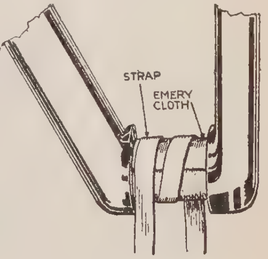


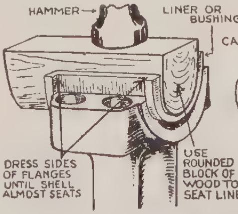
Fig. 68A

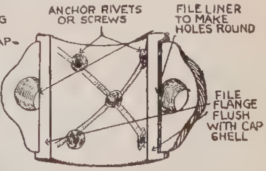
Fig. 68. The marks are put on the rod and cap when the engine is assembled. Note that there are three marks on the cap and three on the rod; thus they are for cylinder No. 3.

Fig. 68A. Dressing down a crank-shaft connecting rod bearing pin which is slightly scored without removing crank shaft.

If there are no marks on these parts it is a simple matter for the operator to put some there with a cold chisel or a file. The rod and cap should be marked with the same mark, but a different mark should be used for each rod so that they will be put back on the same cranks. A common and convenient way of doing this is to mark them 1, 11, 111, 1111—starting at the front end of the engine. With the rods properly marked and a note made on the side of the engine on which the marking was done, all parts should go back in place without any trouble.

Bearings must be fitted to a perfectly round bearing pin: When the connecting rods have been removed, the shaft should be tried for roundness. This is easily done with a pair of calipers carefully handled. If the shaft is found to be out of round or scored, there is no use fitting new bearings without first dressing down the shaft.


HAMMER
LINER OR BUSHING
DRESS SIDES OF FLANGES UNTIL SHELL ALMOST SEATS
USE ROUNDED BLOCK OF WOOD TO SEAT LINER


CAP
ANCHOR RIVETS OR SCREWS
FILE LINER TO MAKE HOLES ROUND
FILE FLANGE FLUSH WITH CAP SHELL

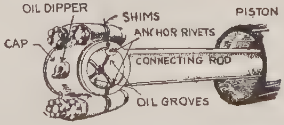


Fig. 69 (upper) Fig. 71 Fig. 70 (upper)

Fig. 69. When bushing or liner flanges are too thick dress with a file and use a half-round block.

Fig. 70. Connecting-rod bearing cap, with liner or bushing.

Fig. 71. A type of connecting rod of heavy construction, usually found on tractor engines.

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[1] *Canadian Power Farmer*, by D. R. A. Drummond.

This work may be done at the time, without removing the shaft if the shaft is not in very bad shape. Wrapping around the journal a piece of emery cloth which will cover it for the full length; around the emery cloth a strap is wrapped once, and the operator pulls back and forth on the ends of the strap (Fig. 68A).

Fit backs of liners or bushings first: If there is any difference between the two half-liners (bushings), they should be fitted to the rod and cap in such a way that the oil holes will match. When the liners are placed in their seats, it will sometimes be found that the **flanges** are a little too thick to allow them to seat properly (Fig. 69).

The sides of these flanges should be dressed down carefully with a fine file until the shell will almost seat. It is driven the rest of the way with a hammer and a round block of wood.

Liner riveted to prevent turning in shells: With the liner or bushing in place, the anchor rivets or screws should be put in and drawn up to place.

If screws are used, they should be screwed in tight and then riveted, to keep them from turning back and scratching the journal.

In some bearings neither screws nor rivets are provided, and the operator occasionally has trouble with the liners seizing on the shaft and turning in their seats. In this case it is just as well to drill the rod, cap, and liners, and to put in either rivets or brass screws (Fig. 70).

With the liners anchored in place, they should be filed flush with the top surface of the shells, and if they cover part of the bolt holes they should be filed to make the holes round.

Fitting the bearing to the shaft: To fit the bearing to the shaft each half should be fitted separately. It will probably be found that the bearing is a little too long to go down in place properly, and a little metal should be filed from each end of the bearing until it goes into position with the end play about equal to the thickness of a piece of ordinary writing paper. In doing this work, the edges of the shell should be rounded off with a bearing scraper to correspond with the rounded fillet on the crank-case journal. The shaft is coated with a very thin layer of Prussian blue, and the half-bearing is placed in position and worked back and forth on the shaft. The blue on the shaft will mark the high spots on the bearing, and these should be removed with a bearing scraper as previously explained under "Spotting-in and scraping bearings."

While scraping a bearing, care should be taken to scrape a very little at a time, as making deep cuts only moves the high spots from one place to another, and the job might go on indefinitely. The marking and scraping operations should be continued until the blue marks the full surface of the bearing.

Assembling the bearing: When both halves of the bearing have been fitted to the shaft, the whole may be assembled and this is where a great many operators fall down. There should be the same shimming in each side of the bearing, and there should be just enough shimming used so that when the bolts are drawn up tight the shaft can be turned by hand. This means that the rod, cap, shims, bolts, and nuts will form one solid piece.

If, when the bolts are tightened, the shaft cannot be turned, shims should be added until the proper fit is obtained. Under no circumstances should the nuts be slackened to obtain the proper fit, as this leaves a certain amount of play on the bolts, which soon causes the shims to wear out and the bearings to be badly damaged.

When the nuts have been drawn up tight, it may be found that the slots in the nut do not match the holes in the bolts. In this case, the nuts should be removed and enough metal filed from the bottom so that they can be turned up to match. The nuts should not be turned back even part of the whole width to get the pins in. New pins should always be used in reassembling these bearings, as old ones are liable to break, causing serious damage to the engine.

Main bearings:[1] The main crank-shaft bearings are fitted in much the same way, except that all the upper liners or bushings must be fitted at the same time. Fitting one bearing at a time would be pretty sure to result in getting one lower than the other, which would cause the shaft to bind when the caps were put on. The caps, on the other hand, may be fitted one at a time, the usual practice being to start at the center.

The job of fitting bearings is not a hard one, but calls for care, precision, and a certain amount of mechanical ability. The work outlined above may easily be adapted to almost any kind of tractor motor bearing.

ALIGNMENT OF PISTON AND CONNECTING ROD

What follows is not a part of the tractor engine bearing subject just treated, but refers to pistons and connecting rods in general.

After having fitted the bearings, as previously explained, the rod bearings should now be tested for **parallelism.** The piston pin and the crank-throw must be parallel, and the bearings that they move in must also be parallel, or binding and rapid wear will take place. This should be done before and after scraping the bearings.

If the connecting rod is distorted or bent, to even the slightest extent, it will cause a knock or "piston slap" and wear on one side of the cylinder wall, and will also cause the rings to stick and leak; therefore, before assembling, some means must be found of determining if the piston is in perfect alignment with the connecting rod, crank shaft, and cylinder.

Very often, knocks that develop in engines (after they have apparently been thoroughly overhauled), will be found to be due to the fact that the connecting rods are slightly bent sidewise, or got out of true when fitting the cylinders down over the piston, or when removing and replacing them. One cylinder will get a slight lead, or one ring does not properly enter, the cylinders are twisted, and in an effort to align them, the rods are bent. When the engine is finally assembled, it is very noisy, due entirely to the fact that one or more of the rods have been bent sidewise, and when the force of the explosion is exerted on the piston head, the wrist-pin end of the connecting rod is driven sidewise against the piston boss.

There are three disalignments possible in the piston and connecting rod: An offset in the direction of the crank shaft; the rods may be bent to right or left in the direction of the crank shaft; a twist in the connecting rod may exist.

Before replacing these parts, great care should be taken to have them in perfect condition before they are assembled. To make sure, they should be tested on a device as shown in Figs. 72 and 73.

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[1] See also Index under "Adjusting truck engine bearings."

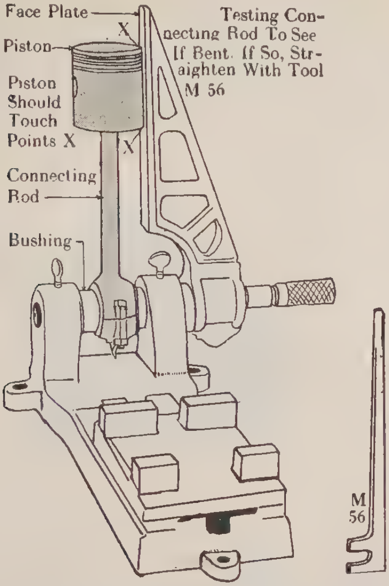
Face Plate
X
Testing Connecting Rod To See If Bent. If So, Straighten With Tool M 56
Piston
Piston Should Touch Points X
X
Connecting Rod
Bushing
M 56

Fig. 72. **A connecting-rod aligning jig.** Note that the test is for the purpose of ascertaining if the connecting rod is **bent sidewise.** If all of the side of piston comes flush with the face plate and if they touch at points (X), then the piston and connecting rod are in alignment. If, however, the piston touches at the bottom at (X) but not at the top, then the connecting rod is bent to the left. If it touches at the top and not at the bottom, it is bent to the right. Note that the test is made on a mandril. If bent, it can be straightened with a straightening bar, as shown at (M56).[1] This device is used for **straightening the connecting rod if bent or twisted.**

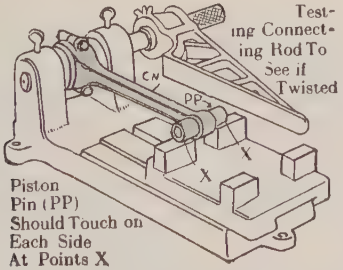
Testing Connecting Rod To See if Twisted
CN
PP
X
X
Piston Pin (PP) Should Touch on Each Side At Points X

Fig. 73. The same device as shown in Fig. 72 is being used to test the connecting rod to see if it is **twisted.** It is clear that if the piston pin (**PP**) should not touch the surface blocks at both points (**X**), the connecting rod is twisted and should be bent back with the tool (**M56**) (Fig. 72).[1]

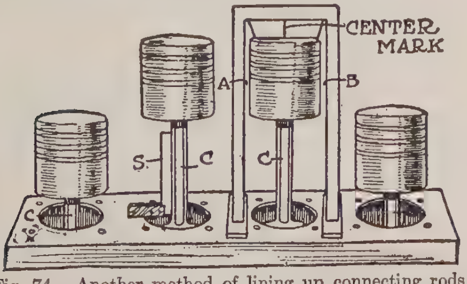

Fig. 74. Another method of lining up connecting rods of block-type engines with the base of the engine. (**S**) represents a square placed alongside the connecting rod (**C**) to determine whether it is true or not. If the rod is true and the piston is square, the space at (**A**) and (**B**) should be the same.

Another example which will illustrate to what lengths makers are going in order to insure the pistons working absolutely parallel with the bores is the method of checking the alignment of the piston and rod in the Rickenbacker engine. If a connecting rod is found to be slightly bent, instead of its being bent to shape while cold, it is faced off in a special fixture by grinding. This will insure no stresses being set up in the rod when it is heated while the engine is operating. Thus there is assurance that the pistons will at all times work correctly in the bores.

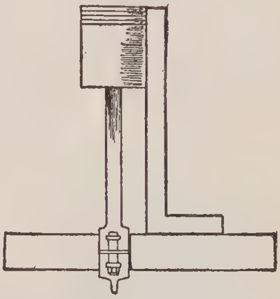

Fig. 75. A ground arbor and a square can be used to check up the alignment of the connecting rod and piston assembly. This should be done both before and after scraping the bearings.

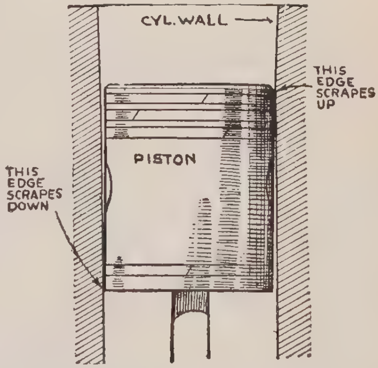

Fig. 76. The illustration is exaggerated in order to show how a piston that is cocked as a result either of the connecting rod being out of alignment with the piston or too great a piston clearance will scrape oil up on one side and down on the other side of the cylinder walls.

The connecting rod has come in for a good deal of attention during the last year or so. In nearly every case makers are now finishing their rods much better. Some go so far as to machine the rods all over, and take great care in balancing them. Heretofore some makers have weighed their rods, and if they were within ½ oz. of each other, they passed inspection. These same makers now carefully balance the rotating ends of the rods and the reciprocating ends, because it is of prime importance to get the rotating weights alike as well as the reciprocating weights.

In order to get a better distribution of the load on the connecting-rod bearings, many engine makers now are flaring the ends of the connecting rods. This naturally results in such a bearing wearing less, because the load imposed upon it by the explosion stroke is taken over a greater spread, than where the I-beam part of the rod is brought to the cap end in approximately a right angle, or a small fillet.

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[1] These devices are sold by the Service Station Equipment Co., Chicago, Ill. The Continental Auto Parts Co., Columbus, Ind., also manufactures devices for aligning purposes.

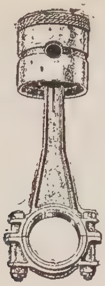

Fig. 77. The spade type of flared-end connecting rod now being introduced.

The Universal Crank-Shaft Support and Aligning Fixture

A device (Fig. 78) **for aligning connecting rods and supporting any make or size of automobile engine crank shaft,** so that the connecting-rod bearings can be fitted, and connecting rods and pistons can be tested for alignment at the same time, is shown in the illustrations.

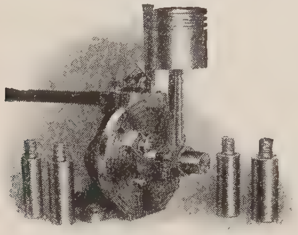

Fig. 78

Note that in Fig. 78 the crank shaft is clamped to the face of the fixture, the other end of the shaft being supported by the floor stand. The connecting rods can be fitted in this position; one advantage in fitting connecting rods in this manner being that the bearings are "spotted" to the shaft. The connecting rod can be turned a complete circle, thus insuring a more perfect marking, or, in other words, the entire circumference can be "spotted."

Fig. 79

After the connecting rods are fitted to the shaft, the connecting rods and pistons are both tested for alignment with the square. Thus each piston is squared on its own bearing.

When a shaft is not taken out of the engine, mandrels (see Fig. 78) are supplied to be used instead. The outfit shown above sells for $60 and is manufactured by the H. & H. Machine Co., St. Louis, Mo.

IMPORTANCE OF OIL PRESSURE IN RELATION TO CRANK-SHAFT BEARINGS

As an example, we will use the Oldsmobile eight-cylinder V-type engine, model "45-B."

Oil-pressure regulation: The oil regulator is shown in Fig. 80. Note the position of the oil-pressure adjusting screw and the ball-check valve. Dirt beneath this valve will cause a drop in pressure, and may be removed by snapping the ball up and down a few times with a piece of wire inserted through the oil passage.

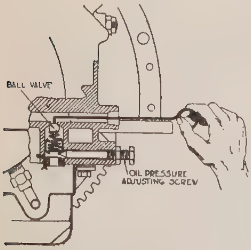

Fig. 80

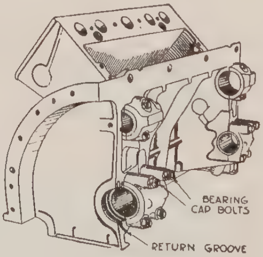

Fig. 81

Fig. 80. Oldsmobile (eight-cylinder, V-type engine) oil-pressure regulator.

Fig. 81. The main bearings are bolted to the left cylinder block. Note the return oil groove. This should be free to permit the oil return.

The oil-pressure regulator is on the front left-hand side of the engine, as shown in Fig. 80. If the oil-pressure gauge on the dash registers below 5 lbs. at 10 m.p.h., it is necessary to regulate the oil pressure. The following is the method:

1. Screwing the oil-pressure adjustment screw inwards should raise the pressure, and remedy the conditions. When the engine is steadily raced, a maximum pressure of 25 lbs. should be shown on the gauge.

2. If this is not the case, remove the oil line from the pump to the regulator, and also the elbow attached to the regulator. Then with a 3/16″ wire or rod, bent at right angles for ⅜″, reach into the oil passage and depress the ball valve a few times. This will release any dirt beneath the seat which has caused low pressure.

After replacing the parts, it will be necessary to adjust the oil-pressure screw as directed. It is also advisable to drain the crank case and flush it out with kerosene, when conditions are as described.

A medium-weight oil should be used, and, as is common with the present-day low-grade gasoline, it will be best to drain the oil, flush out the base, and replace new oil every 500 miles. Five quarts of oil are needed to completely replenish the oil supply.

Should a crank-shaft bearing ever burn out, it will be necessary to see that all oil passages are tested for clearness before replacement is made.

If any of the oil passages in the crank shaft are stopped, a ⅛″ twist drill may be used to remove the babbitt.

Testing should not be done with an air hose. The best method is to clean the end of the oil passage and blow by means of the mouth; the mechanic can thereby feel exactly the condition of the oil passage.

Cleaning oil lines: Usually a short-length twist drill is used for clearing babbitt out of the crank shaft after a bearing is burned out. Most tool stores carry long-shank twist drills, with which this work can be carried out better.

This precaution applies equally well if a connecting rod bearing burns out. Before the new bearing is installed, all oil passages should be **cleaned with**

compressed air. Very probably one will find a thick, black, pasty substance in the oil pipes connecting the crank cheeks, and also in the drilled passages in the crank shaft. This is carbon, road-dirt, and oil emulsion formed by the mixture of oil and water—the water being one of the products of combustion or having entered the crank case through a leaky head gasket.

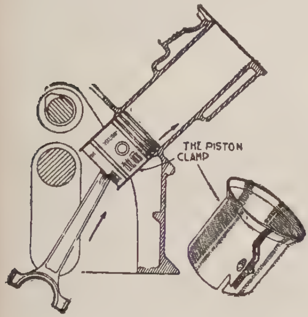

Fig. 82

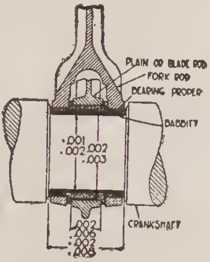

Fig. 83

Fig. 82. A piston clamp, as shown, facilitates piston and ring replacement through the crank case.

Fig. 83. These are the running clearances that should be observed when refitting the connecting-rod bearings.

If air is not available, use a tire pump by removing the connection and applying the end of the hose to the mouth of oil holes.

Connecting-rod bearing clearances: In fitting the connecting-rod bearings, it is essential that the correct clearance be observed in order to give proper action. If the mechanic uses those methods common in fitting the connecting-rod bearings on four-cylinder engines, the bearings will be drawn too tight and will cause future trouble.

The plain, or **blade rod** shown in Fig. 83 bears on a bronze bushing, which in turn runs on the crank shaft. If this bearing does not have from .002–.003″ clearance, the bushing will expand faster than the plain rod and cause binding. This condition will be indicated by a burning out of the babbitt around the center of the bearing proper.

The following is the proper method of fitting the plain or blade-rod bearing to obtain the proper clearance.

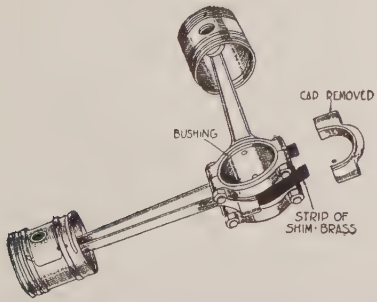

Fig. 84. A strip of shim brass applied in the manner shown above enables the mechanic to obtain the proper clearance between the blade rod and the bearing proper.

1. Fit the babbitted bushing to the crank-shaft bearing, and bolt the fork rod tightly in place.

2. Procure a strip of shim brass ¾″ wide and .001″ to .0015″ thick, just long enough to lap around the plain rod bearing on the bronze bushing (see Fig. 84).

3. Bolt the plain rod in position and adjust until, when the bolts are tight, the plain rod may be turned, but not loosely. Then if the brass shim be removed, the plain rod will have the proper clearance.

The side clearances may be checked up by means of a thickness gauge. It is essential that the clearance shown be followed. An absolute check on the bearing fits may be determined by using an inside and outside micrometer, and the careful mechanic will use this method instead of rule-of-thumb methods.

Adjustment of main bearings on the Oldsmobile model "45B" is described below and serves as an example of how bearings are adjusted on the average eight-cylinder V-type engine:

1. Remove the oil pan, place a jack under the flywheel "take the strain"—noting carefully if the crank shaft has any motion in the bearing. If such motion exists, remove the main bearing cap and take an equal number of shims from each side of the bolts, usually about two.

2. Examine the cap carefully to see that the crank shaft has a good bearing. In some cases the lining of the bronze bearing has been partially ruined, from lack of oil, which later causes leakage from the rear end of the engine.

3. Use air hose or a tire pump to blow through the drain hole which brings back the oil from the rear of the rear main bearing into the oil pan; this is a "cored" passage beneath the bearing, and connects with a groove in which a collar formed on the crank shaft revolves, throwing off the oil. There may be dirt or a stoppage at this point, preventing a proper return of the oil to oil pan.

4. When all of these points have been taken care of, replace the bearing cap and tighten up firmly. Crank the engine by hand. If it is not stiff, but has more "feel" to it than existed before you made the adjustment, this will indicate that the bearing is a close and proper fit. If it is still quite free, it would be advisable to check the bearing again, and see that it is not loose.

Note. In removing shims, be sure to take the same thickness from each side.

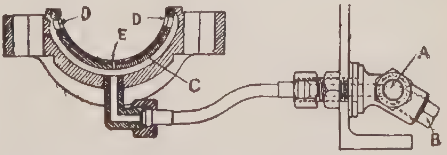

Fig. 85. Method of oiling the main bearings on the Mitchell. The space back of the bearing forms a reservoir, the oil being forced through holes (D) and (E) under pressure.

RELATION OF VIBRATION TO BALANCE

The detailed consideration of vibrations is very complex and is only of interest to specialized engineers. However, some of the factors that affect vibration are of interest to the mechanic and car owner and will be taken up in an elementary way.

Periodic Vibration

A vibration is said to be periodic when it recurs at equal intervals. Thus, during two revolutions of the crank shaft (one cycle), certain vibrations occur; if, during the next two revolutions (cycle), these same vibrations are repeated, they are said to be periodic, that is, they occur at every two revolutions of the crank shaft.

Balancing

Balancing may be considered as the effort to reduce the effects of vibration. It resolves itself into two main classifications: (1) balance of rotating parts; (2) balance of reciprocating (up-and-down motion) parts.

A part or combination of parts may be perfectly balanced when at rest, but may not be balanced when the engine is running at a high rate of speed. This leads to a further classification of balance as: (1) static balance, which means balance when at rest; (2) dynamic balance, which means balance when in motion.

Therefore we may say we have four classes of balance:

1. Static balance of rotating parts.
2. Dynamic balance of rotating parts.
3. Static balance of reciprocating parts.
4. Dynamic balance of reciprocating parts.

Balance of Rotating Parts

The rotating parts include the crank shaft and the flywheel.

It is obvious that in order **to obtain static balance of rotating parts,** it is only necessary to machine them so that the weights are equal in all directions from the center.

The dynamic balance of rotating parts is affected by a number of factors, the most important being distribution of weight along the length of the crank shaft.

One method of aiding dynamic balance is by placing counterweights on the crank throws. Another method is the divided flywheel (one in front and one in the rear), as used on the Rickenbacker engine. Here the flywheel strains are taken up, both at the front and rear ends of the crank shaft.

Whip

Suppose we made a crank shaft out of rubber. It is evident that during a power stroke the connecting rod would bend the crank shaft out of shape and cause it to **"whip"** around. While the steel crank shaft will not bend like rubber, nevertheless it has some elasticity, and it is this deflection (bending) that causes "whip." If the main bearings are out of line, the tendency will be to increase the whip. **Some methods of decreasing whip are:** (1) using a stiffer crank shaft; (2) placing the main bearings closer together; (3) placing counterweights on the crank throws.

Balancing of Reciprocating Parts

The reciprocating parts comprise: pistons and rings, wrist pins and connecting rods.

To produce static balance of the reciprocating parts, it is necessary only to have the parts equal in weight, that is, all pistons with rings and wrist pins equal in weight, and all connecting rods equal in weight.

INSTRUCTION No. 70

PISTONS: Types, Construction, and Fitting; Piston Clearance; Standard and Oversize Pistons; Piston Repairing; Lapping Piston and Rings in Cylinders; ENLARGING CYLINDERS: Different Methods of Finishing Bores of Cylinders

PISTONS

The piston acts as a seal for compressing the gases and for transmitting their energy to the crank shaft; it functions also as a guide for the piston pin. It should, therefore, fit the cylinder as closely as possible, and should be as long as possible.

Pistons are usually made of cast iron, and this type is the one in general use. When heated, cast-iron pistons expand, but not as much as aluminum-alloy pistons.

Aluminum-Alloy Pistons

Aluminum-alloy pistons are used in some engines. They expand more than cast-iron pistons, but since they cool more rapidly than cast iron, they permit a higher compression pressure. (Higher compression increases heat.) By reducing the weight of reciprocating parts, quicker acceleration is also made possible. They give longer life to the bearings by reducing the bearing pressure, especially at high speeds. The inertia of the reciprocating piston is reduced approximately 67 per cent. This cuts down side pressure, or thrust, on the walls of the cylinders and reduces friction and the consumption of lubricating oil. The great heat conductivity of aluminum alloy lessens the carbon deposit on the piston head, and the deposit is more easily removed. It is claimed that in cases of extreme heat the lynite piston will not "score" or cut the cylinder walls. It is a proved fact that the lighter the piston, the quicker it will operate. Therefore **greater speed and flexibility are the result.**

The main drawback, however, is the "slap" which often occurs, as explained on page 779. Unless the pistons fit or the clearance is exact (and it will be observed that if the aluminum-alloy piston expands twice as much as a cast-iron piston when heated, it would be necessary to give twice the clearance), the clearance of an aluminum piston when cold is considerably more than cast iron. Thus, until the engine is warmed up, there is more or less slapping noise. As the heat increases, however, the piston expands and the noise disappears. But during this expansion period raw gasoline is drawn into the cylinder, past the pistons, into the crank case, thinning the oil. Many methods have been devised to overcome this objection.

Gray-iron pistons or semi-steel pistons still are used by the majority of engine makers. With all their other advantages, aluminum-alloy pistons, as just explained, still have the disadvantage of having a rate of expansion different from that of cast iron, of which the cylinder is made. The rate of expansion is considerably greater, and therefore with alloy pistons it has been necessary to allow two or three times the piston clearance that is allowed with cast-iron pistons.

A long step in advance is the **constant-clearance** type of aluminum piston. Briefly, this is a piston which does not expand in the same way as we think of when speaking of piston expansion in an iron piston. Usually there is a cut in the piston, so that when the piston does expand it simply closes this cut and does not, therefore, change its diameter. Hence the clearance substantially remains the same in all cases. Where the constant-clearance type of piston is used, it is generally made with an opening extending circumferentially around the piston excepting for a small portion where the piston pin bosses are located. The object of this slot is to separate the upper portion of the piston, or heat portion, from the skirt.

A very good example of the constant-clearance type of piston is that used in the Cole Eight (Fig. 1). The pistons are cast of aluminum alloy in a metal mold and are slotted circumferentially below the lowest of the three piston rings.

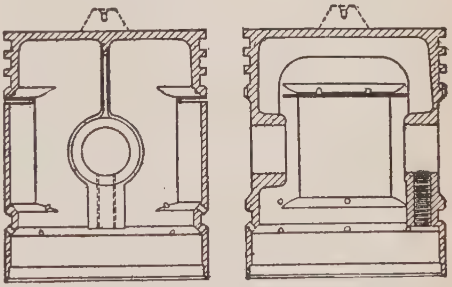

Fig. 1. Sectional view of the Cole aluminum-alloy piston.

The slot is cut by a 1/16" saw and extends over an arc of 83° on each of the two pressure sides of the piston. By means of central ribs the load resulting from the gas pressure is transferred directly from the piston head to the piston bosses. The pistons are a snug fit in the cylinder, even when cold. There is, therefore, no undue noise in the engine when first starting up. When heated, the sides expand circumferentially and along the diagonal slot without increasing the outside diameter.

A piston adopted by the Essex is also of the constant-clearance type. In order to use small clearances and still avoid any trouble due to expansion of the metal, the piston skirt is slotted and split and joined to the head only above the piston pin bosses. Interior ribbing makes for an exceptionally strong piston in which binding of the piston pin has been eliminated. Besides eliminating the effects of expansion of the piston, the slots act as oil drains. There are three rings above the piston pin and two oil grooves below. (*Motor Age.*)

The layout for the making of this piston (Fig. 2) has been arranged in the belief that piston wear, oil pumping, and failure of the piston rings to make proper contact with the cylinder walls are due largely to misalignment. This misalignment causes the piston to cock in the cylinder so that one side of it becomes a scraper, giving unequal lubrication around the walls, as shown in Fig. 76, page 803.

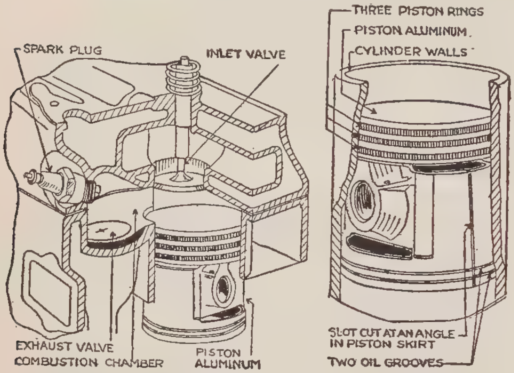

Fig. 2. **Essex aluminum-alloy piston and section of cylinder head.** The Essex engine is the type which has intake valves in the cylinder head and exhausts in the side. The gas passage is arranged so that the carburetor is placed above the inlet port and valve. Thus the flow of gas to the inlet valve is downward, the exhaust being at the side. The inlet valves are 1⅞″ in the clear, with a lift of .3125″. The exhaust valves are 1⅜″, with a lift of .325″. With this arrangement, and by the use of aluminum pistons which cool readily, the use of the large valves and high compression is permissible.

The spark plugs are located on the right side and the ends of the plugs fire in a depression in the head. There are four such depressions or cups. This design is used so that the plugs are constantly fanned by flame, with the result that oil is quickly burned away, if any should work its way up.

The skirt of the piston is split with a slot cut at an angle, so that it does not work vertically in the cylinder, but with a sliding motion. Part of the piston and rod assembly operation is such that a final check is made on the alignment of the piston and makes it certain that the latter will operate on a true axis.

Light Iron or Semi-Steel Pistons

Where iron or semi-steel pistons are used, there has been a tendency to get them very light. In fact, some of the semi-steel pistons weigh little more than aluminum-alloy pistons. Flexible pistons of this type have the advantage that they will shape themselves into the cylinder bores in which they are working. In other words, the pistons will conform much better to the shape of the cylinder, should the latter wear oval.

One of the things in favor of the semi-steel piston is that owing to the nature of the metal it can be machined to much closer limits than is the case with cast iron. There is, therefore, a reduction in weight—and a desirable feature in any of the reciprocating parts of an engine.

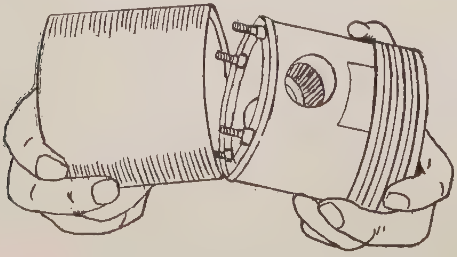

Fig. 3. The Marmon piston is a combination piston. The head and body are aluminum, and the skirt is cast iron.

Most makers of engines are now polishing the heads of the pistons. It is well known that carbon or soot will not so readily adhere to a polished surface, and while it is somewhat more expensive to finish pistons in this manner, it is worth it in the better appearance and in results.

The Deluxe Light-Weight Gray-Iron Piston

Attention is called to the design or construction of the Deluxe light-weight gray-iron piston, and to the system of ribs or webbing extending across the head and down the skirt of the piston. These ribs or braces give the piston extraordinary strength and permit of the walls between the ribs or braces being made very thin.

The strength of the piston depends almost entirely on the ribs or braces extending across the head and down the skirt, and very little on the walls between these ribs. Actual tests show Deluxe pistons to be three times as strong as necessary to hold up in the cylinders under all conditions, but they are in no case strong enough to withstand abuse or rough treatment, nor being handled in the way in which ordinary heavy cast-iron pistons are handled.

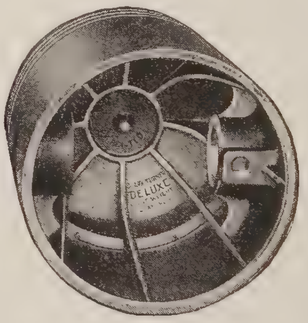

Fig. 4. The Deluxe light-weight gray-iron piston.

The manufacturers of the Deluxe piston (Clark-Turner Piston Co., Los Angeles, Cal.) claim that this piston expands and contracts equally and evenly; that it never warps, and that it is always round and true and can be fitted to a closer clearance than any other piston. Thus, with a close clearance, compression leaks and piston slap on starting are eliminated, and the other advantages of the aluminum-alloy piston are likewise obtained.

The **clearances** recommended by the manufacturers of this piston are as follows:

Diameter of Piston			Clearance	
2″	to 2 13/16″	allow	.0015″	on skirt
2⅞″	to 3 1/16″	allow	.002″	
3⅛″	to 3 11/16″	allow	.0025″	
3¾″	to 4¼″	allow	.003″	
4 5/16″	to 4 15/16″	allow	.0035″	
5″	to 5½″	allow	.004″	
5 9/16″	to 6″	allow	.0045″	
6⅛″	to 6⅞″	allow	.005″	
7″	to 7⅞″	allow	.006″	
8″	to 8⅞″	allow	.007″	
9″	to 10″	allow	.008″	

Exceptions: Allow .003″ on Essex engines and Ford engines.

Deluxe pistons are supplied "semi-finished," finished to "standard," finished "exact," and finished to any "oversize." The semi-finished pistons are from 1/16″ to 3/16″ oversize, according to diameter, and can be finished down to standard, or to any oversize up to within .010″ of the semi-finished size.

On orders for "standard" size pistons, clearance is allowed for. When ordering oversize pistons, allow for clearance. For instance, if you order a 3¼″ piston finished to .010″ oversize, the finished piston will be .010″ over 3¼″. If you have a regrind job ground to .010″ over 3¼″, then you should order the piston finished to .007″ or .0075″ oversize, allowing for "clearance." In other words, when ordering oversizes you receive exactly that size, whereas, when ordering finished to standard, a size equal to the diameter of bore, less proper clearance, is supplied.

When ordering pistons always state the name of the car or engine, the diameter, and the number of cylinders.

Cast-Iron Pistons

We shall now confine our attention to the piston in general use, which is the plain cast-iron piston.

The cast-iron piston expands under heat, as do all other types—some more or less than others—and the extent of this is, of course, governed by the amount of heat generated in the engine. On the Ford piston, the top is .010″ smaller than the skirt, because the piston is subjected to greater heat at the top; consequently there is greater expansion at this point. The clearance of a piston is measured at the skirt.

The piston proper is made with grooves for rings (**R**), which are placed as shown in illustration (Fig. 5), which is of the Ford piston. Note that there are two rings above the piston pin and one oil-ring below. Sometimes an oil groove takes the place of the oil-ring. (**B**) is the bushing for the piston pin.

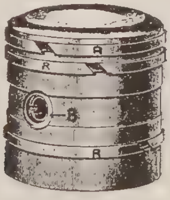

Fig. 5

The average automobile engine piston is fitted with three rings above the piston pin and one below. Pistons are usually ground to fit the cylinders, but not to a tight fit.

Questions and Answers on Pistons

Q. 1: What troubles result from too loose a piston?

Ans.: In addition to a "slap" and the wear of the cylinder wall, there is a third trouble resulting from the gasoline passing into the crank case and thinning the oil, thus injuring the bearings. The piston will also pump oil, causing carbon and smoke.

Q. 2: What is meant by "squaring" the piston?

Ans.: When fitting pistons in the cylinder, if the cylinder blocks are not lowered carefully, the connecting rods will be slightly bent; or, if in scraping a bearing, one side is higher than the other, the piston will set at an angle. It is very important that pistons be in perfect alignment. See Index under "Alignment of pistons."

Q. 3: What are pistons usually made of, and what is meant by "seasoning" and "heat-treating"?

Ans.: Pistons are usually made of cast iron, and are not machined for a long time, to allow them to set so that they will not change their shape. The result of this is that they do not contract so greatly when cold or expand so much when heated, thus permitting maximum clearance, and reducing "slapping" when cold. Heat-treating is supposed to have the same effect as long seasoning.

Q. 4: How are pistons machined?

Ans.: They are turned down to within .005″ of size, then ground to exact size on a special grinding machine. On high-grade engines the pistons are seasoned or heat-treated, then turned and ground to fit each cylinder individually. On some of the cheaper grades of engines they are not always heat-treated or seasoned, and are made in quantities, and the assembler fits the pistons to the cylinders as they come, termed a selective fit.

Piston Clearance

A piston does not fit the cylinder wall tightly. If it did, it would seize and stick when it was heated, as it expands with heat.

The piston rings fit tight, however, but, being split and of spring tension, they fit the cylinder at all points—or at least they should. For this reason clearance must be allowed between the wall of the cylinder and the piston.

Cast-iron pistons require about one-half the clearance that those made of aluminum alloy require, because they do not expand so much under the same degree of heat.

More clearance is required at the top of a piston, because here the heat is greatest, and there is therefore greater expansion at the top.

If pistons are fitted very close to the cylinder they will run very quietly but may heat and stick and cause the engine to slow down or stop if it is driven at a high speed. In fact, all **new engines should be driven at moderate speed** for the first 1,000 miles in order to work or run-in the pistons, bearings, etc., without cutting.

If pistons are fitted moderately loose, they may "slap" until heated up. The practice is to give greater clearance for higher speed.

If pistons fit too loose, a "piston slap" and oil leakage will result.

The amount of clearance depends upon the speed of the engine, the efficiency of the cooling system, the type of water circulation, and the length of the water jacket. If the engine is "hot-running" or heats quickly, clearance is increased proportionately. If it is "cool-running," give less clearance. The clearance needed will vary, depending on the conditions mentioned. Air-cooled cylinders usually expand outwards, which equalizes with the expansion of the piston. Therefore the same ratio applies.

How to Determine Piston Clearance[1]

The clearance of cast-iron pistons is usually graduated. For example, refer to Fig. 6. The piston is ground straight, or one size from the bottom of the skirt up to the lower part of the piston-pin hole. From the lower ring groove to the head of the piston, the piston is slightly tapered, so that it is from .006″ to .010″, or more, smaller at the top than at the skirt.

The clearance of a piston is allowed at the skirt, and, **as a rule,** this part is ground so as to allow approximately **.001″ clearance for each inch in the diameter of the piston.**[2]

For example: If a piston is to be fitted to a cylinder of 3″ bore, the skirt of the piston should be

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[1] **The S. A. E. has never adopted any standards for piston clearance** because the difference in materials, in cooling, and in design both of pistons and cylinders, affects the amount of clearance necessary.

[2] **A clearance of .00075″** (three-quarters of one-thousandth) of an inch for each inch diameter of piston is now more generally used.

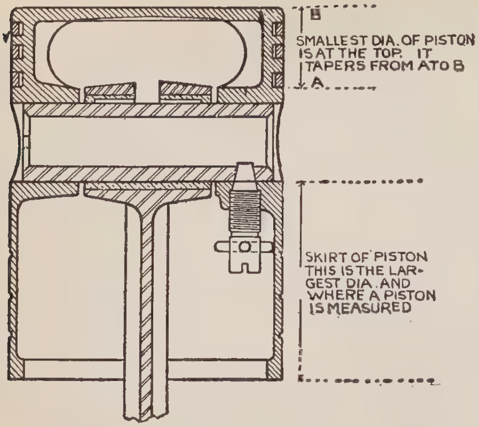
B
SMALLEST DIA. OF PISTON IS AT THE TOP. IT TAPERS FROM A TO B
A
SKIRT OF PISTON THIS IS THE LARGEST DIA. AND WHERE A PISTON IS MEASURED

Fig. 6

measured as .003″ less in diameter than the bore. Thus, in the case supposed, when the cylinder bore is 3″ in diameter the piston should be .003″ less, or 3″ − .003″=2.997″ (two inches and nine hundred and ninety-seven one-thousandths), measured at the skirt.

This rule is not always adhered to. One manufacturer states that they give .002″ to .003″ clearance to passenger-car engines and on racing cars; .003″ to .004″ to truck engines, and .004″ to fire-apparatus engines, **regardless of diameter.** Where engines run for long periods under full power they require more clearance than others, and, of course, the heating of the engine, the cooling surface, etc., as previously stated, are factors governing the clearance to a certain extent. For example, in fire-apparatus engines, where they are run at times for long periods, pumping water at full power, it is clear that greater heat will be generated; there will consequently be greater expansion. Thus in such cases it is necessary to allow more clearance.

It is also clear that a close-fitting piston is desirable—and the idea is not to give any more clearance than necessary.

No hard-and-fast rule can be given as to the amount of clearance which should be allowed between the pistons and cylinder walls. There are many conditions to be taken into consideration, including the construction and speed of the engine, the style and material of the pistons, the service given the engine, after grinding, and even the characteristics of the driver himself.

Even the manufacturers themselves are divided on this point, each having his own pet theory as to what the clearance should be. Some idea of how manufacturers vary can be gathered from the table showing the clearances allowed by a few of the makers of cars, shown on this page.

As a general rule, it is safe to allow .00075″ to .001″ to each inch diameter of the bore on cast-iron pistons. The majority of the regrinding concerns—and, as can be seen from the table above—**the manufacturers themselves, shade this a little.** This can be done, provided that the fitting of the piston rings and pins is an A-1 job, and provided that, when assembling the engine, every precaution is taken in regard to squaring up the pistons and rods, to giving the engine plenty of oil. In addition, the driver **should operate the car at moderate speed the first few hundred miles.**

Manufacturers' Clearance of Pistons in Cylinders when Regrinding Cylinders[1]

Maker	Finish	Diameter	Clearance	Piston Material
Chalmers	Grind	3¼″	0.005″	Lynite
Chevrolet	Ream	3.686″	0.003″	C.I.
Continental	Grind	3¼″	0.001″	C.I.
Continental	Grind	3½″	0.002″	C.I.
Continental	Grind	3¾″	0.002″	C.I.
Continental	Grind	4⅛″	0.002″	C.I.
Continental	Grind	4½″		C.I.
Dodge	Ream	3⅞″	0.003″	C.I.
Franklin	Grind	3¼″	Taper from 0.003″-0.001″	Magnalite
Hudson	Grind	3½″	0.0035″	C.I.
Hupmobile	Grind	3.248″	0.001″	C.I.
Kelly-Springfield	Grind	3.7460″ 4.4970″	0.003″ 0.003″	C.I. C.I.
Locomobile	Grind	4½″	0.015″ 0.003″	C.I.
Lycoming	Grind	3½″	0.004″ 0.0065″	C.I.
Maxwell	Grind	3.622″ plus	0.013″	C.I.
Mitchell	Grind	3¼″	0.0025″	C.I.
Oakland	Ream	2 13/16″	0.005″	Alum.
Oldsmobile	Ream	2⅞″	0.004″	Lynite
Packard	Grind	2.998″	0.002″	C.I.
Pierce	Grind	4½″	0.002″ 0.003″	C.I.

"Lynite" is aluminum alloy; C.I., cast iron.

In many cases, piston manufacturers themselves can tell best what clearance should be left for their particular style of piston, especially on patented construction, or on alloy material.

A prominent piston manufacturer gives the following clearances for different cylinders of different diameters, between the finished piston and cylinder:

Diameter of Piston		Clearance
2 13/16″ or under	allow	.0015″
2⅞″ to 3″	allow	.002 ″
3⅛″ to 3¾″	allow	.0025″
3⅞″ to 4¼″	allow	.003 ″
4 5/16″ to 4⅞″	allow	.0035″
5″ to 5½″	allow	.004 ″
5¾″ to 6″	allow	.0045″
6¼″ to 6¾″	allow	.005 ″
7″ to 8″	allow	.006 ″
Ford	allow	.003 ″

Piston Clearance; How Measured

Method of measuring piston clearance: Place the inside micrometer caliper (**IM**) in the cylinder, as indicated in Fig. 7, and determine **the inside diameter of the cylinder** (see also page 703).

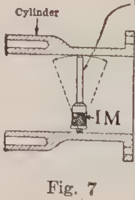

Fig. 7

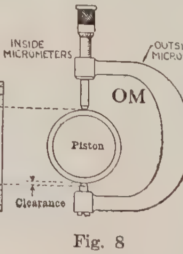

Fig. 8

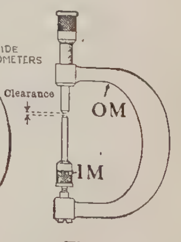

Fig. 9

Then place an **outside micrometer (OM)** over the piston, as shown in Fig. 8, to determine **the outside diameter of the piston.**

Then place the inside micrometer (**IM**) (Fig. 9), as shown, in **between** the outside micrometer, and note the clearance.

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[1] This table is given through the courtesy of the Heald Machine Co., Worcester, Mass., manufacturers of cylinder regrinding machines. (*Copyrighted.*)

In the absence of suitable micrometers, and if the pistons are to be ordered, cut a 3/16″ bar of steel, filing both ends smooth so as to fit the cylinder at its **smallest** point, and number each bar for each cylinder. Send these bars to the piston manufacturer and state the clearance desired.

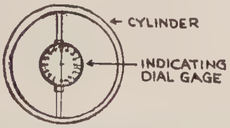

Fig. 10. A device, termed a **dial cylinder gauge,** for comparing the diameter of cylinders, to see if they vary, is called an Indicator Dial Gauge. Manufactured by B. C. Ames Co., Waltham, Mass.

Note. **If a piston is fitted to a worn cylinder,** it will be found that the **wear is where the rings travel** (Fig. 24, page 822), and not at the bottom or top of the cylinder. Thus, if the piston is fitted with proper clearance at these points, it may have considerably **more clearance when up into the cylinder,** and this is one reason why worn cylinders should be enlarged and oversize pistons fitted, if worn more than .003″. When worn, cylinders are usually out of round.

Free-Fit and Tight-Fit Piston Clearance

Frequently instructions advise fitting a piston, say .003″ **"free"** or **"loose-fit,"** and .004″ **"tight-fit."**

This means that the piston is placed in the cylinder and a thickness gauge (also called a "feeler") is placed alongside the piston, between it and the cylinder wall (Fig. 11).

The piston should fit free, or loose, or fairly snug with a .003″ gauge, and tight with a .004″ gauge.

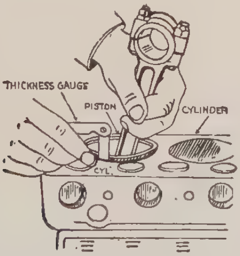

Fig. 11. **Method of testing piston clearance** between piston and cylinder wall. The **"feeler," or thickness gauge,** should be tried at several points between the piston and cylinder bore. The piston should then be turned a quarter turn and checked again. If the piston shows out of round, tap it with a rawhide mallet on the greatest diameter of the skirt to true it up.

Note. A 1″ strip of heavy tough wrapping paper can be **"miked,"** that is, its thickness can be measured with a micrometer and then the paper can be used to test the clearance when fitting pistons, by laying it in the cylinder between the piston and cylinder wall.

How Pistons Are Marked

Pistons are usually stamped on the head, and this stamp indicates the diameter at the skirt. For example, a **standard size** piston for, say, a 4½″ bore cylinder with a .003″ clearance may be stamped 4.497″, meaning that 4½″ in decimals is expressed as 4.500″ and 4.500″−.003″=4.497″. This method of marking, however, does not hold true in all instances, as manufacturers have different methods.

When an **oversize piston** is ordered from the manufacturer of a car, the probabilities are that it will be stamped for the oversize only. For example, suppose the cylinder diameter was 4″, and the standard clearance was .003″, the **standard piston** would then measure 4″−.003″=3.997″.

Suppose the cylinder was worn and the piston was loose, and you ordered a piston .002″ oversize. This would mean that the piston would measure at the skirt .002″ more than the standard size. It may be marked simply .002″ OS ("O.S." stands for oversize), or it may be marked the actual measurement, as 3.999″. The 3.999″ is arrived at by adding .002″ to the standard size of 3.997″.

Standard and Oversize Pistons

Pistons can be purchased in **"standard"** and **"oversize"** diameters.

A standard size piston is the original diameter of the engine cylinder, less the standard clearance.

The oversize piston is fitted to a cylinder when the cylinder is worn, or is enlarged, by re-boring, re-grinding, or reaming, as explained farther on. In many instances, when a cylinder is worn and the piston is loose, an oversize piston of .002″ or .002½″ is ordered, and it is then "lapped" in.

Oversize pistons can be secured in sizes .005″, .010″, .015″, .020″, .031″, .046″, .062″, larger than the original or standard size of the piston. Cylinders are seldom ground less than .010″ oversize.

A concern that makes a specialty of oversize pistons, rings and wrist pins and that specializes on grinding cylinders is the H. & H. Machine Co., St. Louis, Mo.

Finished pistons are furnished complete, minus rings and pins.

The Continental Motors Corporation, manufacturer of the Continental Red Seal engine, and its parts-distribution depots, carry in stock replacement or **oversize pistons** from .002″ to .045″ oversize. These figures represent the actual oversize of the piston, as, for instance, if the **standard piston** is 3.248″ diameter, then a **.002″ oversize piston** would be .002″ larger than the standard, or 3.248″+.002″=3.250″.

Miscellaneous Oversize Engine Parts

Oversize piston pins, are cheaper to use than it is to re-bush a piston. Simply ream the bushing when a piston pin is loose, and fit an oversize pin. (These can be secured of the H. & H. Machine Co., St. Louis, Mo.)

Oversize valve stems, such as are used on the Ford, where there is no provision made to put in cast-iron bushings, are necessary when valves become noisy and air leaks into the cylinder through the inlet valve, causing missing at low speeds. The guide is reamed 1/64″ oversize, and a 1/64″ oversize valve stem is fitted with .002″ or .003″ clearance.

Oversize piston rings can be obtained of any supply house or piston-ring manufacturer. See page 834.

Oversize valve tappets and also **oversize cylinder head bolts** can be secured of the Stevens Co., 375 Broadway, New York.

Questions and Answers on the Standard Bore of Cylinder, Standard Size of Piston, Standard Clearance of Piston, Oversize Pistons, and How a Piston is Measured

The Ford Piston as an Example

Q. 1: **What is meant by a "standard bore" of a cylinder?**

Ans.: The bore or diameter of the inside of a cylinder as it comes from the factory. On the Ford it is 3¾″ or 3.750″, expressed in decimals (three inches and seven hundred and fifty one-thousandths of an inch).[1]

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[1] On all engines the bore may vary even as much as .002″. We shall assume that it varies one one-thousandth on the Ford; thus the cylinder bore may be 3.750″ or 3.751″. Therefore in working out the answers to these questions, we shall assume that the bore is 3.750″, which is what it is intended to be, although, as stated, almost all cylinders vary at least .002″.

Q. 2: What is meant by a "standard size" piston?

Ans.: The diameter of a piston to fit this standard size bore, less the clearance. The actual diameter of a Ford "standard" piston is supposed to be approximately 3.748″ (it may vary .001″).

Q. 3: What is meant by a "standard clearance" of a piston?

Ans.: The clearance adopted by the manufacturers. On the Ford, the standard clearance of the piston in the cylinder is as follows: On a repair job, a Ford piston should fit to the bore of the cylinder so that a .004″ thickness gauge, placed between the piston and the cylinder wall is tight, and at .003″ is loose. On commercial jobs pistons may be fitted so that at a .006″ gauge they will be tight, but in such a case the pistons are liable to slap and be noisy until warmed up. Therefore if the cylinder is 3.750″ in diameter and the clearance is to be .003″, the piston should measure at skirt, 3.750″=.003″=3.747″.

Q. 4: Where is a piston measured?

Ans.: At the skirt.

Q. 5: How much smaller is a piston at the top than at the skirt, and why?

Ans.: On a Ford, the piston is .010″ smaller across the head, and .005″ smaller at the second ring. The reason for the piston being smaller at the top is the fact that cast iron expands when heated, and the heat is greater at the top where the combustion takes place.

Q. 6: What is meant by an "oversize piston" and when is it used?

Ans.: A piston which is larger than the "standard size" is called an oversize piston. It is used when the cylinder is worn, by lapping the piston to a fit, and also when a cylinder is enlarged, by re-boring, grinding, or reaming.

Q. 7: Do some of the manufacturers adopt a "standard oversize piston"?

Ans.: Yes. The Ford has adopted three: a .0025″ (two and one-half one-thousandths); a .03125″ (thirty-one and one-quarter one-thousandths), and a .033″ (thirty-three one-thousandths of an inch).

Q. 8: When is the ".0025″ oversize piston" used?

Ans.: When the cylinder block becomes slightly worn, the .0025″ oversize can be lapped into the cylinder without enlarging the cylinder. After running a new car 4,000 miles with standard-size pistons, the cylinders usually wear enough to be able to fit this .0025″ oversize-piston without much trouble, and it is "run-in."

Q. 9: What is the diameter of a ".0025″ oversize piston"?

Ans.: The standard size plus .0025″.

Q. 10: What is the standard size of a Ford piston expressed in "decimals"?

Ans.: If the bore of the Ford cylinder is 3¾″, or 3.750″ (expressed in decimals), and the standard clearance is .003″, the piston should have a diameter of 3.750″−.003″=3.747″, which would be standard size. Owing to the fact, however, that the cylinders vary slightly, the standard diameter will vary accordingly. Therefore the fit of the piston to the cylinder should be a selective fit.

Q. 11: Would a .0025″ (two and one-half one-thousandths) oversize piston fit this cylinder?

Ans.: If the cylinder was exactly 3.750″ in diameter and the standard piston was 3.747″, a .0025″ oversize piston would mesaure 3.747″+.0025″=3.7495″ (3″ and 749½ one-thousandths); therefore, if the oversize piston measuring 3.7495″ was put into the cylinder measuring 3.750″, there would be .0005″, or only one-half of one one-thousandth of an inch clearance, and the piston would seize when heated.

Q. 12: Then if the .0025″ piston is only one-half of one one-thousandth of an inch (.0005″) smaller than the cylinder bore, this would be too tight, would it not?

Ans.: Yes, but it is assumed that the cylinder is worn somewhat, and the piston can be lapped to a proper clearance, if not worn sufficiently.

Q. 13: Would .002″ clearance answer?

Ans.: Yes. In fact, many Ford mechanics take out the standard-clearance pistons (.003″ size), even in new engines, and lap in the .0025″ oversize pistons with a .002″ clearance. An experienced Ford mechanic states that this is his remedy for a piston pumping oil. He states that he fits the piston until he can easily push it through the cylinders without binding anywhere, and then runs the engine idle for an hour or so, slowly, and with plenty of oil. A .002″ or .0025″ clearance is plenty, as Ford pistons are not polished.

Q. 14: When is the ".03125″ oversize piston" used, and how is it marked?

Ans.: The cylinder must be enlarged 1/32″ or .03125″, by boring, reaming, or grinding, to take this piston. The piston can then be lapped in enough to polish it. It is marked ".03125″−O.S." (O.S. means oversize.)

Q. 15: What is the diameter of an ".03125″ oversize piston"?

Ans.: The standard size plus .03125″, or 3.747″+.03125″=3.77825″.

Q. 16: How much would the cylinder be enlarged to take this ".03125″ oversize piston"?

Ans.: If the standard bore of the cylinder is 3.750″, then, if we take a .03125″ oversize piston, it would be enlarged 3.750″+.03125″=3.78125″.

Q. 17. Would this leave ".003″ clearance"?

Ans.: Yes. If the cylinder was enlarged to 3.78125″ and the diameter of an .03125″ oversize piston was 3.77825″, this would leave .003″ clearance.

Q. 18: Would you advise enlarging a cylinder to to 3.78125″?

Ans.: Enlarge to give a .002″ free-fit clearance after measuring the exact diameter of your piston, providing the engine is not used for long periods of time at full power, otherwise give .003″ free fit.

Q. 19: When is the ".033″ oversize piston" used?

Ans.: When the cylinder becomes worn after it has been enlarged for the .03125″ oversize piston, the .033″ oversize piston is used by lapping it in.

Q. 20: What is the diameter of an ".033″ oversize piston"?

Ans.: The standard size plus .033″, or 3.747″+.033″=3.780″.

Q. 21: What clearance would this ".033″ oversize" require to fit the cylinder?

Ans.: If the cylinder had been enlarged to 3.78125″, then it is assumed that there is wear; hence the reason for fitting the .033″ oversize piston. It is thus lapped in for a .002″ clearance.

Q. 22: Is it advisable to fit pistons of the same size to all cylinders?

Ans.: Yes, otherwise the engine will be out of balance.

Q. 23: What is meant by a "balanced engine"?

Ans.: This is a broad subject, but if all pistons are the same size, and all cylinder bores are uniform, then the cylinders will come nearer getting a uniform charge of gas; and this is still more true if all connecting rods weigh the same, and the crank shaft and flywheel are perfectly balanced. All reciprocating parts should be as light as possible.

Q. 24: What about "oversize piston rings" when fitting oversize pistons?

Ans.: Oversize piston rings should also be fitted. For instance, if a .0025″ oversize piston is fitted, fit .0025″ oversize piston rings; in like manner the fitting of rings should be correspondingly the same for .031″ and .033″ oversize pistons.

Q. 25. How much "clearance" should be allowed at the "gap of the ring"?

Ans.: The top ring should be given not less than .004″ nor more than .008″; the center ring may go as high as .012″, while the bottom or oil ring may have as high as .016″, since it is necessary that a small amount of oil work up between the piston and the cylinder walls.

Q. 26: How is the clearance measured at the gap of a ring?

Ans.: Place the ring in the cylinder and measure the gap with a thickness gauge. If the gap is too small, file.

Q. 27: How are the rings installed?

Ans.: Ford rings are cut .002″ taper, and should be installed with a file or punch mark-up.

Q. 28: Should a ring have equal pressure or tension at all points of its circumference?

Ans.: By all means. See the discussion on the subject of "Piston Rings."

Q. 29: Is "lapping" by hand advisable?

Ans.: No. The compound is liable to get into the bearings unless thoroughly cleaned out. After running a new Ford engine for 4,000 miles, it will be found that the cylinder will be worn sufficiently to take the .0025″ oversize piston, and the process would be to fit it so that the piston can be pushed through the cylinder without binding anywhere, and then to run-in with plenty of oil, slowly, for about two hours. This will take the place of lapping. If pistons are out of round, they will require reboring.

Q. 30: How would you "fit" a piston if you did not lap it?

Ans.: Place the piston in the cylinder and work it around. Take it out, and you will notice bright spots at different points where it binds. This is usually around the piston-pin hole. Then dress these high places down with a mill file and fine emery cloth, being careful to wipe off well with gasoline. Then follow the process of running-in.

Q. 31: What is meant by "running-in"?

Ans.: When pistons are fitted so that they can be pushed through the cylinder without binding, then connect up the engine and run it slowly for two hours, using plenty of oil. Then run the car for the first 200 miles not to exceed 15 m.p.h., using plenty of oil.

Q. 32: Suppose the piston fits too loose?

Ans.: Then try others, as Ford pistons vary. If these are still too loose, and the .031″ oversize will not go in, then you must enlarge the cylinder. When enlarging, however, do not make the clearance over .002″, and "run-in" the piston in oil. Pistons are not all exactly the same size, and are not polished. The high spots are dressed down with a mill file and fine emery cloth held around the piston in the hand while rotating it. The piston is then thoroughly cleaned with gasoline to remove all particles of emery and filings which would cut the cylinder if left on, and is then fitted to the cylinder and is run in.

Measurements of Ford Pistons

The diameter of pistons and the diameter of the bore of a cylinder may vary as much as .002″ from the following measurements:

Length: 3.808″ to 3.817″.
Diameter at skirt: 3.748″ to 3.749″.
Diameter at second ring: 3.743″ to 3.745″.
Diameter at top: 3.738″ to 3.740″.
Ring groove: ¼″ x 13/64″ deep.
Diameter of piston-pin bushing: .740″ to .741″ (15/16″ dia. x 1 7/32″ long), phosphor bronze in pairs.
Diameter of piston pin: .740″ to .741″ (47/64″).
Length of piston pin: 3½″.

Piston Replacement

The three following conditions make it necessary to replace a piston: (1) scored pistons; (2) leaky pistons; (3) undersize pistons.

The scored piston, if it is not too badly scored, may be dressed off with a mill file. However, this practice is not recommended unless the mechanic is skilled in the use of a file. Again, a scored piston usually means a scored cylinder, which requires enlarging the cylinder, and fitting an oversize piston.

Leaky pistons are found by setting the piston bottom side up in a pan of gasoline, or by pouring about 1″ of gasoline into the interior of the piston. The gasoline will seep through any leak.

Undersize pistons cause excessive wear on the walls of the cylinder and cause the engine to knock. A cylinder may be made to hold compression by fitting new rings on a badly undersize piston, but because of the wear on the block, such practice is false economy.

On the Ford car the piston is fitted to the cylinder bore so that it is tight on .004″ and loose on .003″. Commercial repair jobs may be fitted tight on .006″, but this high limit may result in a piston slap.

Owing to the jar and rough handling in shipping, and the various methods used in storing the pistons, they become out of round. In fitting a piston it is therefore necessary to watch for this condition.

Where speed is desired, the lower part of the piston is frequently drilled with holes, and the piston is made of aluminum alloy, or of light construction, to lighten it as much as possible (see Index under "Tuning engine for speed").

Note. When replacing a piston, always replace it on the same cylinder from which it was removed, as each cylinder usually varies in bore to a slight extent.

CYLINDER REPAIRING

When an engine runs without oil, the cylinder wall may become scratched or "scored." In fact, cases have been known where the cylinder was getting plenty of oil, yet, if the rings were loose, the flame from the combustion would work past the loose ring and prevent it from receiving proper lubrication, causing it to heat and cut the cylinder.

The cause of a scored cylinder is lack of oil, and is frequently the result of a loose piston pin, which scores or cuts the cylinder wall, thereby permitting a leak between the wall of the cylinder and the ring.

A scored cylinder can be repaired only by re-boring, reaming, or grinding. This is a job that ought to be done where a special re-boring or re-grinding machine is installed. When a cylinder is enlarged, **oversize pistons and rings** must be fitted.

If the cylinders are not scored too deep, they can be lapped in with an old piston covered with oil and emery, as stated on page 816, or scores can be **filled,** if the cylinders are not out of round.

Repairing scored cylinders: One method is by fusing silver nickel alloy into the scores and regrinding the bores. This is called the Lawrence process, and is controlled by the L. Lawrence Co., 292 Halsey St., Newark, N.J.

Another method is known as the Eagle process, controlled by the Eagle Machine Co., Indianapolis, Ind. Copper alloy is inlaid and rolled into the scores which have been dovetailed, thereby making the alloy a part of the cylinder.

The third process is known as the Bull-Dog process, controlled by the Metal Repair & Supply Co., Washington, D.C. In a way, it is a combination of the two methods mentioned above, since the score is dovetailed and a metallic filler of high melting point is fused into it.

Seized pistons also cut the cylinder walls and the piston itself.

A "seized" piston is where the piston is stuck to the cylinder wall, and this, in turn, is caused by excessive heat which can be due to lack of water or lubricating oil, or running a new engine at too high a speed.

Remedy for a seized piston: Occasionally the repairman receives a call to start an engine that has the symptoms of a seized piston, and that has resisted the best efforts of owner of the car to start it. At such times the repairman must exercise the utmost ingenuity, for the owner has generally tried all the easy methods before he arrived.

In such cases, the first thing to do is to make sure that it is the engine and not some other part of the transmission or the rear axle that is at fault. The rear wheels should be jacked up, the emergency brake released, and the gear-shift lever placed in neutral. The wheels should turn freely, and there should be no binding in the rear axle system.

The spark plugs should be removed, or the compression cocks opened, to relieve the compression. Then if the crank cannot be turned over by hand or by means of the starter, or by the two working together, the car may be towed with the gears in high and the clutch disengaged. As soon as the car has attained some momentum, the clutch may be allowed to engage gently, care being taken not to allow a sudden motion which might strip the gears in the rear axle, or even break a shaft.

If this does not free the engine, kerosene can be poured into the cylinders and allowed to remain for a couple of hours. This will have a tendency to dissolve any old oil which may have gummed the pistons to the cylinder walls. Then the car may be towed again, and an attempt made to turn over the engine by engaging high gear. The engine can be turned over more easily in high than in low gear because it does not have to revolve so rapidly.

After one has succeeded in turning over the engine, one should open the drain cock in the bottom of the crank case and drain out the mixture of kerosene and old oil thoroughly. Then the new oil should be added, the radiator should be filled with hot water in order to expand the cylinders, and the spark plugs should be replaced. After starting, the engine should be run slowly under its own power for some little time, in order that the new oil may work to all parts.

The first troubles caused by worn or scored cylinders are fouled spark plugs and excessive carbon deposits resulting from oil leaking past the piston and rings. Compression also escapes by the worn parts, causing loss of power and wasting gas and oil. A very annoying knock or clatter, known as "piston slap," soon develops. The longer the engine runs, the worse this condition becomes. An engine in this condition is not only wasteful, but also very noisy.

When a cylinder is cut or scored, but not worn, and is not out of round, then the score or cut can be "filled," as stated on this page. In this instance the original or **standard-size piston can be refitted,** if of the correct clearance.

If the cylinder is worn out of round (and it is usually out of round when worn), then it will be necessary to enlarge the cylinder bore and fit oversize pistons and oversize piston rings.

Usually, when a cylinder wears, it wears where the rings travel, which is the upper part of the cylinder. The lower part of the cylinder may measure true, but when measuring the upper part, where the rings travel, it will more than likely be found to be out of true. If, on observing the rings, a black spot is found on the ring and it is not smooth, either the ring has lost its tension at this point or the cylinder is out of round. The result is that the cylinder leaks compression, pumps oil, fouls the spark plugs with oil, and consumes oil and gasoline all out of proportion to the power delivered.

When a piston is too loose or the cylinder is worn, then a "piston slap" develops, which not only causes a knock, as explained on page 779; but in all probability the cylinder will be worn at the upper point, on one side, owing to the explosion pressure forcing the piston, at an angle, constantly against the wall of the cylinder. This permits gasoline to pass into the crank case and to thin the oil, and also permits oil to pass into the combustion chamber. A bent connecting rod will also cause a piston slap. See also page 802.

To test a cylinder to see if it is out of round, an inside micrometer caliper (page 810) is necessary. The cylinder should be tested from top to bottom carefully and thoroughly. If out of round .003″ or more at any one point, then the only safe remedy is to have it re-ground and new pistons ground to fit. After an engine is run 20,000 to 30,000 miles, it most likely needs re-grinding.

To test a piston, an outside micrometer is used. The piston, of course, will measure less at the top than at the skirt, but it should be true. If it is not true, or if the clearance between piston and cylinder wall is greater than normal, then a new piston should be ground to fit the cylinder. Pistons out of round cause oil pockets, which results in an excess of oil entering the combustion chamber.

When and How Much to Enlarge a Cylinder

The following will determine the necessity of enlarging a cylinder: (1) the cylinder condition; (2) the piston condition.

To determine how much to enlarge a cylinder, depends upon how much out of round, how badly worn, or how deep the cut is. Usually, one of the dimensions stated, or the S. A. E. standard oversize for pistons (below), will meet all conditions. One must be careful, in enlarging a cylinder, to see that the wall of the cylinder is thick enough to stand the enlargement.

No uniform practice has hitherto existed as to the amount of metal to be removed in re-grinding worn cylinders, with the result that difficulty is experienced in securing new pistons of correct size from the manufacturers.

Oversize Cylinders (S.A.E. Standard)

With a view to eliminating all unnecessary expense and delay, **the following standards have been adopted by the Society of Automotive Engineers,** and pistons to correspond can be obtained from most engine manufacturers.

10 one-thousandths of an inch (.010″) large for 1st
20 " " " " " (.020″) large for 2d
30 " " " " " (.030″) large for 3d
40 " " " " " (.040″) large for 4th

The meaning of 1st, 2d, 3d, and 4th is this: If the cylinder is scored or cut, say, .009″ deep, then bore it to fit a .010″ oversize piston. (Or enlarge the bore to the original diameter, + .010″.) If cut .011″, then bore it for a piston .020″ oversize—but not between the two. In other words, a number of automobile manufacturers furnish pistons larger than their standard product by increments of .010″, thus making it possible to re-grind scored or worn cylinders to these S. A. E. standards and to procure pistons from stock.

Cylinder and Piston Information

What constitutes a perfect cylinder? A cylinder block, before it is machined ready for use, has holes in it which represent the cylinders, but are considerably smaller than the size required. For instance, if the cylinder is to be 4″ in diameter, when machined and ready for use, the original hole will be about ¼″ smaller. This is because it is impossible to cast a perfectly smooth and true surface, and the holes, or cylinders, must be bored out by machinery to arrive at this result. A cylinder-boring machine is used for this, and generally two cuts are made in the cylinder, a cut which removes all the material except just enough to be taken off in the finishing cut, which is a very fine cut. Sometimes a third cut is necessary to obtain the exact size, and when this is completed the cylinder walls are perfectly straight from top to bottom. **The cylinder is perfectly round and the surface of the wall is nearly as smooth as polished glass. A cylinder in this condition is said to be in perfect condition.**

Examine the condition of the cylinders in a job. First, see if the cylinder walls are perfectly smooth and free from scores or scratches. Second, **see if the diameter of the cylinder is the same throughout,** that is, beginning at the top and measuring the diameter about every inch of the depth of the cylinder. Having done this, determine whether the cylinders need repairing. If the scores or scratches are very slight, they may be remedied by lapping, but if they are too prominent they must be re-bored. The lapping process may be done without any special equipment, but the re-boring requires a boring machine, or at least a special boring tool which can be operated by the lathe by hand.

When a cylinder requires lapping or re-boring, it is understood immediately that the old pistons are useless, so far as this particular job is concerned. Lapping or re-boring increases the size of the cylinder, and the pistons which undoubtedly are worn considerably will be too small.

There are several methods of lapping cylinders. Since the old piston will be of no further use, it probably will be the handiest to use. Remove the connecting rod and attach the piston to a shop-made lapping bar. Apply a moderate quantity of fine valve-grinding compound, thinned with engine oil, to the outside wall of the piston and insert it in the cylinder. Work the piston up and down in the cylinder with the same motion as that described for valve grinding. Keep this operation up for a few minutes and withdraw the piston. Wash the cylinder thoroughly with gasoline, and wipe it dry with a soft cloth. Examine it now to see how nearly it presents a fine, smooth surface. When sufficient lapping has been done to restore the prefect condition of the cylinder, it is ready to be measured for diameter. This measurement is noted, and when making or ordering a new piston, it is made about 0.003″ smaller than the new bore. About 0.003″ is the proper clearance between the piston and cylinder wall of 4″ bore.

There are cases when the scoring of a cylinder is so bad that lapping would be useless, and the cylinder must be re-bored or reground. In this case the most satisfactory results are obtained by turning this part of the job over to a machine shop that is specially equipped for this class of work.

Remarks on Piston and Rings

Next in order are the pistons and rings. Very much the same can be said of the pistons as has been said of the cylinders. Their wearing surfaces should be perfectly smooth, the same as the cylinder wall, but if their surface is badly scored or scratched there is no repair for them.

When a piston is perfect except for a small amount of even wear, for instance, 0.002″ or 0.003″ too small, the trouble can be remedied by heating and expanding the old piston. The heating is done in charcoal, and should be done very slowly and carefully. After the piston reaches a red heat, permit the charcoal fire to die out slowly so that the piston is cooled in its charcoal bed. Pistons can be expanded to as much as 0.004″ in this manner, if the work is done properly.

Piston rings loose their tension after long use, and cease to have enough strength to press against the cylinder wall all around. As a result oil is permitted to pass by them and to enter the combustion chamber. Besides, compression sometimes is lost because the gas is permitted to escape past the rings. Excessive oil coming up into the combustion chamber is one of the first indications of poorly fitting rings. If plain rings are to be fitted, care must be taken to fit them properly. The gap between the ends should not be less than 1/64″ nor more than 0.020″. In the case of fitting patented rings, the manufacturer has a specially machined ring for each type of engine, and it would be well to specify the make and model of engine when ordering. If the engine has been rebored, the amount of oversize should be stated. (*Motor Age.*)

Lapping Piston and Rings to a Cylinder

Lapping piston and rings: When a new set of pistons and rings is installed in a cylinder which has been worn slightly out of round, the practice is to "wear in" or "lap in" each piston asembly for a few moments by moving the piston assembly slowly up and down in its proper cylinder after carefully coating the cylinder wall and the piston assembly with a fine "lapping compound."

When this practice is employed, **care must be used to remove all particles of grit from the cylinder wall or the piston assembly** by a liberal washing in kerosene of all parts to which the "lapping compound" has been applied. Thorough workmanship also demands that the rings be removed from the pistons before washing, in order that no particles may find lodging behind the piston rings. These particles of grit might later find their way out and perhaps severely score the cylinder wall or ruin the bearings in the engine. Replace each ring in the groove from which it was removed.

Lapping Slightly Scored Cylinders

If the cylinders are slightly scored, they can be lapped with an old piston. It is not desirable to use a new piston, because it will be worn away. For the same reason new rings should not be used in the piston during the lapping process.

If the cylinders are badly scored, an old piston with old rings should be used, and after all marks are removed the new rings should be lapped in place, using an old piston.

When the cylinders are badly scored, an expanding lapper may be used instead of the old pistons.

Aluminum pistons cannot be treated in the same way as cast-iron pistons, because they are too soft. High spots on the pistons may be removed by means of a semi-cylindrical brass lap into which the piston fits.

Lapping Rings to Cylinder

If the cylinder surfaces are in good condition, only the rings need be lapped. The purpose in lapping the rings is to make them fit tightly against the cylinder surfaces at all points.

The lapping process consists in moving the rings back and forth in the cylinders in connection with a mixture of ground glass and cylinder oil, or carborundum and cylinder oil. The abrasives should be the finest obtainable.

When the rings bear all around, the work is finished. This can be seen with the naked eye. See also paragraphs above, under "Lapping Piston and Rings."

Another lapping compound for piston, rings, etc., is engine oil or coal oil and flour of emery. For a very fine finish use valve-grinding compound secured at supply stores. It is often made of crocus, which is finer than emery and is usually used on razor strops. A compound for this purpose is the Clover Lapping Compound. Write for a free pamphlet on this to the Clover Mfg. Co., Norwalk, Conn. This concern supplies compound for grinding or lapping pistons, rings, and crank shaft bearings, and for grinding valves, etc.

Note. It is advisable not to use any compound in which there is emery, as it tends to imbed itself in the parts and is difficult to clean out. A mixture of rotten stone ground to a paste with oil and applied to the rings serves very well for lapping and can be cleaned off more readily.

Lapping Methods and Devices

Lapping new pistons into cylinder for clearance is done when the new piston will go into the cylinder but with not quite enough clearance.

Lapping the cylinder for a new piston is done when the piston is slightly too large to go into the cylinder. An **old piston** is split so that it will expand and the cylinder walls are lapped down with it so the new piston will fit with proper clearance.

Lapping the cylinder for a slight score is done with an **old piston** split, and **oversize piston** must then be used.

Lapping rings into the cylinder can be done with new or old piston.

The following illustrations give an idea as to the different devices used for lapping a cylinder.

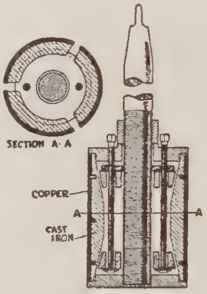

Fig. 12

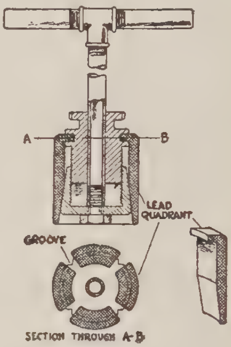

Fig. 13

Fig. 12. A simple design of an expanding lapper. Such a tool as this may be used in the drill press, an up-and-down and rotary motion being supplied at the same time.

Fig. 13 shows another tool of this type. Its construction will be readily understood.

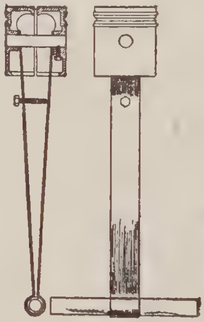

Fig. 14

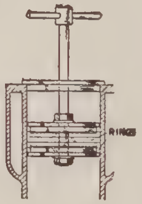

Fig. 15

Fig. 14. An expanding piston lapper which may be used for lapping rings or cylinders. The two operations should not be simultaneous, however. When the cylinders are slightly scored, the marks should be removed first, and then the new rings should be lapped in.

Fig. 15. When no piston is available the rings may be lapped between two blocks of wood as shown.

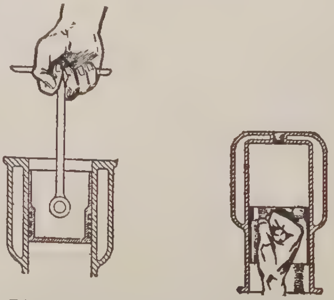

Fig. 16. Rings may be placed in an old piston. A new piston should not be used because it will wear away to some extent, and this is objectionable. The illustration shows two methods of accomplishing this.

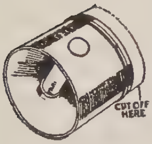

Fig. 17

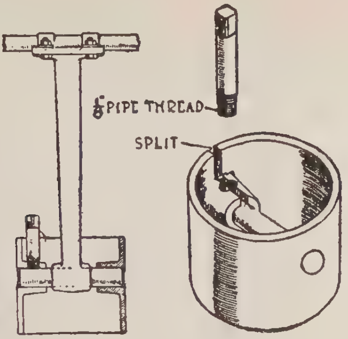

Fig. 18

Fig. 17. **Another method** is to cut off the head of the piston and to use the wristpin for a handle, as shown in Fig. 16.

Fig. 18. **An expanding cylinder lap,** made from a worn-out piston. The head of the piston is removed. One wristpin bearing is tapped; the piston is then split, as shown in the right-hand cut, so that a plug screwed into the tap hole will cause the piston to expand. An old connecting rod and handle is then provided as shown in the left-hand cut. Ground glass and oil are used for a lapping compound. (*Motor World.*)

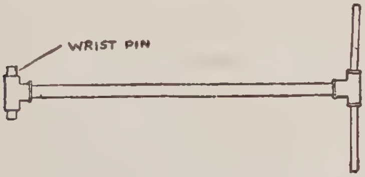

Fig. 19. **Piston lapping handle.** When it is desirable to lap a piston of a detachable-head engine without removing the cylinder casting, the tool shown is a time-saver. It is made of ordinary ½″ pipe, a T at the lower end slipping over the wristpin of the piston. The wristpin used in lapping should be made of fiber, as a metal one is likely to score the cylinders. Ground glass and crocus mixed in equal parts are used at the finish, and ordinary valve-grinding compound at the start.

Questions and Answers on Enlarging Cylinders

Q. 1: When should a cylinder be enlarged?

Ans.: When it is badly scored, worn, or out of round more than .003″. See pages 811, 814, 818.

Q. 2: How can you tell if it is out of round?

Ans.: By measuring with an "inside micrometer," as described on page 810.

Q. 3: Suppose it is not out of round but cut, should it then be enlarged?

Ans.: No; it can then be "filled," as described on page 814.

Q. 4: How much should it be enlarged if out of round?

Ans.: Enough to have it perfectly true.

Q. 5: How is a cylinder enlarged?

Ans.: By grinding, boring, reaming, or lapping.

Q. 6: Which is the best?

Ans.: Grinding. Boring, on a special boring machine is next best. Reaming is third best. Lapping would come fourth. See pages 821, 815 relative to lapping.

Q. 7: How is a grinding machine operated?

Ans.: Grinding is done on a special grinding machine, employing a wheel made of abrasive material revolving at a high rate of speed on the end of a rigid spindle. The spindle at the same time moves in a circular path, so that the revolving wheel travels around the hole. The path of the spindle is adjustable to the diameter of the hole. The cylinder is held stationary, and a multiple cylinder block can be ground without moving it, thus insuring all cylinders being perfectly round, smooth, straight, and square with the base of the cylinder casting. Grinding gives a true, smooth surface and no matter how hard or soft the material, the grinding wheel will grind it just the same. A lathe tool cannot leave a cylinder as smooth as a grinding wheel.

Q. 8: How are cylinders bored?

Ans.: By placing them in a lathe; by placing them in a drill press; by placing them in a special boring machine.

When placing a cylinder on the face plate of a lathe, a long boring bar is used. The cylinder, unless clamped securely, will move and ruin the job. Other disadvantages are that the long boring bar is likely to vibrate or jump and slide over a hard spot without cutting. Furthermore, the cylinder must be moved and reset on the face plate, if a multiple cylinder block, thus requiring skill to bore each cylinder straight with its base. A lathe tool cannot leave a cylinder as smooth as a grinding wheel. When placed in a drill press, this is better than on a lathe, as the cylinder does not revolve, and can be held more securely, but otherwise there are the same disadvantages. When placed in a special boring machine, the work can be done better than on a lathe or drill press, as the cylinder is held securely in place and the boring-bar spindle is heavy and rigid.

Q. 9: How are cylinders reamed?

Ans.: Cylinders can be reamed on a drill press (see page 694), or by a reaming outfit which can be attached to cylinder block (page 714). The disadvantage of reaming, to enlarge a cylinder, is the tendency of the reamer to follow the course of the old hole, thus preventing it from making a new and perfect hole. It is also necessary to take a deeper cut than would be necessary if grinding. Reaming can be done without removing engine, and thus costs less.

Q. 10: Is it necessary to fit larger pistons when a cylinder is enlarged?

Ans.: Yes; oversize pistons must be fitted as directed on pages 811, 824, and oversize rings must also be fitted to piston (page 828).

Q. 11: Would you advise sending a cylinder to a specialist to regrind, and do you advise having the entire block reground?

Ans.: Yes. If you wish a perfectly balanced engine it is best to have the block reground, especially if the engine has been run 20,000 to 30,000 miles. Also have oversize pistons ground to fit each individual cylinder. Read also answers to questions 4, 3, and 2, page 824.

The best plan is to have cylinders reground and have new pistons ground to fit each individual cylinder, with new rings, and in this way you will obtain a job that will give full power to the engine. After having cylinders reground and pistons and rings fitted, it is necessary to run the engine the first 500 miles at not over 15 m.p.h. and to use a lot of oil.

Q. 12: What are the symptoms of a worn or cut cylinder?

Ans.: Lack of power, heavy fuel and oil consumption, smoke, fouled spark plugs, and a piston slap. See answer to question 1, page 809, 817.

Q. 13: Where do cylinders usually wear?

Ans.: In the space where the rings travel. If the piston is loose, then the constant pressure from explosion force will wear the cylinder on one side, near the top, owing to the piston striking the cylinder wall at an angle.

Q. 14: Isn't it possible to fit oversize rings to a worn cylinder?

Ans.: Yes, but it is not altogether satisfactory, because the wear is usually where the rings travel, and in order to fit the rings, they must go in at the open end which is not worn. In this instance the rings are filed at the gap, so that they will pass the lower part; then they open up at the point where the cylinder is worn. If the cylinder is oval, then no round ring can fit it true (this also applies to pistons).

Q. 15: Is it advisable to lap oversize pistons to a worn cylinder?

Ans.: The piston or lapping tool is sure to follow the old hole. Thus, while lapping may improve conditions, it is impossible to make the cylinder perfectly round, if it is out of round. If the cylinders are perfectly round and the pistons are too small, then oversize pistons can be fitted. See also, Ans. 14.

Q. 16: Are all high-grade engine cylinders ground?

Ans.: Yes, and heat-treated, or seasoned castings are used and ground pistons are fitted to each individual cylinder. Almost all cylinders, when new, are first bored to within about .005″ of size, and then ground. Read the answer to question 4, page 809.

CYLINDER, PISTON, AND CRANK-SHAFT GRINDING AS A BUSINESS

The following material is taken by permission from the copyrighted 116-page booklet (price 50c.) issued by the Heald Machine Co., Worcester, Mass., manufacturer of cylinder-grinding machines. This book discusses the following subjects:

> "The Field and Profits; Equipment and Component Parts; Reasons, Advantages, and Methods of Refinishing Cylinder Bores; Kinks and Time-Savers; Operation of the Heald Machine; Advertising and How to Get Business; Facts Worth Considering."

Reground cylinders fitted with new pistons and rings will give the engine as much, if not more, power and pep than when it was new. It cuts the oil and gas consumption in two, and stops all excessive smoking.

It has been shown that quite a virgin field presents itself in the smaller shops, because on a small investment they can often place themselves in the class with the larger shops. Many of the small shops are fully equipped with the exception of a grinder.

There is no business today that has the possibilities and which fits so nicely into a small machine shop, automobile repair shop, or a concern doing welding as the regrinding of worn or scored cylinders.

The field for regrinding: There were over 9,000,000 commercial and pleasure cars registered during last year. Truck and tractor cylinders require attention once a year. Passenger cars should be looked over at least once every two or three years. Figure out for yourself what your chances are with only approximately 350 concerns properly equipped for such work. Consider also the fact that 3 four-cylinder blocks a day will bring profitable returns.

No one knows so little about cylinder regrinding as the average repairman. The car manufacturers as, for instance, Brewster, Cadillac, Cunningham, Dorris, Franklin, Hudson, Lafayette, Lincoln, Locomobile, Marmon, Mercer, Packard, Peerless, Pierce-Arrow, Stevens-Duryea, Stutz, and Winton, have their cylinder bores ground, and Heald machines are used for the purpose. Many engine manufacturers, such as Continental, Beaver, Buda, Herschell-Spellman, Lycoming, Duesenberg, Teetor, Erd, Fales, Hercules, Waukesha, Midwest, Rutenberg, have long since recognized this as the best method of finishing cylinders. Many of the repairmen advocate it; but to the owner it still means an unnecessary operation—only another way to add a few more dollars to his already overtopped garage bill.

It is, however, so vitally important in helping the engine to function properly that careful thought and study should be given it by every driver.

Prices Charged for Regrinding

As for prices that are charged for regrinding, they vary in different sections of the country, as well as in the localities in the same sections. It is best to get several price lists from the nearest concerns doing business, and to charge according to the conditions in your particular city. Never cut prices under a competitor, as regrinding is a quality proposition and it will cheapen your work and eventually be a losing proposition.

On the other hand, remember you cannot make a fortune overnight. Excessive prices will simply be an incentive for your customers to buy new blocks or to refinish by the boring method.

Average Prices in Different Parts of the Country for Regrinding Cylinders

Size	Cyl.	East	South	High Middle West	Low Middle West	Far West
Under 3″	2	$22.50	$24.00	$23.00	$17.00	$28.00
	4	43.00	41.50	45.00	34.00	42.00
	6	58.00	60.00	64.00	51.00	60.00
	8	74.00	77.00	83.00	66.00	76.00
	12	109.00	100.00	120.00	101.00	107.00
From 3″ to 3½″ dia.	2	22.50	27.00	24.00	18.00	32.00
	4	46.00	45.00	48.00	36.00	50.00
	6	59.00	64.00	68.00	53.00	71.00
	8	75.00	79.00	87.00	68.00	90.00
	12	114.00		131.00	106.00	128.00
From 3⅝″ to 4″ dia.	2	24.50	29.00	28.00	23.00	36.00
	4	44.00	49.00	54.00	42.00	58.00
	6	66.00	70.00	76.00	63.00	81.00
	8	82.00		104.00	85.00	104.00
From 4⅛″ to 4½″ dia.	2	25.00	35.00	32.00	24.00	43.00
	4	50.00	55.00	60.00	46.00	69.00
	6	68.50	77.00	84.00	68.00	97.00
From 4⅝″ to 5″ dia.	2	28.00	37.00	35.00	26.00	49.00
	4	53.00	62.00	67.00	50.00	79.00
	6	72.50	82.00	93.00	73.00	111.00
From 5⅛″ to 6″ dia.	2	28.00	40.00	42.00	26.00	60.00
	4	55.00	66.00	78.00	50.00	93.00
	6	72.50		130.00	73.00	136.00
		Prices without pins				Prices with Pins

Parts to Carry in Stock

For small concerns starting in the re-grinding business, it is by all odds more desirable at first to buy pistons, rings and wrist pins in various sizes from the manufacturers of these parts, confining all the efforts to re-grinding and fitting up the component parts. In this way a large volume of business can be done with a very small organization, and thus a very tidy profit can be made.

A certain amount of stock of all these parts should be carried, depending on the class of trade, the distance from the source of supply, and the size of the shop.

Pistons can be carried in three different stages of completion: rough, semi-finished, and finished, depending on whether the equipment of the shop will take care of the rest of the finishing operations.

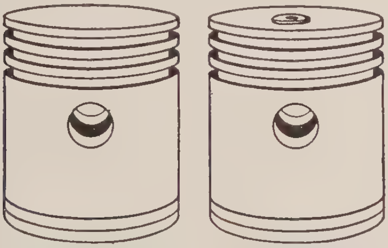

Fig. 20

Finished pistons are furnished finished complete, minus rings and pins; but these in many cases will be included, if so ordered. They usually come in oversizes of standard, .003″, .005″, .010″, .015″, 020″, .025″, .030″, and .040″.

Semi-finished pistons are finished with the exception of the outside diameter, which is left large to be ground down to the required diameter, and the wristpin holes which are rough-reamed and must be finished-reamed.

Finishing Semi-Finished Pistons

There is one operation on pistons that can be nicely taken care of by practically all re-grinding concerns, and that is the finishing of the outside diameter.

Most piston manufacturers will furnish them finished or semi-finished. By using a semi-finished piston, which usually comes 1/16″ oversize, and grinding it down to fit the bore, not only will it increase production, but it will allow the carrying of a larger supply on the same investment.

Finished pistons will change, even when bought from the best of manufacturers, and will frequently be found out of round. (A slight tap with a wooden hammer when fitting out-of-round pistons to holes will usually bring them back.)

In finishing the outside of the pistons a suitable external grinding machine must be obtained, as the cylinder grinder is of no value for such work. In securing such a machine, it is well to keep in mind two facts: that the length of a piston seldom exceeds 6″ or 8″, and the diameter, even on the larger sizes, does not ordinarily run over 5″. Therefore a small-size external grinder that will swing 6″ or 8″ with sufficient length between the centers is very satisfactory.

The pin holes on semi-finished pistons come rough-reamed with .002″ or .003″ left for finish-reaming. Any good adjustable hand-reamer will take care of this.

Remember, that in finishing the outside diameter, the lands should be relieved and made smaller than the skirt by at least .008″ or .010″. The excess heat and solid metal cause greater expansion at this point.

Always measure a piston below the wristpin hole, and not above it on the head.

Crank-Shaft Grinding

An allied line which fits in very nicely with cylinder grinding is that of crank-shaft grinding. Too much cannot be said about the importance of keeping a crank shaft in perfect condition. The crank shaft, virtually the backbone of the motor, when sprung out of alignment or when its journals are worn out of round, will soon wear the main bearings and connecting-rod bearings which bear directly on the shaft; consequently it will cause the motor to knock.

It is impossible properly to fit a set of bearings to a shaft which is out of round or out of alignment, and the extra time consumed in obtaining even a fair job would more than pay for re-grinding of shaft.

There has, however, been a great deal of misunderstanding regarding actual crank-shaft grinding.

By the old method of filing, lapping, and polishing a shaft—a slow and expensive operation, which is often misconstrued as grinding—it is impossible to obtain accurate results. This work should be done on machines built especially for crank-shaft grinding.

Equipment Required[1]

To do re-grinding, or to fit pistons, rings, and pins successfully, one must have the proper equipment. We have listed below the machines and accessories that make up such a shop. Prices for these will vary, especially if second-hand tools are used. Therefore it is hard to state any given value. All local machine-tool dealers will be glad to fill these in, and the amount of capital required can be determined at that time.

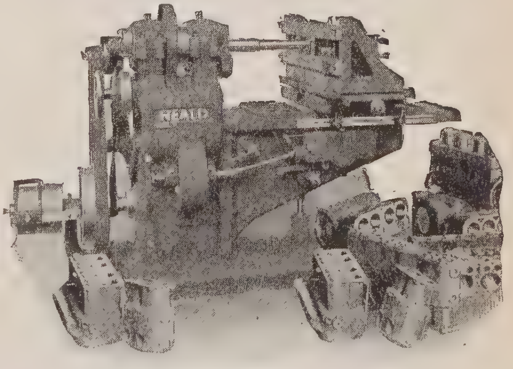

Fig. 21. A Heald cylinder grinder.

Machines Needed for the Average Shop

One style No. 55 or 65 Heald cylinder grinder fully equipped.
One small external grinder.
One 12″ lathe.
One 16″ lathe.
One sensitive drill press.
One back-geared drill press.
One 15 h.p. motor.
One emery stand.
Expanding reamers, sizes ⅝″ to 1½″.
Shafting hangers and belts.
Benches and tools.
Supply of pistons, rings, and pins.
Office equipment.

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[1] From copyrighted booklet of Heald Machine Co., Worcester, Mass.

This comprises a fully equipped shop planning to use semi-finished pistons. For anyone just starting in, it is possible to do away with part of this equipment. By using finished pistons, it will not be necessary to have an external grinder; and while two lathes are much more convenient, the 12″ one will handle the work very nicely, and for the work which you would ordinarily use the back-geared drill press for, such as drilling wristpin holes, a lathe will answer the purpose.

When to Grind

Passenger cars: Cars that do not run tight, that use an excessive amount of gas or oil, lack power or pep, or smoke, need overhauling. A disagreeable piston slap is a sure sign of worn cylinders. This is usually heard on hills, or when the engine is laboring hard.

After it is taken down, it can best be determined whether it needs to be re-ground or not. If found scored, out of round, or with excessive clearance between the piston rings and cylinders, the cylinders certainly need regrinding.

All cars that have been run two or three years should be pulled down, re-ground, and fitted with new pistons and rings.

If the cylinders have been welded for any purpose, such as a score or a crack, they must be re-ground. Welding distorts and changes the shape, in addition to leaving excess metal. Only by being re-ground can it be brought back to a true, round, smooth hole.

With commercial cars or tractors, the same reasons for re-grinding hold true as with passenger cars. They are usually worked constantly to their full capacity, and are required to perform tasks which require every ounce of power.

Tractors, in particular, are subject to excessive wear, owing to the conditions under which they must work, and to the dust and dirt working into the engine. Re-grinding should be done at least once a year.

Why Engine Cylinders Should Be Re-Ground

It is essential, in order to have an engine run properly, that the cylinders be re-ground so that they do not vary more than a .001″ as to roundness. The hole must be straight and absolutely square with the base of the cylinders, otherwise there will be a noticeable loss of power and pep, excessive use of gas and oil, piston slap, continual fouling of the spark plugs, and general troubles of all kinds.

Compression

It is necessary that a cylinder bore be straight and round to obtain the proper compression. You cannot fit a ring and have it tightly seal a cylinder with an unround hole or one which has been enlarged in the top, either by error or inaccurate machining. Compression means a live engine, and rings must fit the hole. See also page 765.

Waste of Oil and Gas

When an engine has lost its compression, and knocks on the hills, etc., the owner usually makes the mistake of trying to cure the trouble by enriching his mixture. While this will temporarily cure the trouble, an excess of raw gasoline in the cylinder, on the compression stroke, is forced past the rings, thinning the oil and destroying its lubricating qualities, and possibly resulting in scored cylinders.

This gasoline eventually reaches the crank case, where it thins the oil to such a degree that it is useless as a lubricant. Old and worn cylinders are not the only places where this happens, as it also occurs in many motors where the holes were not originally ground, but were inaccurately bored or reamed.

Thus not only is excess gas being used in proportion to the power secured, but a large share of oil is going off in smoke, or is being rendered useless, thus requiring constant renewal.

Missing

Ill-fitting rings not only allow leaking of gas, but on the suction stroke air is sucked up from the crankcase, thinning the mixture and causing the engine to skip. This is particularly noticeable when traveling at idling speeds or starting on cold mornings.

Carbon

When the oil gets by the piston rings into the combustion chamber and is burned by ignition, it gives off a bluish smoke, leaving carbon formed on the head of the piston and in compression chamber.

Carbon holds heat, and if the compression is high, it will often explode the mixture earlier than it should. This is called pre-ignition, and it very often results in a broken piston pin, bent connecting rods, or a scored cylinder. Of course, burned oil soots the spark plugs and requires constant cleaning to keep a hot spark.

Engine Knocks

There is nothing more aggravating to the driver than to have his engine knock. Some engines have such a thick carbon deposit that the slightest pull will result in this annoying sound. This condition is all caused by oil leaking past the rings into the combustion chamber, where it is burnt by ignition.

Are Re-Ground Cylinders, with Pistons Ground to Fit, Better than New?

When the statement is made that a re-ground engine which has been fitted with new pistons and rings is better than it was originally, few people can understand why. It is a well-known fact among those connected with the metal industry that castings change shape after they are cast. This is caused by strains and stresses resulting from the heavier walls of metal cooling last and shrinking from the already cooled lighter walls.

These strains can be relieved if the castings are seasoned for a long time, or by heat-treating processes.

Castings that are immediately machined and put to work in a car change more or less, owing to the heating and cooling of the engine, which acts as a heat-treating operation. Therefore, an engine which has been run several hundred miles is thoroughly seasoned and is in ideal condition to be re-ground and fitted up.

Once having been relieved of all the strains and stresses, the castings will retain their shape continuously after grinding, if properly machined and fitted up.

Actually, of course, an engine does not have any more power after re-grinding than that for which it was originally designed.

The fact, however, that the casting is seasoned, and that each hole has had individual attention, often gives better results than a general-assembly proposition. (*Motor Age.*)

DIFFERENT METHODS OF FINISHING BORES OF CYLINDERS

Methods of Finishing Bores

There are four methods of enlarging cylinders: (1) by boring; (2) by reaming; (3) by lapping; (4) by grinding.

The prime object of either operation is to **finish** the cylinder, so that it is absolutely round and straight, and then to fit the cylinders with new oversize pistons and rings.

The following discussion of the advantages and disadvantages of each method is taken from the instruction book of the Heald Machine Co.

Reboring Cylinder

Boring is done by a steel-cutting tool in the same manner as that in which a lathe cuts. It produces a porous-like surface which is subject to rapid wear.

When a cylinder is re-bored, the tool must get under the hard surface skin of the worn and polished cylinder wall, and as a result a heavy cut, as compared with grinding, must be taken. Therefore, the cylinder bore is enlarged 5 to 10 times more than is necessary and the walls are often reduced in thickness to a dangerous degree.

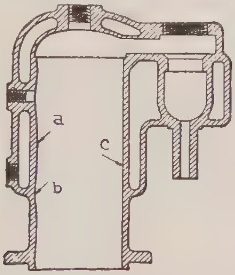

Fig. 22. Cross-section of a gas-engine cylinder.

With the re-boring method, a considerable amount of pressure will be exerted on the walls of the cylinder. Since these walls are comparatively thin and are reinforced only by the water jacket in certain places, it will be found that the walls where they are not reinforced will spring away from the cutting tool, when it springs back after the tool passes on, leaving an elevation, shown at (a). Where the walls are reinforced, the tool will take a slightly heavier cut, as at (b) (Fig. 22).

There are also hard and soft spots in the iron, and the cutting tool will bite into the soft spots and spring away from the hard ones.

It is not, therefore, practical to produce a true, straight bore within exceedingly close limits of accuracy by the re-boring method; and, furthermore, if a bore is out of square with the flange, reboring will not correct this error, since the tool will follow the bore.

Reaming Cylinder

Reaming is similar to boring, except that a number of tools set in one head are used instead of a single tool. What has been said about the disadvantages of boring applies equally well to reaming.

When the pistons and rings are assembled in the cylinder, **after reaming,** as shown in Fig. 23, they will rest on minute hills of metal. About half the bearing surface is thus lost, owing to the depression of metal between each hill. A full bearing surface is not realized until from .002″ to .005″ of metal has been removed by the pistons and rings. This causes a very rapid wearing of the cylinder walls until they are worn to solid metal. This extra amount worn off permits a large percentage of gas and oil to leak by the ring.

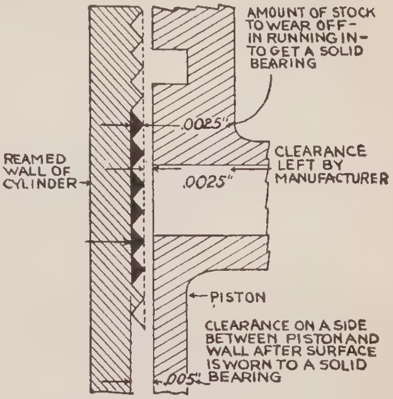
AMOUNT OF STOCK TO WEAR OFF- IN RUNNING IN- TO GET A SOLID BEARING
.0025″
REAMED WALL OF CYLINDER
.0025″
CLEARANCE LEFT BY MANUFACTURER
PISTON
CLEARANCE ON A SIDE BETWEEN PISTON AND WALL AFTER SURFACE IS WORN TO A SOLID BEARING
.005″

Fig. 23. Showing uneven surfaces left on walls of cylinder after reaming (exaggerated).

Lapping Cylinder

Lapping the holes of worn cylinders will not make them round or straight, because the lapping process is good only for polishing surfaces, and even after hours of work, but little material is cut away, leaving much of the lapping compound imbedded in the walls. It is an expensive operation, and the degree of accuracy and success to be achieved depends entirely on the skill and experience of the workman.

A worn cylinder is always larger at the top than at the crank end, owing to the friction of the rings and also to greater heat and poorer lubrication. Therefore, the grinding machine must be used to cut away the material necessary to get a round and straight hole for the entire length.

When lapping is done, two metallic surfaces are rubbed together with oil and abrasive material between them. This will charge the surfaces with grit.

Grinding in a machine with a hard, vitrified grinding wheel running at a high speed to cut the metal away is an entirely different proposition, and is the only way to secure right results.

Finishing by Grinding

In finishing a cylinder by grinding, an abrasive wheel held by a very rigid arm moving at high speed cuts away the metal freely without putting undue pressure on the cylinder walls. The feed of the wheel into the work can be adjusted so that it will remove the metal rapidly if a large amount is to be taken off, or so lightly that it is practically immeasurable.

The grinding wheel revolves in a perfectly true circle and cuts away the iron until a round and straight hole is produced, without either high or low spots, and having a beautiful, smooth, and mirror-like surface throughout.

The work is held on an angle-plate attached to the cross-slide of the machine; the main table, traveling lengthwise, moves automatically. When a hole is finished, movement of the cross-slide gives the proper position for the next hole.

The block remains set during the entire operation, insuring the bores being absolutely parallel to each other and at right angles to the base.

By this method all the disadvantages of boring or reaming are absolutely overcome. The high-grade cylinder-grinding machine produces a true, straight, accurate bore, the usual limits of accuracy being within one one-thousandth of an inch. The bore is absolutely square with the flange, the surface produced is hard and glass-like, and the amount of stock taken out is only a fraction of what would be necessary in re-boring.

New Rings No Help

A large share of repair shops are still advising new rings when an owner is confronted with motor troubles. He believes it is a cure, but it is only temporary, since in most cases the carbon has been cleaned out, valves have been ground, and the motor has been generally tuned up. It therefore seems to have overcome the ailment. It is not lasting, however, for no matter how expensive or complicated the rings may be that are used, with or without compression guaranteed, a round ring will not fit an egg-shaped hole; and if the motor has been run at all, that is what you will have.

Thousands of strokes of the rings up and down the cylinder, while aided by road dust and other abrasives which are sucked into the cylinders with the mixture, will gradually wear down the cylinder wall.

This wear is greater on the two sides at right angles with the crank shaft. It is the result of the pressure of the piston against one side of the cylinder wall on the compression stroke, and on the opposite side of the cylinder wall on the power stroke.

No ring will fit such a shaped hole, so there is bound to be a chance for gas to escape and a long time needed for the rings to wear in, if they ever do so.

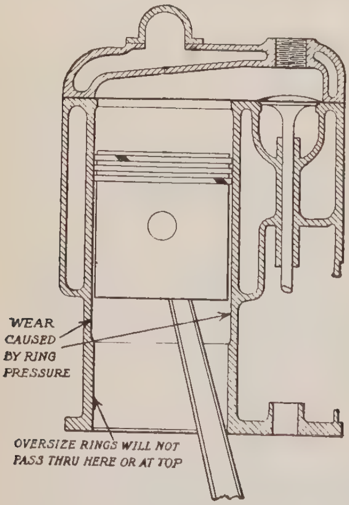
WEAR CAUSED BY RING PRESSURE
OVERSIZE RINGS WILL NOT PASS THRU HERE OR AT TOP

Fig. 24. Showing the points where rings usually wear cylinder walls.

Therefore, as the **cylinders are worn only the length of the ring travel, it leaves the lower and upper ends smaller.** To put a ring of the proper oversize in the worn part through the smaller hole is impossible.

The only cure for a worn cylinder—and it takes but a few thousandths of an inch to show appreciative loss of power—**is to have the cylinders reground and fitted with new pistons and rings.**

Fig. 24, which has been somewhat exaggerated, shows the wear in a cylinder which may have been made by various causes. Note how the gaps in the rings are spread, allowing gas to pass up through or around the rings.

New rings in such a worn cylinder would do no good, unless they were of the correct size to fill this hole. This is impossible, since rings of the proper size would not pass through the space either at the top or bottom of the cylinder. It will require grinding to take out sufficient stock to allow proper oversize pistons and rings to be inserted.

At Right Angles to the Flange

What is meant by "square with the flange," is indicated in Fig. 25.

It does not matter so much if the holes are not at right angles with the flange from side to side, but end to end they must be parallel, and perpendicular to the base.

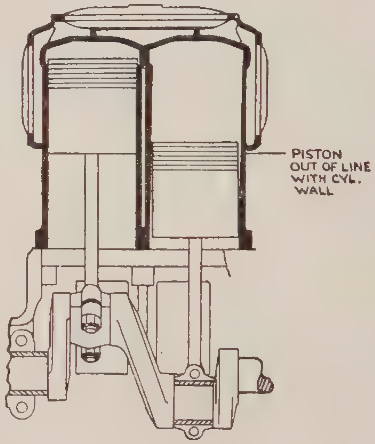

Fig. 25. Cylinder bore that is at right angles with the flange.

The right-hand side of the cut shows how the piston is often cramped in the cylinder by being out of square.

This may be caused in several ways. First, the bore in the cylinder may not be square with the crank case. Second, the piston-pin hole may not be drilled square with the sides of the piston. Third, the holes in the ends of the connecting rod may not be parallel with each other. Any one or more of these may result in excessive wear on the cylinder walls, or in a frozen motor.

Thin Cylinder Walls

Occasionally the shifting of the cores, when molding the cylinders, leaves a thin wall. In re-grinding such cases, if the wheel should break through, of course the man doing the work cannot be held for this misfortune. Furthermore, should there be a deep score and the owner wished it ground out and not filled, he must assume all the responsibility if he has trouble later.

It would be better business for all re-grinding concerns to refuse to touch such jobs, if, in their opinion, there is a doubt as to the strength of the wall after grinding.

New Pistons and Rings Necessary

If the cylinder is re-ground, new pistons and rings must be installed. The amount of stock to be removed in order to bring a bore back to a true round hole is usually at least .010″ and, if the cylinder is scored or badly worn, will go from .030″ to even .040″. Such clearance would never allow the use of the old pistons.

Many a perfect re-grinding job has been spoiled when the engine is being assembled. If you are in a position to take down and reassemble, then you are more fortunate than many who must trust this final and very important part of the job to someone else.

Great care should be taken first to wash the cylinders and pistons, rings, etc., carefully with gasoline. Be sure that every particle of abrasive material and foreign matter is removed.

Make certain that the **wristpin fits both the rod and the piston,** and see that it is securely fastened on. Better go over this an extra time and make sure, for a loose pin or screw will ruin the entire job the first time the engine is run.

Measure the pistons for roundness after assembling with the connecting rods, to see that they have not gone out of shape. A slight tap with a wooden hammer will correct any change.

After reassembling the pistons on the crank shaft, test them to see if they are absolutely square. Do not take it for granted, because the connecting rods were straight before it was pulled down, that they will be so when you reassemble them. There are many chances and reasons for their having become twisted or out of square. This could happen in taking off the block with the pistons still connected to the crank shaft, when it is an easy matter to bend or twist the rods. Again, in scraping in the connecting-rod bearing or in tightening the caps, a slight variation at this end will increase many times at the piston end.

That the **pistons should be square** (see Fig. 25) is highly important; if they are not, the cylinders might just as well not have been ground, for the pistons hitting on the sides will give all the troubles of an out-of-round hole.

Put plenty of oil on all the pistons before assembling in the cylinder.

The rest of the assembling is purely a repairshop job, but every detail should be thoroughly gone into as if it were a brand new car. In fact, the vital parts are new and with limits usually closer than those allowed by the manufacturer; therefore, they should receive careful attention.

Be sure that the crankcase is well filled with a good light or medium oil, and that the system is working perfectly. Run the engine slowly for one half-day, giving it time to cool naturally.

RE-BORING OF CYLINDERS TO FIT THE PISTONS

The preceding pages are devoted to matter taken from the booklets of a prominent cylinder grinding machine manufacturer.

The following is taken from the printed matter of K. R. Wilson, Buffalo, N.Y., who specializes on repair-shop tools for Ford motors.

The proper method is to bore cylinders to fit the pistons, thus giving same clearance in every cylinder.

The old method of boring the cylinders "all one size," and hoping to find pistons to fit them (selective fit), has been abandoned as obsolete, and expensive, because Ford pistons vary so much from the size with which they are marked that hand-fitting, filing, turning, or lapping in is necessary to turn out even a fair job. All of this extra work contributes toward the cost of the finished product.

Measuring and Marking Pistons

The pistons are first marked 1-2-3-4. They are then measured with a 4″ micrometer ("miking" is the trade name for measuring with a micrometer), first for roundness, by measuring them across the skirt in the direction of the wristpin; then at right angles to it. The piston is then laid on a block of wood, with the high side up, another block is laid on top, and a few sharp taps with a hammer will suffice to drive it back into its original roundness.

Measuring the piston with a micrometer, to check the size as stamped on it, and thus to obtain its actual measurement, is the first operation, because pistons do not always measure as marked. Suppose a piston was stamped .031″ oversize, meaning that it should be .031″ larger than the standard size (3.750″), or a total of 3.781″. By means of the micrometer (**E**) (Fig. 26), measure the piston. Suppose this measurement shows that the piston is actually 3.784″, it would thus be 3.784″−3.781″= .003″ **larger** than stamped. This piston would then be chalk-marked 3.784″. Suppose that the next piston is also stamped .031″ oversize, but the micrometer measurement proves it to be 3.777″, this piston would be 3.781″−3.777″=.004″ **smaller** than stamped. This piston would be chalk-marked 3.777″.

Setting the cutter to bore the cylinder is the next operation. A clearance of .003″ must be allowed between piston and cylinder. Take the piston which was chalk-marked 3.777″. By adding the specified amount for clearance, we obtain 3.777″+ .003″=3.800″. Therefore the single-bladed cutter (**C**) (Fig. 27) must be set to bore the cylinder to 3.800″. Take another piston, as the one chalk-marked 3.784″. Allowing .003″ for clearance, we obtain 3.784+.003″=3.787″. Therefore the cutter must be set to bore the cylinder to 3.787″ for this piston.

Boring Operation

The boring bar is now placed in the cylinder, and is instantly located by means of two (two-piece) tapered locating plugs (**L**), as shown in Fig. 27. One of the plugs at each end of the cylinder on the boring bar insures perfect centers.

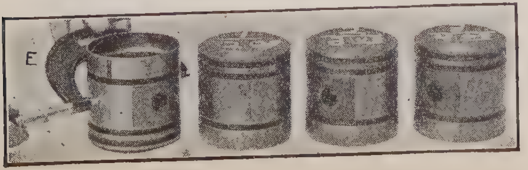

Fig. 26. "Miking" and chalk-marking pistons.

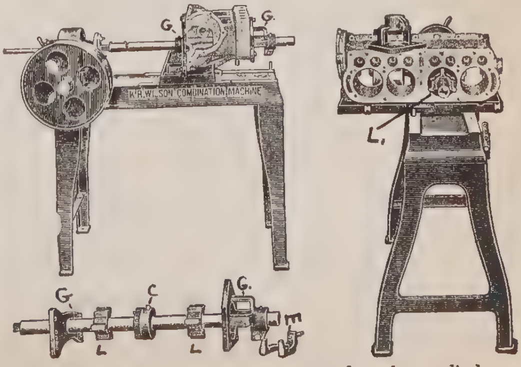

Fig. 27. K. R. Wilson machine being used to rebore cylinders.

The permanent guides (G) are then positioned and fastened to the block on both cylinder-head and crank-case ends. The tapered locating plugs (L) are then removed through the openings provided, leaving the boring bar all set up. We now place an 8″-wrench on the square end of the boring bar, and with another "speed-type" wrench, we tighten the adjusting screws of the split bearings on each of the permanent guides until it requires considerable pull on the 8″-wrench to turn it. Note that it is impossible to bore a tapered or uneven hole unless you purposely allow these bearings to become loose and a sloppy fit for the boring bar. The bearings on the two permanent guides are adjustable, and will take up any possible wear, and will thus prevent "chatter." Now place the universal joint in position, and throw in the feed lever. In 9 minutes the cylinder will be rebored, during which time no other attention except setting up is required.

The table holding the cylinder block contains four sets of two No. 5 taper-pin holes and one 7/16″ cap-screw hole opposite the center line of each cylinder. Corresponding holes are drilled into the bed of the machine by moving the table with the cylinder block attached on the bed. Any cylinder can be brought into exact location wherever the pins will fit into place.

The time required is about 1¾ minutes to set up for each hole, and 9 minutes to bore it, making a total time of 43 minutes; but on account of the automatic feature, not more than 10 minutes labor cost can be charged to boring the four cylinders, for the reason that the operator can be grinding valves, fitting pistons, connecting rods, or overhauling the transmission or doing many other jobs while the machine is taking care of itself.

Cutters are interchangeable (cost 50c. each), and it is not necessary to tie up the cylinder re-boring machine while the cutters are returned to the factory to be re-sharpened and fixed up. The cutter is adjustable to take up any wear, and on account of the narrow cutting edge will not dub over when it hits a hard spot or a scored cylinder. A narrow cutting edge could not be used with any equipment other than a cylinder boring bar, having a fixed guide on each end that will prevent chatter and keep cutter from digging in or following the old hole.

Because the "cylinders are bored to fit the pistons," eliminating nearly all hand operations, such as filing, turning, lapping-in, etc., only a slight amount of hand filing to remove the high spots and niches is required. Pistons fitted by this process to .002″ clearance are absolutely free in the cylinder and, without rings or oil on them, will "fall through" without friction.

Mr. Wilson states that lapping-in will cut off some of the high spots in the cylinders and pistons, but it will not fill up the low spots.

Filing pistons in a lathe will make them smaller, but will throw them out of round more than ever, for the reason that when the file hits the relieved portion of the piston near the piston pin boss, it will jump and "dig-in" again about one inch from the edge of this relieved portion.

Lathe turning is unsatisfactory because the average service station is not equipped with proper tools for this work. Even if it were, it is a difficult proposition to "chuck up" a Ford piston accurately to remove only a few thousandths of an inch. These facts show why it is necessary to bore the cylinder accurately in the first place, if you want a first-class job at a minimum cost.

Questions and Answers on Enlarging Cylinders; Continental Engines

The following questions and answers pertain to the Continental engine (see Index), but are applicable to many other engines:

Q. 1: Are cylinders ground, reamed, or bored?

Ans.: All Continental cylinders are bored and reamed with special fixtures and tools which insure perfect alignment. After these operations they are ground accurately to a glassy smooth finish.

Q. 2: Are pistons fitted to each individual cylinder, and what is the standard clearance?

Ans.: Not only the piston, but the piston rings as well, are individually hand-fitted to each cylinder bore. The clearances allowed in each case depend upon the size of the engine and the service for which it was designed.

Q. 3: How are engines marked to show the original diameter of the cylinder bores?

Ans.: The diameter of each cylinder is stamped on the lower machined face of the cylinder block where the valve-chamber cover is attached. These marks are in decimals.

Q. 4: What factor determines the amount of clearance to be allowed when fitting pistons in the cylinders?

Ans.: The amount of expansion. This depends upon the materials used in the pistons and cylinders, the general design, and the operating temperature of the engine. The temperature of an engine in operation is affected by the amount of fuel consumed, the resistance offered the power impulses, and the timing of the ignition.

Q. 5: What is meant by .003″ loose-fit and .004″ tight-fit of piston clearance?

Ans.: The piston would be free in the cylinder with a .003″ thickness gauge (also called "feeler") between it and the cylinder walls, and the same piston would be tight in the cylinder with a .004″ feeler.

INSTRUCTION No. 71

PISTON RINGS: Types, Construction, and Fitting; Piston-Ring Gap Clearance; Piston-Ring Groove Clearance; Measurements of Piston Rings; Standard and Oversize Piston Rings; Testing and Fitting Piston Rings

PISTON RINGS

The piston ring is used to fill the gap between the piston and cylinder walls, preventing the gases escaping into the crank case and an excess of oil working into the combustion chamber.

A piston must be fitted with piston rings. The piston is slightly smaller than the bore of the cylinder, in order that it will not stick to the cylinder wall (termed "seizing"), when it becomes hot and expands.

Since the rings are softer than the cylinder walls against which they are tightly pressed, and also present small wearing surfaces, they become undersize in time. To insure maximum power, together with minimum oil and gas consumption and the best all-round satisfaction, the rings should be renewed about once every 10,000 miles.

Ring grooves are provided on pistons for the rings. The grooves are slightly wider than the ring. For instance, the Ford ring is ¼″ wide and the width of the groove is one and a half one-thousandth of an inch wider (clearance). On the Dodge, the ring is 3/16″ wide, and the groove has a clearance of one and a half one-thousandth of an inch.

If a ring groove becomes worn and is over .005″ clearance, the piston can be put in the lathe and the groove can be widened to take a 1/32″ oversize-width ring.

The depth of the grooves averages about 3/16″. The average **thickness of a ring** is 5/32″; thus the groove is 1/32″ deeper than the ring is thick. On some of the V-type engines the grooves are shallow. The rings are about ⅛″ thick, and the depth of the groove is about 1/32″ or 1/64″ more.

If the groove is too large, there will be a compression leak between the groove and the ring. If **too narrow,** the ring will stick in the groove and will not exert its tension against the cylinder wall.

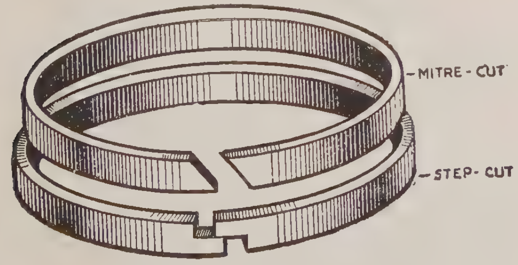

Fig. 1 (upper); Fig. 2 (lower).

Fig. 1. Piston ring with a beveled joint, cut slantwise, Easier to make than the other type, but not quite so effective in preventing possible leakage. Termed a "mitre cut" or "diagonal" joint or "bevel joint."

Fig. 2. Piston ring with stepped or lapped joint which prevents leakage of pressure at the joint. Termed a "step-cut" or "lap-joint" ring.

The ring gap is provided on all rings in order that it can be fitted to the piston groove and so that it can expand and exert tension equally against the cylinder walls at all points of its circumference.

The two types of ring joints which are generally known and used are shown in Figs. 1 and 2, and are known respectively as the **"step-joint"** and **"mitre-joint"** ring. There are many other kinds of joints or gaps used on the various patented rings. The step-joint is used most.

Patented Piston Rings

Patented rings are made in many different constructions, some of which are shown in Figs. 3 and 4.

The two principal advantages claimed by the patented ring manufacturers for their rings over the ordinary type are: (1) that the joints are gas tight at all times, and (2) that they exert equal tension or pressure on the cylinder wall at all points of their circumference. Usually the manufacturers make two types of rings: a "high-compression ring" and an "oil ring."

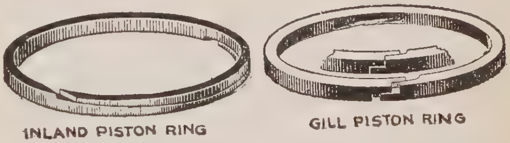
INLAND PISTON RING
GILL PISTON RING

Fig. 3. A few of the popular patented type of piston rings. Note the different joints and methods employed to obtain equal tension at all points of the ring circumference.

The Inland, or Star-K-Inland, as it is known, is a one-piece ring with a long lap (made by Star-K-Inland Machine Works, St. Louis, Mo.).

The Gill is also a one-piece piston ring of the concentric type made from a single-piece casting of special gray iron and machined to accuracy. This ring has an interlocking joint and is termed the "Gill joint," or, technically, "a double-step interlocking-joint" ring (made by Gill Mfg. Co., Chicago, Ill.).

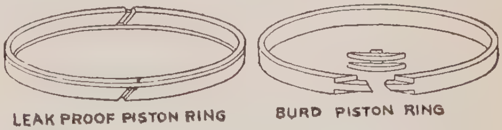
LEAK PROOF PISTON RING
BURD PISTON RING

Fig. 4. The Leak-Proof piston ring is a two-piece ring, manufactured by the McQuay Norris Co., St. Louis, Mo.

The Burd ring will best be understood by referring to the illustration above (made by Burd Ring Co., Rockford, Ill.).

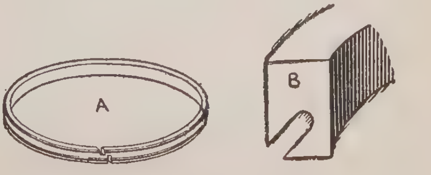

Fig. 5. **The oil ring** made by two different manufacturers. **(A)** is the Star-K oilless quick-seating piston ring, designed to

overcome oil pumping. It has two oil grooves: one in the middle for lubrication; one on the lower shoulder to scrape down all excess oil. (B) is an end view of the "Superoyl" piston ring.

A small oil groove, or reservoir, is cut around the lower edge of this concentric ring, providing a scraping edge. One "Superoyl" ring is placed in the top groove of the piston and the two Leak-Proof piston rings below, in cases where an excess of oil reaches the combustion chamber (manufactured by the same concern that make the Leak-Proof ring).

When the ring is in the cylinder, the gap clearance is very slight. If it were too great, there would likely be a leakage of compression through the gap, or if all of the gaps were in line when in the cylinder, it is likely that there would be a leakage of compression from the combustion chamber to the crank case through the gaps. Inasmuch as the rings are free to work in their grooves, the common belief is that the rings move, or work around in the grooves, until they are all in line at one time. However, this is improbable, as well as probable; for if the rings thus work around, they are likely to continue working, and if originally placed on the piston an equal distance apart, there is not much chance for all of them to get in line at the same time.

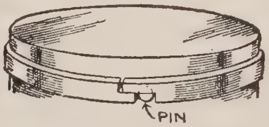

Fig. 6. A pinned piston ring.

Before the advent of the patented ring, the rings were usually pinned, that is, the gaps were first placed 120° apart on the piston, and then the ends of the rings were notched with a fine round file, so that the semicircular notches just closed over the pins (see Fig. 6). The pins were a source of trouble in high-speed engines, and unless great care was exercised in screwing or fitting the pins tight into the piston, they would loosen and project and cut the cylinder wall. Thus this practice was abandoned to a certain extent. Pins are still used on many large, slow-speed engines and on two-cycle engines. There is no doubt that the pins had the advantage of insuring against their getting in line. But they also had disadvantages. The growth of the popularity of all kinds of patented rings with gas-type joints has thrived on this claim as well as on the claim that the patented ring exerts equal pressure at all points of its circumference. For instance, note the long lap of the Inland ring and the construction of the Leak-Proof and the Gill ring.

Concentric and Eccentric Piston Rings

It is important that a piston ring exert equal pressure or tension against the cylinder wall at all points of its circumference. Right here is one of the most important duties of a piston ring. If it fails to do this, then the part of the ring which does not press against the cylinder wall is bound to permit the compressed gas to pass into the crank case.

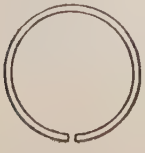

Fig. 7

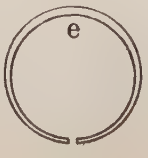

Fig. 8

The concentric ring (Fig. 7) is one of equal thickness throughout its entire circumference.

The eccentric ring (Fig. 8) is made eccentric (thicker) at one point, as shown at (e).

Some manufacturers claim that the concentric ring will maintain equal tension under heat, if made of the right material, and others claim that the eccentric ring is the best—see Q. 6 and answer, page 834.

A very popular step-cut concentric ring is the "hammered ring," made by the American Hammered Ring Co., Baltimore, Md. This ring is shown in Fig. 9. Note that the inside of the ring has been hammered, or peened, with hammer marks.

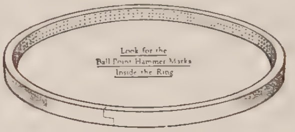

Fig. 9

The makers claim that this operation causes the ring to have **equal tension** at all points of its circumference. This make of ring is used on the Buick, Dodge, Pierce-Arrow, Locomobile, and Stutz engines. Another peened, or hammered, ring is made by the Wasson Piston Ring Co., Plainfield, N.J. and also by the Victory Piston Ring Co., Newark, N.J.

Number of Piston Rings to Piston

There are usually two or three piston rings above the piston pin, and quite often an oil groove is in the skirt of the piston. On many engines, there are three piston rings above the piston pin and one oil ring below the piston pin. On the Ford, there are two piston rings above the piston pin and one below. See Fig. 10, and note how the Ford rings are tapered in order to prevent an excess of oil getting to the combustion chamber.

Racing engines often use one or two piston rings, so as to facilitate more perfect lubrication, perfectly tight compression not being so necessary for high-speed motors as for low-speed ones. Moreover, good compression is more necessary for good carburetion at low speeds, while it is not so imperative at the higher speeds.

The ring below the piston pin serves two purposes: (1) to prevent piston slap; (2) to keep oil down, and is often called the **oil ring.**

Therefore, we might term the rings above the piston pin, the "compression rings," and below, the "oil ring." The oil ring is usually given slightly less clearance at the gap (see Ford ring-gap clearance, Fig. 10).

If the piston pumps oil and the spark plugs are constantly oil-soaked, the oil ring should have holes drilled in the groove behind the lower ring, as directed on page 169 (see also Index under "Piston pumping oil").

On this page, it will be noted that the oil holes are in the ring groove above the piston pin, as well as below. The practice is first to drill holes in the ring groove below the piston pin, and if this does not relieve the excess oil reaching the combustion chamber, then do the same with the first ring above the piston pin.

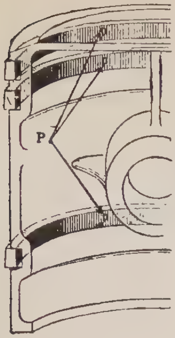

Fig. 10

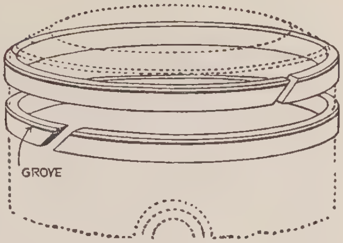

Fig. 11

Fig. 10. **The Ford rings are cut .002″ taper.** This insures the ring wearing so as to conform to the cylinder walls in the shortest possible time, and, when assembled with the file or punch mark up, as shown, the ring presents a sharp edge to the cylinder wall on the down-stroke and an incline on the up-stroke. The incline rides over the oil, while the sharp edge pushes the oil before it, thus preventing the oil from working into the combustion chamber.

On some of the earlier rings, there was a file mark in the upper edge, to show which side to place up. If the ring is upside down, it will have a tendency to pump oil.

Ford piston rings are also machined with a **groove** near the edge, which **should be toward the top** when installed on the piston. See Fig. 11. On later models, the word "Ford" is stamped on the upper side of the ring.

Ford ring-gap clearance: First and second rings, .008″ to .015″; bottom, or oil ring, .004″ to .005″, since it is necessary that a small amount of oil work up between the piston and the cylinder wall.

Measurements of Piston Rings

Manufacturers differ as to the measurements of a piston ring. A gauge is generally used for this purpose.

One type of gauge[1] consists of hollow tubes in which the piston ring is fitted. For instance, this tube would represent, say, a 4″ ring, and when the ring fits into this tube with a certain opening of the ring gap it would be a 4″ ring. Thus it will be observed that a ring is not measured by closing it tightly and measuring its outside diameter, but, in other words, the gap opening of the ring must be considered.

For example, the average clearance of a piston ring is approximately .002″ **diametrical clearance,** so as to allow for an oil film between the piston ring and the cylinder wall.

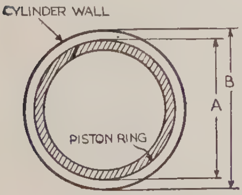

Fig. 12

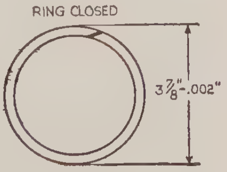

Fig. 13

The term "diametrical clearance" means the difference between the diameter of the cylinder wall (the bore) and the outside diameter of the piston ring (gap closed). In Fig. 12 the diametrical clearance is the distance (**B**) minus the distance (**A**).

The term "radial clearance" means the radius of the cylinder minus the radius of the piston ring. In Fig. 15 it is represented by (**B**-**A**). It should be 001″.

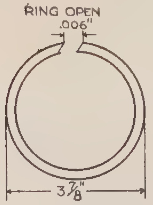

Fig. 14

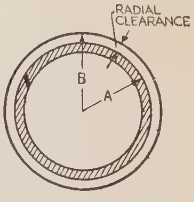

Fig. 15

Therefore a ring that was rated as of a 3⅞″ diameter would, when **closed** (Fig. 13) measure 3⅞″ less .002″ in diameter, or, in other words, if the ring were allowed to **open** .006″ in its gap, it would measure 3⅞″ (Fig. 14), because a **difference** of .002″ in **diameter** equals a **difference** of .006″ in **circumference** (.002″ x 3.1416″=.0062832″).

Piston-Ring-Gap Clearance

If the **ring is out of the cylinder,** it would approximately measure on its outside diameter, with a .006″ open gap, 3⅞″, as shown in Fig. 14. **If in a cylinder** of 3⅞″ bore, the gap would be approximately .006″ when stationary.

When the **engine is in operation,** the piston-ring gap would almost close, and in that position should have approximately .002″ diametrical clearance from the cylinder wall for an oil film, which would force its way between the ring and the cylinder wall.

The **oil film** would occupy a radial clearance or space of .001″ all around the piston ring, consequently the **diameter** of the piston ring would be reduced .002″. And, if the diameter is reduced by .002″, the **circumference** is reduced by 3.14″ x .002″ =.006″. This reduction must be taken up by the gap, and consequently the gap of .006″ is reduced. However, in actual practice, the gap is not closed entirely, but should be almost closed when in operation, so as to prevent oil from being pumped through the gap. This clearance is allowed so that the ring can expand and contract and yet fit firmly to the cylinder wall, allowing for the oil film. Thus if the gap is too great, the diametrical clearance will be greater, and consequently a greater oil film will result in that part, and the oil will pass to the combustion chamber. Hence the importance of the exact gap clearance which should be ascertained from the piston-ring manufacturer when ordering piston rings.

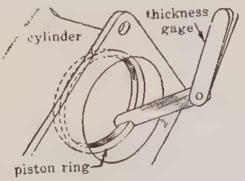

Fig. 16

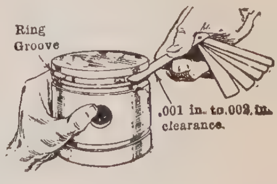

Fig. 17

Method of finding the ring-gap clearance in the opening of the ring (see Fig. 16): Place the piston without rings into the cylinder. Then slip the ring into the cylinder behind the piston, as shown in Fig. 16. Pull the piston up against the ring in order to square the ring up in the cylinder. If the cylinder is worn, it is usually so at the upper end. A thickness gauge is then applied, as shown in Fig. 16.

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[1] Another make of piston-ring gauge, made by D. F. Dunham, Oxnard, Cal. The piston ring is measured across the extreme outside diameter when the piston ring is tightly closed.

The average ring-gap clearance, or the distance between the end of a gap-cut ring, should be .0015″ (1½″) to .002″, for each inch in diameter of the cylinder. Some manufacturers, the Gill Co., for instance, advise .003″ clearance for each inch in diameter of the cylinder.

In the absence of explicit instructions from the piston-ring manufacturer, the following gap clearances could be followed:

2″ to 3″ ring: gap clearance .006″
3″ to 3½″ ring; gap clearance .007″
3½″ to 4″ ring; gap clearance .008″
4″ to 4½″ ring: gap clearance .009″

The usual method of ordering piston rings is to measure the diameter of the piston and the width of the groove, and to state the make of engine. The manufacturer has a list which he refers to, and can then give the proper ring. The best plan is to measure the cylinder, as it may be worn. To do this, cut and file a wire which will fit **exactly** to the bore of the cylinder, and measure the width of the piston groove, and send this to the manufacturer.

Note that the test of the cylinder for size should be made in that part of the cylinder where the rings travel, as more wear usually takes place at this point.

Standard and Oversize Piston Rings

On new cylinders, where they are perfectly round, the piston ring is the standard size.

On old cylinders which have been worn out of round, as a result of piston slap, or in cases where the rings "travel," it is necessary to fit **oversize** piston rings.

Therefore, **in ordering oversize piston rings,** it is necessary to measure the cylinder where the rings travel. However, it will be found that the fact that the cylinder is out of round will necessitate a slightly larger ring which should be lapped in and the gap dressed down as the fit is being made, the idea being to **seat** the ring to the out-of-round position of the cylinder. Usually, when this work is done, the rings are very stiff, and the engine is run at idling speeds with water running through the radiator and with plenty of oil. The rings are fitted tight, so that they will work or seat to the cylinder, and many hours of running in this manner may be necessary to make a good fit.

Piston-Ring-Groove Clearance

The ring should be rolled around the ring groove in the piston, as shown in Fig. 26, page 831. The proper fit of a piston **ring in a groove** is that which permits the ring to **fit snugly without binding** or sticking at any point. When it is loose or sloppy in its ring groove, there is danger of lubricating oil getting behind the ring and traveling to the combustion chamber, resulting in the formation of carbon and in gumming the ring.

Likewise, extreme care should be taken to see that the groove is clean, and that the wall thickness of the ring is not greater than the depth of the ring groove. Therefore the inner edge of the ring should not extend above the edge of the piston at any point when placed in the groove.

S.A.E. Depth and Width of Ring-Groove

Size of Piston	Depth of Groove	Width of Groove
2½″	.113″	.126″
3 ″	.127″	.188″
3½″	.142″	. 188″
4 ″	.158″	.188″
4½″	.174″	.251″
5 ″	.190″	.251″
5½″	.207″	.314″
6 ″	.224″	.314″
6½″	.240″	.377″

Owing to slight variations in the width of ring grooves, it will occasionally be found that the ring is slightly tight or wide for the groove for which it is intended. This difficulty can be overcome by the use of a piece of fine emery cloth tacked to a flat surface (Fig. 30, page 832). The ring should be gently rubbed with a circular motion on this emery cloth until it will fit the groove without sticking.

To measure ring-groove clearance (see Fig. 17): Remove all grit and see if the groove walls are straight and not worn. The rings should fit freely into the grooves, and should be from .001″ to .002″ narrower than the groove.

PISTON-RING TROUBLES, TESTS AND REPAIRS

If the rings do not fit the cylinder wall with equal tension at all points, there will be a loss of compression and a smoky exhaust.

If the rings are exerting equal tension, they will be smooth and shiny, as will also the cylinder walls.

If the rings are dull, and there are spots in streaks on them, it will indicate that the flame from the combustion passes between the piston rings and the cylinder wall, leaving a sooty deposit, and the compression will also pass, reducing the power of the engine.

Causes of Leaky Piston Rings

1. **Rings sticking in their grooves** because of gummy deposit from lubricating oil; rings that are stuck in their grooves will usually not press against the cylinder walls.
2. **Rings may have become broken.**
3. **The joints of the rings may be in line,** allowing the compression to escape.
4. **Rings may be worn or cut** from lack of oil.
5. **Rings may not be wide enough** for the grooves.
6. **The oil pressure may be too great,** and oil of too thin a body may be used.

Testing Rings and Cylinder for Leaks

In order to find out if the rings leak, try the piston and see if the gas is escaping through the rings into the crank case. This can best be accomplished by removing the lower part of the crank case, after which turn the crank so that the piston makes its compression stroke, and listen for a bubbling sort of hiss in the crank case. Test each cylinder separately by opening the relief cocks in the cylinders that are not being tested. First determine which cylinder it is that is leaking. There is no mistaking this sound, since the crank chamber acts as a resonator, and even the slightest leakage is distinctly audible.

If the sound of gas escaping past the piston rings continues for an appreciable time (upward of a minute or so), the chances are that the use of an oil of slightly heavier "body," for cylinder lubrication, might cure the fault.

However, if the escape is of short duration, the matter is more serious, involving as it may a cracked piston, scored cylinder walls, or broken, warped, or gummed rings.

If this is suspected, flush out the cylinder combustion chamber with an oil-gunful of gasoline, making no attempt fully to remove the liquid. Again put the piston on lower dead center, and with the aid of an electric lamp and a small mirror, observe the bubbles caused by the escape of the gas about the lower edge of the piston. There will naturally be no bubbles at this point if the piston head is fractured, but it may be possible to see the crack through which the leakage occurs. At any rate, if enough gasoline has been left in the cylinder, one will be able to see it trickling down the connecting rod or inner piston walls, should such a crack exist.

If the cylinder walls are scored, one will see the liquid at but few points about the lower edge of the piston, and, as the gasoline washes the oil away, possibly the score marks will also be seen.

In case the trouble is with the rings, the bubbles will be more evenly distributed about the periphery of the piston, and will be all of about the same size. Should this latter be the condition, use the kerosene treatment for gummed rings; this may eliminate the leak if the rings are only gummed. If this latter is not effective, the job is one of replacing rings.

If the gas is escaping through the rings, it will be necessary to take out the pistons and to look at the rings. If there are **black spots on the rings,** it is evident the gas has been escaping at this point.

To test a piston for a leak: Set the piston bottom side up in a pan of gasoline and pour about 1″ of gasoline into the interior of the piston. If there is a hole in the piston, the gasoline will seep through it.

Remedying Piston-Ring Troubles

Gummed rings: After long periods of running, a deposit of charred, or partially charred, lubricating oil is liable to form behind the ring and to interfere with its free movement; it is a good plan, therefore, when overhauling the engine, to slip the rings from the piston and thoroughly to clean out the grooves.

A kerosene oil treatment to loosen rings: Engines have been known to lack power merely from the rings becoming gummed up. This trouble can be remedied by first running the engine until it is warm; then stop it, take out the spark plugs, and pour some kerosene into each cylinder, by pouring the kerosene through the spark-plug holes. Plug up the holes with old spark plugs, and then crank the engine several times by hand, so that the oil will work its way down around the rings; leave this oil in over night, and next morning crank the engine a number of times until you think the oil has passed into the crank case. Drain the crank case. After thoroughly draining, and putting in fresh lubricating oil, start the engine. The engine will smoke considerably to begin with, but this will soon pass away. This will not only loosen up the rings, but will also clean any carbon that may have become deposited in the combustion chamber. This treatment often saves the trouble of fitting new rings, and in some cases will make a marked difference in the running of the engine. Be sure, however, to clean out all kerosene, otherwise the lubricating oil will be thinned.

If the ring is broken or if it is dull and dirty in spots and streaks, a new ring or rings must be fitted.

If a ring is cut or scratched, a new ring is necessary.

If the walls of the cylinder are cut or scratched, then rebore, grind, ream or lap, as directed on page 815, and fit oversize rings.

If the ring has lost its tension and does not spring freely against the walls of the cylinder, it can be peened, as shown in Fig. 18.

Remedying Excessive Smoke

As previously stated, if the rings are leaking, an excess of smoke will pass out of the exhaust, as a result of the oil passing the rings and entering the combustion chamber. See pages 168, 768.

Peening Piston Rings

This operation is for a ring which has lost its tension. A peening hammer should be used instead of the various flat-headed types that are used at times for peening a piston ring. The metal may be more readily distributed by the blows from a peening hammer, which can be directed better, since the head is so designed that a large part of the surface is not covered at one time nor struck by any single blow.

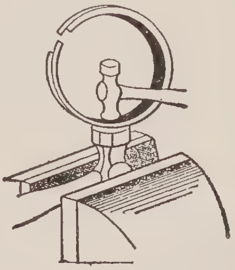

Fig. 18. Peening a piston ring.

In this manner slight changes in the shape of the metal may be made without distorting the metal in any way. It is very important in any peening operation that the surface upon which the hammering is done be as flat and hard as possible, for any irregularities in the shape of the surface plate will be just as effective in causing distortions as a blow from a badly shaped hammer. A good method of providing such a surface plate is shown in Fig. 18.

Note. This work should be avoided if possible, by selecting a new ring.

Removal of Rings

The removal of rings from piston grooves is not difficult if a little forethought is taken. To open them, it is best to use a pair of very thin-jawed pliers, the jaws opening outward (see Fig. 19). A substitute for pliers can be made from iron wire.

When the ring is slightly expanded by the use of special pliers, similar to those shown in Fig. 20, a

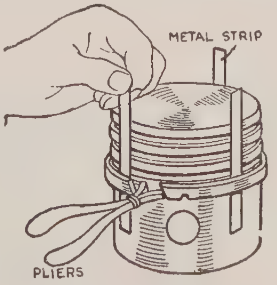

Fig. 19

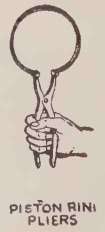

Fig. 20

Fig. 19. One method of removing piston rings from piston grooves. The ring is expanded slightly by special pliers. Strips of metal are then inserted under the rings at equidistant points, when the ring can be safely slid off. In replacing the rings, the lower one is first fitted on over the strips, and then the other two.

Fig. 20. Piston-ring pliers.

narrow strip of very thin metal (tin or brass will do) should be pushed through the opening and worked to the opposite side of the slot; then if the ring is opened a trifle more, an additional strip of metal can be placed near the ends of the ring, when it can be worked off quite easily and without any risk of breaking it, such as would result from an attempt to expand it larger than the piston diameter.

It is a good plan to mark each ring for its own groove, and also, when they are not pinned, to mark just where the slots should come on the piston.

Marking Piston Rings when Removing

The amateur or junior repairman who removes the piston rings from a piston for the first time, either for examining the piston-ring slots for sandholes or wear, or for cleaning the rings and slots, generally neglects to see that the rings are marked so that they may be replaced in their proper grooves. The result is that considerable difficulty often is experienced in getting the rings back into the piston in good order. To avoid this, mark the piston rings as indicated.

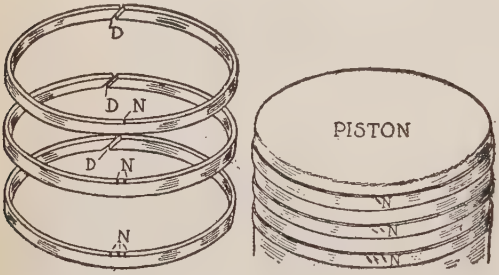

Fig. 21. Mark piston and rings when removing the rings.

The ring in the top groove of a piston has one notch (N) in the upper, inner edge, opposite the diagonal (D) where the ring is thickest. This notch is made with a file and is very small, so as to be just visible, but at the same time not deep enough to weaken the ring. In a similar manner, the next ring below it is marked with two notches, and the third ring, with three notches. If more rings are used, a corresponding number of notches are employed to mark them. With rings thus marked there should be no difficulty in getting them replaced in their proper grooves. Care should be taken, however, when the rings from more than one piston are removed at the same time. In fact, it is advisable to remove, clean, and replace the rings of one piston before removing them from others.

Fitting and Testing a Ring to Cylinder

After having selected a set of rings, the first operation is to fit them into the cylinder to see if they have the proper ring-gap clearance. Taking one of the rings, try very carefully to shove it straight in, concentric with the cylinder walls; if the ring is of the diagonal slot or miter-cut type (Fig. 1, page 825) and its diameter is a little large, the ends will run upon each other, throwing the edges out of line; while if a ring with step-cut overlapping ends (Fig. 2, page 825) is used, it will not go in at all. In such case, the ring ends must be filed (see also page 827, for testing piston-ring gap clearance).

Filing Ring Gap for More Clearance

A very simple and effective means of **holding a ring for filing** is shown in Fig. 22. The ring is placed on a block of wood and a few small nails are driven into the block both inside and outside of the ring in such a manner that the ring is held securely in place for filing.

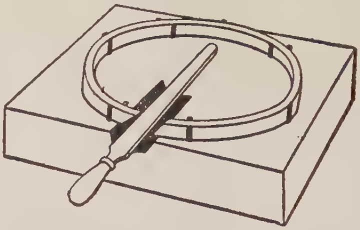

Fig. 22. Filing a ring joint.

The heads of the nails are then cut off, the ring is removed, and the nails are filed down so that they will extend just below the top surface of the ring when it is replaced on the block. With the nails well placed, there will be no danger whatever of breaking the ring when filing. A thin, smooth, flat file is best for this. The ring can also be placed in a vise, between vise clamps, and filed.

The ends must be trimmed off so that when the ring is well up into the cylinder there will be a clearance space of at least .006″ between ends (Fig. 16, page 827), to allow for expansion caused by heat of the explosions. The groove on the block shown in Fig. 22 is used when reducing the diameter of diagonally slotted rings.

Try each ring in the cylinder to which it is to be fitted, being sure to have it placed fully up into the cylinder where the ring travels. Then measure the opening in the ring as described on page 827 (Fig. 16). If too great an opening is allowed to exist, compression can easily escape. See page 827 for "Gap clearances."

The ring should be repeatedly tried in the cylinder in order that the space may not be filed to exceed the dimensions stated. The inside portions of the rings near the ends should rest against the nails (Fig. 22), in order that they may not be broken off when filing the slot. Having attained the proper space between the ends of the ring, now place a light in the cylinder behind it and see how its face conforms to the wall of the cylinder.

If one part of the circumference of the ring fits and another part does not, the high spot shows up when the ring is dipped in gasoline and then rubbed with cloth. The high spot will be more shiny than the rest.

When the ring fits well all around, the overlap of the ends should be absorbed; if they are not, file them until the edges have at least .006″ clearance when the ring is in the cylinder.

If the ends of the rings are hard butted against one another when in place in the cylinder, they may be buckled by expansion when hot, and make starting the engine a two-man job.

If there is a contact all around, when testing rings in the cylinder, the ring is then ready to be fitted to the piston; but if the contact is poor, either the ring or the cylinder is out of round, leaving space between cylinder wall and the ring, as at (C) and (P) in Figs. 23 and 24.

If the fault lies in the ring, the face can probably be dressed down to fit, or another can be selected; but if the cylinder is badly out of round, it will have to be rebored or reground, or both, as the case may be.

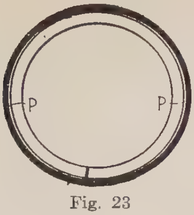

Fig. 23

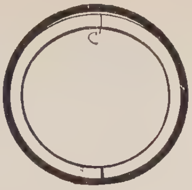

Fig. 24

Fig. 23. Cylinder out of round or ring is not exerting equal tension at all points. Note open space at (P).

Fig. 24. Note space at (C). The same conditions may have existed, or the ring was sprung when it was removed or was originally placed on the piston.

A ring which does not fit or seat the cylinder wall all around permits oil to pass to the combustion chamber and gasoline to pass to the crank case, thus thinning the lubricating oil.

Lapping a Ring to the Cylinder

To work or lap a ring to fit the cylinder: Make a plug of yellow pine (Fig. 25) to fit easily into the cylinder and square one end. Lay the ring on this end with a small batten across, secured by a screw through the center, but not holding the ring tightly.

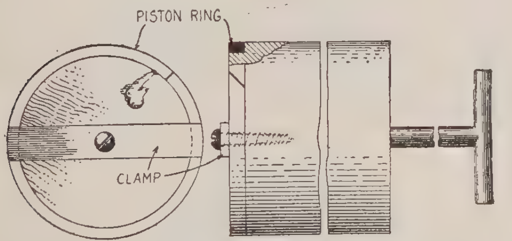

Fig. 25. **A handy device for testing and fitting the piston rings in a cylinder.** This device consists of a round block of wood with a handle on one end. The piston ring is placed on the other end and is held by a block and screw. It is placed in the cylinder and worked back and forth. (*Automobile Dealer and Repairer.*)

Smear the bore as evenly as possible with a little vermilion and lubricating oil mixed to a paste, and move the ring to and fro in the cylinder while it is held square by the plug. Generally, it will be found to bear hardest at each side of the slot. File such places carefully with a smooth file. See also page 816, for directions for lapping rings, pistons, etc. An old piston can be used for this purpose, but it is best not to use the regular piston. Rotten stone mixed with oil to form a paste can be used, and is preferable to emery (see page 816).

Testing Rings to Fit Piston Grooves[1]

When the rings have been fitted to the cylinder, the next operation is to test them for a fit in their respective grooves on the piston. As regards the fit of the rings in the grooves, they should be just a free fit, neither tight enough to jam, nor slack enough to rock.

If the piston ring is loose or sloppy in the groove, do one of two things: (1) turn the grooves out 1/32″ larger on the lathe and get rings to fit, or (2) buy and install new pistons. Remember, no piston ring will function properly if loose or sloppy in the ring groove.

If the pistons have too much play in the cylinders, replace them with new pistons. Don't expect the impossible of any piston rings.

If the bore of the cylinder is found to be worn extremely out of round, we recommend that the cylinder block be sent to some reliable concern for regrinding or reboring. Such a degree of efficiency in that art has been reached that a worn cylinder can often be made as good as, if not better than, new, and particularly when the repairman or mechanic specifies and insists on the installation of good piston rings. Have the same concern fit oversize pistons or rings individually to each cylinder at the time the cylinders are ground, as this is necessary if the cylinders are enlarged. Where this is not possible, secure oversize piston rings and lap to fit the cylinder, as explained on page 816.

Try each ring in its groove by rolling it around the groove in the piston, as shown in Fig. 26, and make certain it fits properly. This is extremely important as no piston ring will function properly if it is loose or sloppy in the ring groove, or if it is too tight.

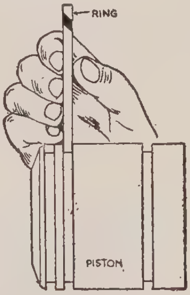

Fig. 26. **Testing a piston ring in the piston groove.** The ring should fit in the groove with about .002″ play, and should move freely all around.

It is very important that the groove be thoroughly cleaned of carbon and gum, which can be done with a small screwdriver, some kerosene, or gasoline, and a cloth.

Also be sure that the piston is perfectly round. If the piston is slightly oval, squeeze it in a vise, the jaws of which are covered with copper or lead, or tap the piston gently with a rawhide or wooden mallet.

The piston ring should fit snugly, as at (A) (Fig. 27), but should still be free to slide in and out easily; if it binds in any place, dress the sides down as in Fig. 30.

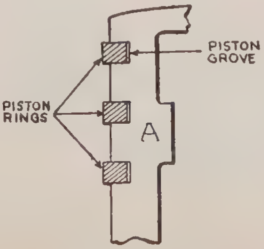

Fig. 27

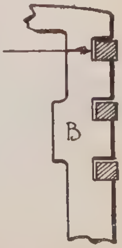

Fig. 28

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[1] **When fitting patented rings,** remember, if the rings are absolutely tight at the joints and the wall of the cylinder, they might prevent lubrication altogether, and the cylinder would run dry. Therefore many place merely one patented ring in the top groove, and the regular rings in the other grooves.

The patented type of ring requires very little lapping by hand. When the rings, fitted to the pistons, are put in, the engine is allowed to run at low speeds until rings are worked in. You will find that that is all the lapping that is necessary, unless, of course, the cylinder is scored or badly out of round. In such cases, the proper remedy is to have the cylinder rebored and new oversize pistons made, and piston rings made to fit the new diameter of the cylinder.

An example of an ill-fitting piston ring is shown at (B) (Fig. 28) and also in Fig. 24, page 831, where (C) (Fig. 24) shows the space left open between the ring and cylinder wall by the ring being sprung when it was put on the piston.

Occasionally small ridges or shoulders are found at the back or bottom of the ring groove, which may prevent the ring fitting into the groove. These can be removed with a lathe, but where no lathe is available, this trouble can be overcome by making a slight change in the piston ring as follows: Take a file and rub it slowly around the inner edges of the ring—the edges which come in contact with the ridges at the back of the groove—and remove enough material in this manner to permit the ring to fit into the groove without touching these ridges.

It sometimes happens that a ring does not seat all the way round. Such a ring allows the oil and gas to pass, and should be replaced.

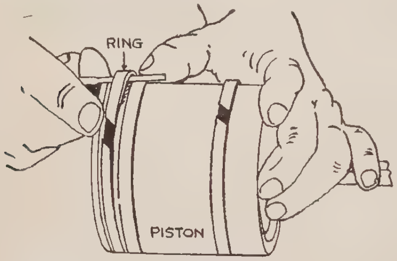

Fig. 29. **To remove a ring,** insert the handle end of a file or some similar object under the ring near the gap, and raise the end of the ring out of the groove. While pressing the ring out of the groove, run the file around the piston until the ring has been completely lifted out. It may then be slipped off the end of the piston. Before replacing a ring, the groove should be cleaned of the carbon.

Most manufacturers now cut the grooves in the piston, and grind the face and edges of the rings to a gauge, making very little hand-fitting necessary. But there are cases (and these are the ones that generally come into the repair shop), where the cut was just a trifle larger, or the ring a little smaller, than the gauge, making it essential that each ring be individually fitted to the groove in which it shall subsequently rest.

Lapping Sides of Ring to Fit Groove of Piston

Tight rings in grooves may be eased by grinding or lapping the sides on a sheet of fine emery or crocus cloth, fastened to a piece of board planed quite flat and true. The ring is gently rubbed back and forth with a downward pressure, as shown in Fig. 30.

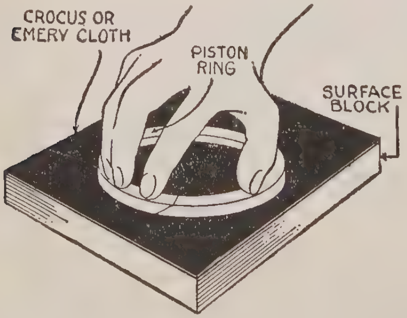

Fig. 30. Method of dressing or lapping the sides of a piston ring on a surface plate to fit the groove in the piston.

Lapping should not continue for a long period on one side. The ring should be turned over occasionally. After lapping, the ring should be immersed in clean gasoline and fitted to the groove—not to any groove, but to the groove which it nearly fitted before. If every part of the circumference of the ring fits every part of the groove, the lapping is complete and the ring may be tagged or marked to designate its location.

To dress down a ring properly requires some skill, and a good mechanic will select a ring which will demand the least amount of trimming, for it is a delicate operation.

Fitting Rings to Grooves of Pistons

When fitting rings in the grooves, begin with the ring selected for the bottom groove, so that that ring will be the first to be slipped on to the piston.

Select the best fitting ring for the top, so that oil below it cannot be consumed by the high temperature of the exploding gas. If fire, or flame from the combustion chamber flows past the rings, oil will be burned off the piston and the cylinder wall, causing it to become scored, even though the oiling system might be working perfectly with the best grade of oil.

When placing the rings on the piston ready to replace the cylinders, they should be set with the joints (if it is a piston with three rings) about one-third way from each other, so that the openings will not come in a straight line or be close together.

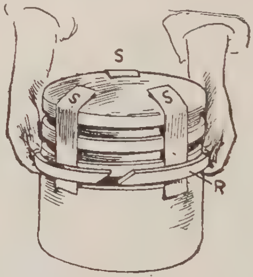

Fig. 31. One method of slipping a ring on a piston and into the groove.

A quick and safe method of slipping rings into the grooves is shown in Fig. 31. Take three strips of sheet metal, brass or tin (S), for instance, about 1/32″ thick, ½″ wide, and 5″ long; bend these at right angles and hang them on the edge of the piston at equal distances apart. The ring (**R**) may then be slipped over these skids till it is opposite its groove, when the strips may be removed and the ring allowed to slide into place. Install the ring in the lower groove first and work to the top groove last. The same strips may also be successfully used in removing the rings.

Replace the same piston rings in the same cylinders if removed and replaced again. The use of boards with numbered pegs is recommended, to avoid mixing the rings.

A ring should never be sprung over a piston to the second or third groove. Use strips (S) (Fig. 31), which will permit easy replacement without distorting the ring.

Piston-Ring Travel in Cylinder

Note (Fig. 32) the ring travel on a cylinder wall and how the cylinder wall is in time worn lower in this space, with the result that a projection is left at the top and bottom of the cylinder wall.

Overlap of Piston Ring

On some of the modern types of engines the ring is permitted slightly to overlap the cylinder wall, at top and bottom, as shown in Fig. 33.

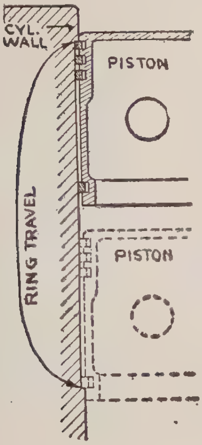

Fig. 32

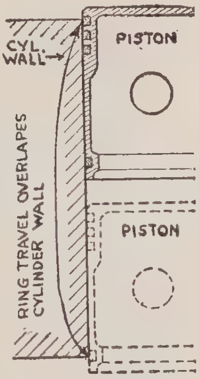

Fig. 33

Hudson and Essex Piston Ring

On the Hudson and Essex engines the piston-ring groove is burnished at top and bottom to prevent oil working up past the piston into the combustion chamber. Note also (Fig. 34), the oil duct to the piston pin.

See also page 808 for illustration and description of Essex piston.

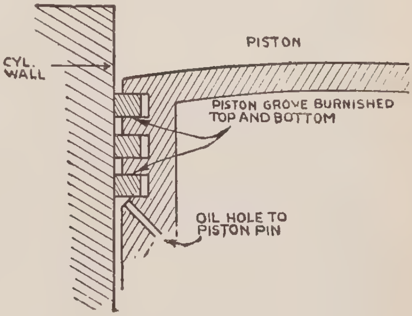

Fig. 34

REPLACING A PISTON IN THE CYLINDER

Before putting pistons into cylinders, oil the inside of the cylinder and the inside of the piston with cylinder oil, as oil will not have a chance to reach the upper portion when first starting. Also see that the piston pin is properly set, and that the set screws are tight, and that the piston and connecting rod are in alignment.

When replacing the piston in cylinder, some device must be provided for holding each ring in its groove, so that it will easily enter the cylinder. By no means force or drive the piston and rings into the cylinder. A string may be used as shown in Fig. 35. A better method is shown in Fig. 36.

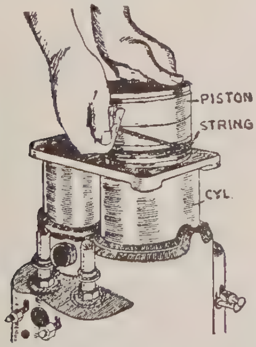

Fig. 35

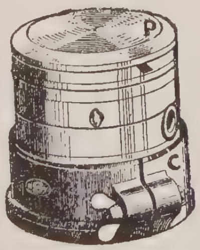

Fig. 36

Fig. 35. Method of **replacing a piston in the cylinder** with a string holding the ring in its groove.

Fig. 36. A serviceable **device (C) for compressing rings when fitting piston (P) to the cylinder.** Especially adapted for Ford pistons, which are not champfered. This tool is bored with a long gradual taper which allows the open rings to enter easily at the top. It is placed in position over the cylinder, and as the piston is forced downward into place, the rings are gradually compressed sufficiently to enter the cylinder.

Replacing cylinders over pistons: It is not difficult to put a single cylinder back on its piston after it has been necessary to take it out, but it is not so easy when the cylinders are cast in pairs, as it is difficult to guide the rings into the cylinder barrels simultaneously. The job is greatly simplified by taking the precaution to place the cranks up and down, so that one piston is at its highest point and the other is at its lowest. This means that the pair of cylinders can be dropped straight over the pistons, the rings of the upper piston being guided into the cylinder before those of the lower piston are replaced. When it comes to dropping one of the mono-block castings of four cylinders on to four pistons, it is still best to work this way, so that only one other pair of hands is required, and that the two upper pistons may be guided into their cylinders first.

Note. When **reinstalling a piston,** be careful not to push it up into the cylinder as far as it will go. The upper ring may jump over the valve opening, holding the piston until the ring is released, which is a difficult situation to remedy.

On many engines the piston and rings are fitted to the cylinder from the under side, and in many modern engines the lower ends of the cylinder bores are beveled to facilitate the insertion of the piston with the rings attached. In some cases there is a slight champfer at this point.

Running-in after Fitting

After completing the job, put plenty of oil in the crank case; enough so that not only the oil pan will be full, but that enough is above the oil pan so that the connecting rods will dip. Connect the radiator with the hose so that water will run through; run the engine slowly for about an hour or so. Do not race engine. Then run car at not over 15 or 20 m.p.h. for first 500 miles. Use plenty of oil. Thus rings will burnish to a nice fit to cylinder wall.

When fitting new rings to a piston, be sure that all the other cylinders have good compression, otherwise the cylinder with good compression will have a rich mixture and those with poor compression a lean mixture; result engine will not idle properly.

Piston Rings—Oversize

Oversize piston rings must be fitted to the pistons when oversize pistons are fitted to the cylinder. The oversizes of piston rings are: .005″, .010″, .015″, .020″, .031″, .046″, .062″, the same as in the case of the pistons. See also, page 828.

Questions on Pistons and Rings

Q. 1: How many rings are generally used?

Ans.: 3 or 4.

Q. 2: How many rings are generally used on racing car engines?

Ans.: 1 or 2. (See reason on page 826).

Q. 3: What clearance should cast-iron pistons have on an average?

Ans.: .001″ per inch of piston diameter. See page 809.

Q. 4: What clearance should aluminum-alloy pistons have on an average?

Ans.: .002″ per inch of piston diameter.

Q. 5: What is the difference between concentric and eccentric piston rings?

Ans.: A concentric ring is one of equal thickness throughout its entire circumference. An eccentric ring is not. At a point (e) (Fig. 8, page 826) opposite the split in the ring, it is made thicker.

Q. 6: What is the advantage of eccentric rings?

Ans.: Unless a piston ring bears with equal tension on the cylinder wall at all points of its circumference, the compressed gas would pass at the point where it did not bear, and thus leak compression. A ring is subjected to considerable heat, at which time it may loose its tension at some point of its circumference. Some claim that by making a ring eccentric, it will retain its tension under heat more than a concentric ring. Others claim that if a concentric ring is made of the proper material it will retain its tension. Most of the patented rings are concentric; in fact the majority of plain rings (page 826) are concentric. Sometimes two concentric rings (patented type) are fastened to each other, so as to have the splits diametrically opposite each other, as in the case of the Leak-Proof (page 825). The Inland (see page 825) is a one-piece concentric ring with a long lap. Some advantage is claimed for concentric rings over eccentric rings; for instance, the carbon that accumulates back of the ring will tend to lock an eccentric ring sooner than a concentric ring, thereby preventing the natural shifting of the ring around the piston groove.

PISTON RINGS OF ASSORTED SIZES

Regrinding and reboring shops have found that there is greater demand for their services when they **carry a stock of piston rings** and when they are able promptly to finish their jobs by installing rings.

The assortment below[1] includes popular sizes. Repairmen who specialize in overhauling particular make of car, truck, or tractors can make up stock assortments accordingly.

Suggested Sizes	For Following Cars	ASSORTMENTS 144	300	504	720	1008	1200
2 13/16 x 3/16	Oakland, Oldsmobile, Scripps-Booth	24	24	36	48	72	72
2⅞ x 3/16	Oldsmobile, Saxon, National, Singer		24	36	36	36	48
3 x 3/16	Packard, Cameron, Vim Truck, Avery Truck		24	24	24	36	48
3⅛ x 5/32	Paige, Roamer, Crow-Elkhart, Auburn		24	24	24	24	24
3⅛ x 3/16	Cadillac, Velie, Studebaker, Auburn		...	24	24	36	48
3¼ x 3/16	Hupmobile, Beggs Six, Continental 7-W	24	24	36	60	72	72
3¼ x ¼	Overland, Kline Kar, Noma, Harroun		....	12	12	12	12
3⅜ x 3/16	Buick, Essex, Keystone Truck, Chevrolet	24	24	36	48	96	96
3½ x 3/16	Hudson, Roamer, Haynes, Continental 7N	24	....	36	72	96	108
3½ x ¼	Apperson, Holmes, International Truck		....	....	....	12	12
3 9/16 x 3/16	Reo		....	....	12	12	24
3 9/16 x ⅜	Reo		....	....	....	12	12
3⅝ x 3/16	Maxwell, Kissel Kar, Willys-Knight		12	24	36	36	48
3 11/16 x 3/16	Chevrolet, Samson Truck, Oldsmobile	12	12	24	36	36	48
3¾ x 3/16	Marmon, White Truck, Huffman Truck		24	24	36	48	48
3¾ x ¼	Ford, Vim Truck, Indiana Truck Dispatch	24	36	60	108	144	144
3⅞ x 3/16	Dodge, Case Truck, Kissel Truck, Studebaker	12	24	36	48	72	84
4 x 3/16	Pierce-Arrow, Peerless, Oneida Truck		....	..	....	....	12
4 x ¼	Fordson Truck, Yankee Truck, Wetmore Truck		12	12	24	24	24
4⅛ x 3/16	Republic Truck, Velie Truck, Niles Truck		12	12	24	24	24
4⅛ x ⅜	Willys-Knight, Overland Truck, Reo Truck		....	12	12	12	12
4¼ x ¼	Locomobile, Dart Truck, Old Reliable Truck		....	....	....	12	12
4½ x ¼	Kelly-Springfield Truck, Diamond Truck		....	....	....	12	12
4¾ x ¼	Stutz, Standard Truck, Wisconsin Truck		....	....	....	12	12
3¼ x 3/16 .015	Oversizes for rebored, reground or worn cylinders of cars, truck or tractors mentioned above.	....	....	....	....	....	12
3¼ x 3/16 .031		....	....	....	....	....	12
3½ x 3/16 .005		....	....	....	....	....	12
3½ x 3/16 .015		....	....	....	....	....	12
3½ x 3/16 .031		....	....	....	....	....	12
3¾ x ¼ .005		....	....	12	12	24	24
3¾ x ¼ .015		....	....	12	12	12	12
3¾ x ¼ .031		....	....	12	12	24	24
3⅞ x 3/16 .015		....	....	....	....	....	12
3⅞ x 3/16 .031		....	....	....	....	....	12

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[1] This assortment has been listed by the Gill Mfg. Co., 8300 So. Chicago Ave., Chicago, Ill. All or any part of the list can be secured.

SIZES AND NUMBER OF PISTON RINGS REQUIRED ON VARIOUS PASSENGER CARS, TRUCKS, AND TRACTORS[1]

Year	Model	Rings Required	Size Inches
	ADVANCE RUMELY—"Oil Pull" Tractor		
1910-21	E30-60	10	10 x⅝
1910-21	G20-40	10	8 x7/16
1912-17	F15-30	15	10 x⅝
1918-21	H16-30	10	7 x⅜
1918-21	K12-20	12	6 x5/16
	ADVANCE RUMELY—"Gas Pull" Tractor		
1913-17	15-30	6	7½x½
	ADVANCE RUMELY—"All Purpose" Tractor		
1916-18	8-16	20	4 x7/32
1916-17	12-24	20	4½x¼
	ALLIS-CHALMERS—Tractor		
All	6-12	12	3⅛x3/16
All	10-18	6	5¼x5/16
All	18-30	12	4¾x5/16
1921	12-30	12	4⅛x¼
	AUBURN—Passenger		
1914	4-40, 4-41	12	4½x¼
1914	6-46	24	3¾x¼
1914	34L	16	3¾x¼
1915	4-36		3¾x3/16
1915	6-40		3½x3/16
1915	6-47		3¾x¼
1916	6-38 1st Series	18	3 x5/32
1916	6-38 2nd Series	18	3⅛x5/32
1916	6-38 Late	18	3⅛x3/16
1916	6-40A	18	3½x3/16
1916	4-38	12	3⅞x3/16
1917	6-39 1st Series	18	3⅛x5/32
1917	6-39 2nd Series	24	3⅛x3/16
1917	6-39 Late	18	3¼x3/16
1917	6-44	18	3½x3/16
1918-21	All 6-cylinder	18	3¼x3/16
	AULTMAN-TAYLOR—Tractor		
1913-21	30-60	20	7 x⅜
1914-17	25-50	20	6 x⅜
1915-18	18-36	16	5 x5/16
1918	15-30	12	4¾x¼
1919-21	15-30	12	5 x¼
1919-21	22-45	16	5½x⅜
	AVERY—Tractor		
1910-15	20-35	10	7¾x¼
1910-21	5-10	12	3 x3/16
1910-21	8-16	10	5½x⅜
1910-21	12-25	10	6½x⅜
1910-21	18-36	20	5½x⅜
1910-21	25-50	20	6½x⅜
1910-21	40-80	20	7¾x [illegible]
1918-19	5-10 Plnt. Cultv. 2-rw.	12	3 x3/16
1918-21	5-10 Plnt. Cultv. C2-rw.	18	3 x3/16
1918-21	14-20	20	4⅝x5/16
1919-21	C5	18	3 x3/16
1920-21	B1-row Cultivator	12	3 x3/16
1921	12-20	20	4⅜x7/16
1921	45-65	20	7¾x½
	BRISCOE—Passenger		
1915	B15	8	3⅛x¼
1916	4-38 (1st 800)	8	3 7/16x¼
	(after 800)	8	3 7/16x3/16
1916	8-38	24	3 x3/16
1916	4-24	12	3⅛x3/16
1917-19	B4-24	12	3 3/16x3/16
1920-21	4-32	12	3⅜x3/16
	BRISCOE—Truck		
1918-21	T34 1-ton	12	3⅜x3/16
	BUICK—Passenger		
1914-15	All 4-cyl. Models	12	3¾x3/16
1914-15	All 6-cyl. Models	18	3¾x3/16
1916	DK44, DX45, DXL45, DR44, DR45, DRL45	18	3¼x3/16
1916	D54, D55	18	3¾x3/16
1916-17	D44, D45, D46, D47	18	3¼x3/16
1917-18	All 4-cyl. Models	12	3⅜x3/16
1918-21	All Models	24	3⅜x3/16
	CADILLAC—Passenger		
1915-21	51 to 59	24	3⅛x3/16
	CASE—Passenger		
1914	O	16	4½x¼
1914	R	12	3¾x¼
1914	S	16	4¼x¼
1915	R15-25	12	3¾x3/16
1915	R15-30	12	3⅞x3/16
1916	T	12	3⅝x3/16
1917	T	16	3⅝x3/16
1918-21	All Models	18	3½x3/16
	CASE—Tractor		
1913-17	30-60	8	10 x7/16
1914	12-25	8	6¾x⅜
1914-16	20-40	8	8 x⅜
1915	10-20	16	4½x¼
1915-18	12-25	8	7 x⅜
1916-20	10-20	12	4¼x3/16
1917	9-18	12	3⅞x3/16
1917-20	20-40	8	8¾x⅜
1919-21	10-18	12	3⅞x3/16
1919-21	15-27	12	4½x¼
1920	20-36	12	5½x5/16
1920-21	22-40	12	5½x5/16
	CHALMERS—Passenger		
1917-21	35	18	3¼x3/16
	CHANDLER—Passenger		
1914	15	18	3⅜x¼
1914	15B	12	3⅜x¼
1915	16	6	3⅜x3/16 3⅜x⅜
1915	16	18	3⅜x¼
1916	17	18	3⅜x3/16
1917-21	All	18	3½x3/16
	CHEVROLET—Passenger		
1914-21	All 4-cyl.	12	3 11/16x3/16
1918-19	D2, D4, D5		3⅜x3/16
	CHEVROLET—Truck		
1918-21	All	12	3 11/16x.1890
	CLEVELAND—Passenger		
1919-21	40	18	3 x3/16
	COLE—Passenger		
1914	9	12	4¼x5/16
1914	Big 6	18	4¼x5/16
1915	660-666	18	4¼x5/16
1915	10	12	3½x¼
1915	650-651	24	3½x¼
1915	440	12	4¼x¼
1916	666	24	4¼x¼
1915-21	All 8-cyl.	32	3½x3/16
	CUNNINGHAM—Passenger		
1914-15	R-S	12	4¾x3/16
1916-20	V1, V2, V3, V4	32	3¾x3/16
1921	V4 2nd. Series	40	3¾x3/32
	DANIELS—Passenger		
1915	A	24	3¼x3/16
1916-18	B	24	3¼x3/16
1919-21	All Models	24	3½x3/16
	DIAMOND—Truck		
1915-16	¾-ton	12	3½x3/16
1915-20	1-ton	12	3½x3/16
1915-21	1½-ton	12	3¾x3/16
1915-20	2-ton	12	4⅛x3/16
1916-20	3½-ton	12	4½x3/16
1917-20	R5-ton	12	4½x3/16
1920-21	U2-ton	12	4 x3/16
1920-21	EL5-ton	12	4½x¼
1920-21	S5-ton	12	4¾x¼
1921	O1-ton	12	3¾x3/16
	DODGE—Passenger		
All	All	12	3⅞x3/16
	DORT—Passenger		
1915	4-5	12	3 x3/16
1916-17	All	12	3¼x3/16
1918-21	All	12	3½x3/16
	ELGIN—Passenger		
1916-18	Series E	18	3 x3/16
1918-21	All	18	3⅛x3/16
	EMERSON—Tractors		
1913-16	F30	12	6½x7/16
1913-16	E45	18	6½x7/16
1913-17	D20-35	12	5 x⅜
1914-17	L12-20	12	4½x5/16
1916-18	H9-16	12	4⅛x9/32
1916 17	Q12-20	12	4½x5/16
1918	Q12-20	12	4¾x5/16
1918	Q12-20	12	3¾x5/16
1919-20	D20-35	12	5¼x⅜
1913-19	R40-65	8	7¼x½
1918-21	AA12-20	12	4¾x5/16
	ESSEX—Passenger		
1919-21	A	12	3⅜x3/16
	FEDERAL—Truck		
1915	H 1½-ton	12	4⅛x3/16
1915-16	J-K 1½-ton	12	4⅛ 3/16
1916	M 1½-ton	12	4⅛x3/16
1916	O-P 2-ton	12	4⅛x3/16
1916	L 3½-ton	12	4½x3/16
1917	S 1-ton	16	3½x3/16
1917	T 1½-ton	16	3¾x3/16
1917	U 2-ton	16	3¾x3/16
1917	W 3½-ton	16	4¼x7/16
1917	X 5-ton	16	4¼x3/16
1918	TC 1½-ton, UC 2-ton	12	4⅛x3/16
1918	WC 3½-ton, XC 5-ton	12	4½x3/16
1918	T85 3-ton	12	4⅛x3/16
1918	W108 7-ton	12	4½x3/16
1919	TD 1½-ton, UD 2-ton	12	4⅛x3/16
1919	WC 3½-ton, XC 5-ton	12	4½x3/16
1919	TC85 3-ton	12	4⅛x3/16
1919	WC108 7-ton	12	4½x3/16
1920	WE 3½-ton, XE 5-ton	12	4¼x3/16
1920	WC114 7-ton	12	4½ x3/16
1920-21	SD 1-ton	16	3¾x3/16
1920-21	TE 1½-ton	12	4⅛x3/16
1920-21	UE 2-ton	12	4⅛x3/16
1920-21	UE10 3-ton	12	4⅛x3/16
1921	WE 3½-ton, XE 5-ton	12	4½x3/16
1921	WC9.5 7-ton	12	4½x3/16
1921	X2 5-ton, 6-ton	16	4¾x¼
	FORD—Passenger		
All	All	12	3¾x¼
	FORDSON—Tractor		
1918-19	22	12	4 x¼
1920	10-20	12	4 x¼
1921	18	12	4 x¼
	FRANKLIN—Passenger		
1914	Series 4, 5, 6	18	3⅝x¼
1915	Series 7, 8	18	3⅝x¼
1916-21	Series 9	18	3¼x3/16
	GARFORD—Truck		
1915	64 ¾-ton	12	3½x3/16
1915	67 3-ton	12	4¼x¼
1915-17	75 1-ton	12	3½x3/16
1915-19	1½-ton	12	3¾x3/16
1915-19	6-ton	12	5.10x¼
1915-20	5-ton	12	4¾x¼
1915-21	2-ton	12	4¼x¼
1916-17	77 3½-ton	12	4¾x¼
1917-18	77B 3½-ton	12	4¼x¼
1917-19	75B 1-ton	12	3½x3/16
1918-19	75C 1-ton	12	3¾x3/16
1919-21	25 1¼-ton	12	3¾x3/16
1919-20	77-77C 3½-ton	12	4¾x¼
1920-21	77D, 3½-ton	16	4½x¼
1921	5 and 7 ½-ton	16	5 x¼
	G. M. C.—Truck		
1915	15 3¼-ton	12	4 x3/16
1916	15 ¾-ton	12	3½x3/16
1916	40, 41 2-ton	12	4⅛x3/16
1916-20	3½ and 5-ton	12	4½x3/16
1916-20	1½ and 1-ton	12	3¾x3/16
1917-18	¾ and 1-ton	12	3¾x3/16
1917-20	41 2-ton	12	4⅛x¼
1918-19	23 1-ton	12	4⅛x¼
1921	16-31 ¾ and 1½-ton	12	3¾x3/16
1921	K15 ¾-ton	16	3½x3/16
1921	K16 1-ton	16	3½x3/16
1921	K41 2-ton	16	4 x¼
1921	K71, K101, 3½,5-ton	16	4½x¼
	GRAMM-BERNSTEIN—Truck		
1915-16	W 1½-ton	12	3½x¼
1915-16	W 3½-ton	12	4¼x¼
1915-16	W 5-ton	12	4½x¼
1915-17	W 1-ton	12	3½x¼
1915-19	W2½-ton	12	4¼x¼
1916-19	W1½-ton	12	3¾x¼
1917-19	W 3½-ton	12	4½x¼
1917-19	W 5-ton	12	4¾x¼
1918-19	W 2-ton	12	3¾x¼
1920-21	15	12	3¾x3/16
1920-21	20	12	4⅛x3/16
1920 21	25	12	4¼x¼
1920-21	35	12	4½x¼
1920-21	50	16	4¾x¼
1920-21	65	12	3¾x3/16
	GRANT—Passenger		
1914	M	12	2¾x3/16
1915	T	18	2⅞x3/16
1915-18	All Models	18	3x 3/16
1919	H	18	3⅛x3/16
1920	HX	18	3 1/16x3/16
1921	All	18	3⅛x3/16
	HART-PARR—Tractor		
1916-17	Little Devil 22	8	5½x⅜
1916	Crop Maker 27	5	8½x½
1917	Crop Maker 27	4	8½x½
1916-17	Oil King 35	5	10 x½
1916	Steel King 40	10	8 x½
1916	Old Reliable 60	10	10 x½
1917	Steel King 40	12	8 x½
1917	Old Reliable 60	12	10 x½
1918-19	New Hart-Parr 12-24	8	6½x5/16
1919-21	Hart-Parr 30	8	6½x5/16
1921	Hart-Parr	8	5¼x5/16
	HAYNES—Passenger		
1914	26-27	24	4¼x¼
1914-15	28, 31, 32	16	4¼x¼
1915	30-33	18	3½x3/16
1916	34-35	18	3½x3/16
1917-18	40, 41, 44	18	2¾x3/16
1917-18	All 6-cyl.	24	3½x3/16
1918	43-44 Early	48	2¾x3/16
1918	43-44 Late	24	2¾x3/16
1919	45	24	3½x3/16
1921	47-50 Early	18	3½x3/16
1921	47-50 Late	24	3½x.1975
	HUDSON—Passenger		
1915-16	40	18	3½x3/16
1914-15	54	18	3½x3/16
1921	O	18	3½ -3/16
1916-20	H, J, M, O	18	3½x3/16
	HUPMOBILE—Passenger		
1915	K36	12	3⅜x3/16
1916	N1-2-3	12	3¾x3/16
1917	N4-5-6	8	3¾x3/16
1918-21	R1-2-3-4	12	3¼x3/16

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SIZES AND NUMBER OF PISTON RINGS REQUIRED ON VARIOUS PASSENGER CARS, TRUCKS AND TRACTORS[1]

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Year	Model	Rings Required	Size Inches
	HURLBURT—Truck		
1914	1-ton	16	3¾x3/16
1914	2-ton	16	4⅛x¼
1914	3-ton	16	4¼x¼
1915-16	1-ton	12	3¾x3/16
1915-16	3½-ton	12	4¼x¼
1916	5-ton	18	3¾x3/16
1916-18	1½-ton	12	3¾x3/16
1917	5-ton, 7-ton	18	3¾x3/16
1917-18	2-ton	12	4¼x¼
1917-18	3½-ton	12	4½x¼
1918-19	5-ton	12	4½x¼
1919	2-ton	16	4¼x¼
1919	3½-ton	16	4½x¼
1920-21	A 1-ton, 1½-ton	16	4¼x¼
1920-21	2½-ton, 3-ton	16	4¼x¼
1920-21	C 3½-ton	16	4½x¼
1920-21	D 5-ton	16	4½x¼
	INTERNATIONAL—Tractor		
1914-15	Mogul 8-16	5	8 x9/16
1915-21	International 15-30	16	5¼x7/16
1916-21	Titan 10-20	8	6½x⅜
1917-19	Mogul 10-20	5	8½x9/16
1917-19	International 8-16	16	4 x¼
1920	International 8-16	16	4¼x¼
	INDIANA—Truck		
1914	B 1½-ton	16	3¾x¼
1914	K4-ton	12	4⅛x¼
1914-15	F 2-ton	12	4⅛x¼
1915	B 1½-ton	12	3¾x¼
1915	K 3-ton	12	4¾x¼
1916	S 1-ton	16	3½x¼
1916-17	D 2-ton	12	4⅛x¼
1916	R 3½-ton	12	4⅛x¼
1916	L 5-ton	12	4¾x¼
1916	Special	18	3 x5/32
1916	Special	24	3¾x¼
1917	T 1-ton	8	3½x¼
1917	R 3½-ton	12	4¼x¼
1917	L 5-ton Early	12	4¾x¼
1917	L 5-ton Late	12	5.10x¼
1918	T 1-ton Early	16	3½x¼
1918	T 1-ton Late	16	3¼x¼
1918-19	Q 1½-ton	12	4⅛x¼
1918-19	D 2-ton	12	4⅛x¼
1918-19	R 3½-ton	12	4⅜x¼
1918-19	L 5-ton	12	4¾x¼
1919	T 1-ton	16	3¾x¼
1920-21	12 1¼-ton	12	3¾x¼
1920-21	200 2-ton	12	4⅛x¼
1920-21	25 2½-ton	12	4⅛x¼
1920-21	35 3½-ton	12	4⅜x¼
1920-21	50 5-ton	12	5 x¼
	JACKSON—Passenger		
1913-14	43	12	4½x5/16
1913-14	53	18	4⅛x5/16
1914	40	12	4⅛x5/16
1915	46	12	4½x5/16
1915	48	18	3½x3/16
1916	34	12	3½x3/16
1916	348	32	2⅞x3/16
1916	68	24	3½x3/16
1917-18	349	24	3 x3/16
1917-18	350	24	3 x3/16
	On Models 349 and 350, all engine numbers with O prefixed are .020 oversize		
1919-21	6-38	18	3¼x3/16
	JORDAN—Passenger		
1917-18	B and C	18	3½x3/16
1919-21	F	18	3½x3/16
1920-21	M	18	3¼x3/16
	KELLY SPRINGFIELD—Truck		
1914-18	All 1½- and 2½-ton	12	3¾x¼
1914-19	All 3½, 4, 5, 6-ton	12	4½x¼
1920-21	1½ and 2½-ton	16	3¾x¼
1920-21	3½, 4, 5, 6-ton	16	4½x¼
	KING—Passenger		
1914	G50	12	3 5/16x7/32
1915	D50	24	2¾x5/16
1915	D60	24	2⅞x3/16
1916-21	All	16	3 x3/16
	KINNARD—"Flour City" Tractor		
1909-21	30-50	16	6¼x⅜
1909-21	40-70	16	7½x7/16
1917-19	15-25	16	5 x3/16
1917-21	20-35	16	5¼x5/16
1918-20	12-20	8	6½x⅜
1920-21	14-24	16	5 x5/16
	KISSEL KAR—Passenger		
1914	36M-14	16	4¼x3/16
1914	40H-14	16	4½x3/16
1914	60F-14	24	4½x3/16
1914-15	6-48	18	4 x¼
1915	6-60	24	4½x3/16
1915	4-32	12	3⅞x3/16
1915	6-42	18	3⅜x3/16
1915	4-36	12	4¼x¼
1917	100 Point 6	12	3¼x¼
1917-18	100 Point 6	24	3¼x3/16
	KISSEL KAR—Passenger (Cont.)		
1917	6-42	12	3⅝x¼
1917-18	4-32	8	3⅞x¼
1918	Double 6	36	2⅞x3/16
1918	Silver Special	24	3 5/16x3/16
1918	6-42	18	3⅝x3/16
1918	Custom-Built Six	24	3 5/16x3/16
1921	Custom-Built Six	12	3⅝x3/16
	KISSEL—Truck		
1913-14	1¼-ton	16	4½x3/16
1914	1-ton, 2½-ton	16	4½x3/16
1914	2¼-ton	16	4¼x3/16
1914	3½-ton, 6-ton	16	4⅞x3/16
1914	3½-ton, 6-ton	16	4⅞x3/16
1915-16	½-ton, ¾-ton	12	3⅞x3/16
1915-16	1-ton. 1½-ton	12	4¼x¼
1917	1-ton, 1¼-ton	8	3⅞x¼
1917	2-ton, 4-ton	8	4¼x¼
1918	¾-ton	12	3⅞x3/16
1918	1¼-ton	12	3⅞x3/16
1918	2-ton, 3½-ton	12	4¼x3/16
1919	¾-ton	12	3⅞x3/16
1919	1½-ton	12	3⅞x3/16
1919	2-ton, 3½-ton	12	4¼x3/16
1920	¾-ton, 1½-ton	12	3⅞x3/16
1920	2-ton, 3½-ton	12	4¼x3/16
1921	1-ton, 1½-ton	12	3⅞x3/16
1921	2½-ton, 3½-ton	12	4¼x3/16
	KLINE KAR—Passenger		
1914	40-30 B and C	12	4 x9/32
1914	4-40 B and C	12	4 5/16x9/32
1914	6-50 B and C	18	4⅛x9/32
1914	6-50 B and C	18	4 5/16x9/32
1915	6-42 A and D	12	3½x¼
1916	6-36 E	12	3¼x¼
1917	6-38 F	18	3¼x¼
1917	6-38 G	18	3¼x3/16
1918	6-38 GA	18	3¼x3/16
1918	6-42 G	18	3¼x3/16
1919	6-42 H	18	3¼x3/16
1920	6-55 J	18	3¼x3/16
1921	6-55 K	18	3¼x3/16
	LEXINGTON—Passenger		
1914	4H	12	4 x3/16
1915	4K	12	3⅞x⅛
1917	6P	24	4¼x¼
1915-16	6L, 6N	18	3½x3/16
1916	6O-16	12	3¼x¼
1917-21	Al	18	3¼x3/16
	LOCOMOBILE—Passenger		
1912-16	R38	30	4¼x¼
1913-16	M48	30	4½x¼
1917	R7-38	18	4¼x¼
1917-21	M48	18	4½x¼
	MACK—Truck		
1914-19	AB 1½-ton, 2-ton	12	4 x5/32 4 x¼ 4 x⅜
1915-18	AC3 ½, 5, 6½, 7½-ton	8	5 x¼ 5 x½
1919-21	AC 3½, 5, 6½, 7½-ton	16	5 x¼
1920-21	AB 1½, 2-ton	16	4 x5/32
	MAXWELL—Truck		
1917-18	1-ton	12	3⅝x3/16
1918	750 Lbs.	12	3⅝x3/16
1919-22	1½-ton	12	3⅝x3/16
	MAXWELL—Passenger		
1914-15	25	12	3⅝x¼
1916-21	25	12	3⅝x5/16
	MARMON—Passenger		
1916-21	All	18	3¾x3/16
	MERCER—Passenger		
1913-14	35J	8	4⅜x¼
1914	35O	8	4⅜x¼
1914	35M	8	4⅜x¼
1915	22-70 Early	12	3¾x3/16
1915	22-70 Late	8	3¾x3/16
1916-17	22-72, 22-75	12	3¾x¼
1918	22 74	8	3¾x3/16
1919-20	All	12	3¾x3/16
	MITCHELL—Passenger		
1914	A40	12	4¼x¼
1914	A50	18	4¼x¼
1915	B45	18	4 x¼
1915	B48	18	3 x¼
1915	B35	12	4 x¼
1916	C42	18	3½x¼
1917-18	D40	18	3¼x3/16
1919	E40	18	3½x3/16
1919	E42	18	3¼x3/16
1920-21	F40	18	3¼x3/16
1921	F42	18	3½x3/16
	MOLINE-KNIGHT—Passenger		
1914-15	B	12	4 x¼
1915-17	C	12	3¾x3/16
1916-17	G	12	4 x¼
1918-19	L	12	3¾x3/16
	MOLINE UNIVERSAL—Tractor		
1916-17	B and C	6	4¾x3/16
1918-21	D 9-18	12	3½x3/16
	MOON—Passenger		
1913-15	6-50	18	3¾x3/16
1915-16	6-30	18	3¼x3/16
1915-16	6-40, 6-44	18	3½x3/16
1917-18	6-43, 6-45	18	3¼x3/16
1916-19	6-66	18	3½x3/16
1917	6-36	18	2⅞x3/16
1919	6-46	18	3¼x3/16
1920-21	6-48	18	3¼x3/16
1920-21	6-60	18	3½x3/16
	NASH—Passenger		
1918	671	24	3½x3/16
1918	683	18	3¼x3/16
1918-21	681-682	18	3¼x3/16
1918-21	684-685	18	3¼x3/16
1919-21	686-687	18	3¼x3/16
1921	41, 42, 43, 44	12	3¼x3/16
	NASH—Truck		
1918-21	2018-3018	6	3¾x3/16
1918-21	4012	12	4¼x¼
	NATIONAL—Passenger		
1914-16	6W, AA	24	3¾x3/16
1914-16	AB	18	3¾x3/16
1916-17	All 6-cyl.	18	3½x3/16
1916-17	AD and AH	48	2¾x7/32
1917-19	All 12-cyl.	48	2⅞x3/16
1918-21	All 6-cyl.	18	3½x3/16
	NELSON AND LEMOON—Truck		
1911-14	D 1-ton	12	3¾x3/16
1911-14	D 2-ton	12	4⅛x3/16
1911-14	D 3-ton	12	4½x3/16
1914-18	E 1-ton	12	3¾x3/16
1914-18	E1½-ton	12	3¾x3/16
1914-18	E 2-ton	12	4⅛x3/16
1914-18	E 3½-ton	12	4½x3/16
1914-18	E 5-ton	18	3¾x3/16
1918	E5B 5-ton	16	4½x¼
1919-20	F 1½-ton	12	4⅛x3/16
1919-20	F2½-ton	12	4⅛x3/16
1919-20	F 3½-ton	12	4½x3/16
1919-20	F 5-ton	16	4¾x¼
1921	G 1½-ton	16	4⅛x¼
1921	G 2½-ton	16	4⅛x¼
1921	G 3½ ton	16	4½x¼
1921	G 5-ton	16	4¾x¼
	OAKLAND—Passenger		
1914	36	12	3½x¼
1914	43	12	4¼x5/16
1914	48	18	3½x¼
1914	62	18	4¼x5/16
1915	37R	12	3½x3/16
1915	49R	18	3½x3/16
1916-17	38	12	3½x3/16
1916	32B	18	2 13/16x3/16
1916-17	8-50	24	3½x3/16
1917-21	All 6-cyl.	18	2 13/16x3/16
	OLDSMOBILE—Passenger		
1914	42	12	3½x3/16
1914-15	54-55	18	4¼x5/16
1915	42	12	3½x¼
1916	43	16	3½x3/16
1916-21	All 8-cyl.	32	2⅞x3/16
1921	43A	12	3 11/16x3/16
	OLD RELIABLE—Truck		
1913-15	2-ton	16	4¼x¼
1913-15	4, 5-ton	16	4¾x¼
1915	1½-ton	16	3¾x¼
1915	3-ton	16	4¼x¼
1915	7-ton	16	4¾x¼
1916	WD 1-ton	16	3¾x¼
1916	WD 2-ton	16	4 x¼
1916	CD 2-ton	16	4¼x¼
1916	WD 3-ton	16	4¼x¼
1916	WD-CD 4-ton	16	4¾x¼
1916	CD 6-ton	16	4¾x¼
1916	CD 7-ton	16	5.10x¼
1917-18	WD 1½-ton	12	4 x¼
1917-18	WD 2-ton	12	4 x¼
1917-18	CD 2-ton	12	4¼x¼
1917-18	WD-CD 3-ton	12	4¼x¼
1917-18	WD-CD 4-ton	12	4¾x¼
1917-18	WD 5-ton	12	4¾x¼
1917-18	CD 5-ton	12	5.10x¼
1917-18	CD 7-ton	12	5.10x¼
1919	W15 1½-ton	12	4 x¼
1919	W25 2½-ton	12	4¼x¼
1919	W35 3½-ton	12	4¼x¼
1919	W50 5-ton	12	5.10x¼
1919	C50 5-ton	12	4¾x¼
1919	CD 7-ton	12	4¾x¼
1920	K & M 7-ton	12	4¾x¼
1920-21	A1½-ton	16	4 x¼
1920-21	B 2½-ton	12	4¼x¼
1920-21	C 3½-ton	12	4¼x¼

[concluded on next page

SIZES AND NUMBER OF PISTON RINGS REQUIRED ON VARIOUS PASSENGER CARS, TRUCKS AND TRACTORS[1]

[concluded from page 836

OLD RELIABLE—Truck (Cont.)

Year	Model	Rings Required	Size Inches
1920-21	D 5-ton	12	4¾x¼
1921	K, L & M, 7	12	5 x¼

OVERLAND—Passenger

Year	Model	Rings Required	Size Inches
1914	65-79	8	4⅛x⅜
1915	80	8	4⅛x⅜
1915	81	12	4 x3⁄16
1915	82	18	3½x3⁄16
1916	83	8	4⅛x⅜
1916	86	18	3½x3⁄16
1916	75	16	3⅛x3⁄16
1916	75B	16	3⅜x3⁄16
1917	85-4	8	4⅛x⅜
1917	85-6 next 2,000 cars	18	3¼x3⁄16
1917	85-6 first 13,500 cars	12	3¼x¼
1917-18	85-6 after 15,500	24	3¼x3⁄16
1917-19	90	16	3⅜x3⁄16
1919-20	4-cylinder	12	3⅜x3⁄16

PACKARD—Truck

Year	Model	Rings Required	Size Inches
1913-14	2B 2-ton	16	4 1⁄16x¼
1913-14	3A 3-ton	16	4½x¼
1913-14	5A 5-ton	12	5 x¼
1915-19	1, 1½, 2-ton	12	4 x¼
1915-19	3, 4-ton	12	4½x¼
1916-19	5, 6-ton	12	5 x¼
1920-21	EC, EX, 2-ton	12	4 3⁄16x¼
1920-21	ED, EY, 2-ton	12	4½x¼
1920-21	EF 5-ton	12	5 x¼

PAIGE—Passenger

Year	Model	Rings Required	Size Inches
1914	F4-36	12	4 x3⁄16
1915	H6-36	18	3 x5⁄32
1915-16	G6-48	18	3½x3⁄16
1916	H6-38	18	3⅛x5⁄32
1917	6-51	18	3½x3⁄16
1917-18	6-39	18	3⅛x5⁄32
1918-19	6-55	18	3½x3⁄16
1919	6-42	18	3⅛x3⁄16
1920-21	6-44	18	3¼x3⁄16
1920-21	6-66	18	3¾x3⁄16

PAIGE—Truck

Year	Model	Rings Required	Size Inches
1918-19	50-18 2½-ton	12	4¼x3⁄16
1918	51-18 Early 3½-ton	12	4½x3⁄16
1918	51-18 Late 3½-ton	12	4½x¼
1919-21	51-18 3½-ton	12	4½x¼
1919-21	52-19 1½-ton	12	4 x3⁄16
1920-21	54-20 2½-ton	12	4¼x¼

PEERLESS—Passenger

Year	Model	Rings Required	Size Inches
1914	3J-38	18	4 x3⁄16
1914	3K48	18	4½x3⁄16
1914	3L60	24	5 x3⁄16
1915	5K48	18	4½x3⁄16
1915	DD54	12	3¾x3⁄16
1915	EE55	18	3½x3⁄16
1916-21	All	24	3¼x3⁄16

PIERCE-ARROW—Passenger

Year	Model	Rings Required	Size Inches
1914-15	C2, C3	24	4 x¼
1914-15	B2, B3	24	4½x¼
1914-15	A2, A3	24	5 x5⁄32
1916-18	C4-38	18	4 x¼
1916-18	B4-48	18	4½x¼
1916-18	A4-66	18	5 x5⁄32
1919-20	31	18	4 x¼
1919-20	51	18	4½x¼
1921	32	18	4 x3⁄16

PIERCE-ARROW—Truck

Year	Model	Rings Required	Size Inches
1914-21	All 2-ton	12	4 x3⁄16
1914-20	All 5-ton	12	4⅞x5⁄32
1921	W2 3½-ton	12	4½x¼
1921	R10 5-ton	12	4½x¼

PREMIER—Passenger

Year	Model	Rings Required	Size Inches
1914	A	18	3⅝x3⁄16
1914	6-49	18	4 x¼
1915	6-50, 6-51, 6-56	24	4 x3⁄16
1916-17	6B	18	3⅜x3⁄16
1918-19	6C	18	3⅜x3⁄16
1920-21	6D	18	3⅜x3⁄16

R and V KNIGHT—Passenger

Year	Model	Rings Required	Size Inches
1920-21	J	18	3½x3⁄16
1921	R	12	3¾x3⁄16

REO—Passenger

Year	Model	Rings Required	Size Inches
1915-16	MN	12	3 9⁄16x⅝
1915-16	RS	18	4⅛x⅜
1917	R	12	4⅛x3⁄16
1917-18	MN	18	3 9⁄16x3⁄16
1918	TU	12	4⅛x3⁄16
1920-21	T6, U6	18	3 9⁄16x3⁄16

REO—Truck

Year	Model	Rings Required	Size Inches
1915-16	All	8	4⅛x⅜
1918-21	All	12	4⅛x3⁄16
1917-18		12	4⅛x⅜

REPUBLIC—Truck

Year	Model	Rings Required	Size Inches
1914-15	L 1-ton	12	3¾x3⁄16
1914-21	All 1½-ton	12	3½x3⁄16
1915-17	F 1-ton	12	3½x3⁄16
1916-18	9 Dispatch 1-ton	12	3¼x3⁄16
1917-18	10 1-ton	12	3½x3⁄16
1918	10X 1-ton	12	3½x3⁄16
1919	16 1-ton	12	3½x3⁄16
1916-17	AA Spec. 2-ton	12	4⅛x¼
1916-17	Series T 3½-ton	12	3¼x¼
1916-18	9 Dispatch ¾-ton	12	3¼x3⁄16
1916-18	9 Special ¾-ton	12	3¼x3⁄16
1917-18	Series 12 2½-ton	12	4⅛x¼
1918	9 Dispatch ¾-ton	12	3½x3⁄16
1918	9 Special ¾-ton	12	3½x3⁄16
1918-21	Series 10 1-ton	12	3¾x3⁄16
1919-21	Series 19 2½-ton	12	4⅛x3⁄16
1920	19W 2½-ton	12	4 x¼
1919-21	20 3½-ton	12	4½x3⁄16

ROAMER—Passenger

Year	Model	Rings Required	Size Inches
1920-21	6-54	18	3½x3⁄16
1920-21	4-75E	12	4 x¼
1920-21	4-75E	12	4¼x3⁄16

SAXON—Passenger

Year	Model	Rings Required	Size Inches
1916-19	All 4-cylinder	12	2¾x3⁄16
1916-20	All 6-cylinder	18	2⅞x3⁄16
1920	125	16	3⅜x3⁄16
1921	125G	12	3½x3⁄16

SCRIPPS-BOOTH—Passenger

Year	Model	Rings Required	Size Inches
1915-17	C	12	3 x3⁄16
1917	H	24	3⅝x5⁄32
1917-19	G	12	3 11⁄16x3⁄16
1918	D	24	2⅝x5⁄32
1919-20	B39, 40, 41, 5	18	2 13⁄16x3⁄16
1921	F43, 44, 45, 46	18	3¼x3⁄16

SERVICE—Truck

Year	Model	Rings Required	Size Inches
1913-14	Q 1½-ton	12	4⅛x¼
1913-14	P 2-ton	12	4⅛x¼
1913-14	H 3½-ton	12	4¼x¼
1915	W 1-ton	12	3¾x3⁄16
1915	QW 1½-ton	12	4⅛x¼
1915	PW 2-ton	12	4⅛x¼
1915	HW 3½-ton	12	4¼x¼
1915	HX 5-ton	12	4¾x¾
1916	RU120 1-ton	12	3½x3⁄16
1916	OU130 1½-ton	12	4⅛x¼
1916	TU140 2-ton	12	4⅛x¼
1916	TU170-175 3½-ton	12	4¼x¼
1916	200 5-ton	12	4½x¼
1917-18	230 1½:ton	12	4 x¼
1917-18	240 2-ton	12	4¼x¼
1917-18	270 3½-ton	12	4¼x¼
1917-18	275 3½-ton	12	4½x¼
1917-18	300 5-ton	12	4½x¼
1917-21	220 1-ton	12	3½x3⁄16
1919-20	33 1½-ton	12	4 x¼
1919-20	35 1½-ton	12	4¼x¼
1919-20	41 2-ton	12	4¼x¼
1919-20	51 2½-ton	12	4¼x¼
1919-20	71 3½-ton	12	4¼x¼
1919-20	76 3½-ton	12	4½x¼
1919-20	101 5-ton	12	4½x¼
1921	15 ¾-ton	12	3⅝x¼
1921	31 1½-ton	16	4 x¼
1921	35 1½-ton	16	4¼x¼
1921	51 2½-ton	16	4¼x¼
1921	71 3½-ton	16	4¼x¼
1921	76 3½-ton	16	4½x¼
1921	101 5-ton	16	4½x¼

STEWART—Passenger

Year	Model	Rings Required	Size Inches
1920-21	Four	16	3½x¼
1920-21	Six	24	3⅛x3⁄16
1921	Sp. Roadster	24	3¼x3⁄16

STANDARD 8—Passenger

Year	Model	Rings Required	Size Inches
1917	E	24	3x3⁄16
1917	F	24	3¼x3⁄16
1918-21	All	24	3¼x3⁄16

STEARNS KNIGHT—Passenger

Year	Model	Rings Required	Size Inches
1914-15	SK4	8	4¼x⅜
1914-16	SK6	12	4¼x⅜
1915-16	SKL4	8	3¾x⅜
1916	SK8	16	3¼x⅜
1917	SKL4	16	3¾x3⁄16
1917-18	SK8	24	3¼x3⁄16
1918-21	SKL4	12	3¾x3⁄16

STUDEBAKER—Passenger

Year	Model	Rings Required	Size Inches
1914-15	EB6, EC6	24	3½x3⁄16
1914-15	SC4, SD4	16	3½x3⁄16
1916-17	ED6	24	3⅞x5⁄32
1916-17	SF4	16	3⅞x5⁄32
1918	ED6	24	3⅞x3⁄16
1918	SF4	16	3⅞x3⁄16
1919	SH4	16	3½x3⁄16
1919-21	EG6	24	3⅞x3⁄16
1919-21	EH6	24	3½x3⁄16
1920-21	EJ6	18	3⅛x3⁄16

STUTZ—Passenger

Year	Model	Rings Required	Size Inches
1914	E4	16	4¾x¼
1914	E6	24	4 x¼
1915	F4	16	4¾x¼
1915	F6	18	4 x¾
1916-17	C & R	12	4¾x¼
1918-21	S, G, H, K	12	4⅜x¼

TEMPLAR—Passenger

Year	Model	Rings Required	Size Inches
1918-21	445	16	3⅜x3⁄16

TWIN CITY—Tractor

Year	Model	Rings Required	Size Inches
1911-20	TA 40-65	16	7¼x½
1911-20	TE 60-90	24	7¼x½
1912-16	TB 25-45	16	6 x⅜
1913-16	TF 15-30	16	4¾x¼
1916-18	TL 16-30	12	5 x5⁄32
1918-21	TR 25-45	16	6¼x⅜
1918-21	TW 12-20	16	4¼x¼
1919-21	TL 16-30	20	5 x5⁄32
1920-21	AE 20-35	20	5½x3⁄16
1921	BE 40-65	16	7¾x½

WALL'S—Tractor

Year	Model	Rings Required	Size Inches
1914	C	12	6 x⅜
1915-16	D	12	6 x⅜
1917	J 15-25	12	4¼x¼
1919-21	K 15-25	12	4¼x¼

WATERLOO BOY—Tractor

Year	Model	Rings Required	Size Inches
1914-18	R 12-25	8	6 x3⁄16
1916-21	N 12-25	8	6½x3⁄16

WESTCOTT—Passenger

Year	Model	Rings Required	Size Inches
1914-15	O30, O35	12	3½x3⁄16
1915	U50	18	3½x3⁄16
1916	41	18	3¼x¼
1916	42-51	18	3½x3⁄16
1917-18	S17, S18	18	3½x3⁄16
1919-21	A38, B38, C38	18	3¼x3⁄16
1919-21	A48, C48	18	3½x3⁄16

WHITE—Passenger

Year	Model	Rings Required	Size Inches
1913-14	GEB	12	4¼x¼
1914	GAG (GBB) Taxi GAE, GAGR, GAER, GAF	12	3¾x3⁄16
1914	GEC, GECR	12	4¼x¼
1914	GFD	18	4¼x¼
1914-16	GAHR	12	3¾x3⁄16
1914-16	GEDR	12	4¼x¼
1914-17	GAH	12	3¾x3⁄16
1914-17	GED	12	4¼x¼
1915	GL, GAIR	12	3¾x3⁄16
1915-16	GAI	12	3¾x3⁄16
1915-17	GFE	18	4¼x¼
1916	GAFT	12	3¾x3⁄16
1916	GEF, GEET	12	4¼x¼
1916-18	GM	12	4¼x¼
1916-21	15A (Taxi)	12	3¼x3⁄16
1917	GMTR	12	4¼x¼
1917-18	GMT	12	4¼x¼

WHITE—Truck

Year	Model	Rings Required	Size Inches
1911-15	GTA 3-ton	12	3¾x3⁄16
1912	GTE 1½-ton	12	4¼x¼
1912-14	TC 5-ton	12	4¼x¼
1913-16	GBE ¾-ton	12	3¾x3⁄16
1914	GTD 2-ton	12	4¼x¼
1914	GTC, BTX, 5-ton	12	4¼x¼
1914-15	GTC-IT-TI 3-ton	12	4¼x¼
1914-16	GTR ¾-ton	12	4¼x¼
1914-16	GTF 2-ton	18	4¼x¼
1914-16	TH 3-ton	18	4¼x¼
1914-16	BTCD 5 ton	12	4¼x¼
1914-16	TH-ATH, 5-ton	18	4¼x¼
1914-18	ATAD-TAD or 25, 3-ton	14	3¾x3⁄16
1914-18	TCD or 30, 3-ton	12	4¼x¼
1914-19	TEB or 15-30, ¾-ton	12	4¼x¼
1914-19	TDB or 20-30, 2-ton	12	4¼x¼
1914-19	ATCD-TCD or 30, 5-ton	12	4¼x¼
1914-21	GBBE or 15, ¾-ton	12	3¾x3⁄16
1914-21	TBC or 20, ATBC or 20D, 2-ton	12	3¾x3⁄16
1915	TADR-BTAD, 3-ton	12	3¾x3⁄16
1915	TCDR, 5-ton	12	4¼x¼
1915-16	GBB, ¾-ton	12	3¾x3⁄16
1915-16	GTB, 2-ton	12	3¾x3⁄16
1916	ATK-AETC, 5-ton	12	4¼x¼
1917-21	TDC or 20-35, 2-ton	12	4¼x¼
1917-21	TC or 45, ATG or 45D, 5-ton	12	4¼x¼
1918	TEBO, 1-ton	12	4¼x¼
1918	XEBC, 2-ton	12	3¾x3⁄16
1918	TK-ATK, 5-ton	12	4¼x¼
1918-21	TJ or 40 3, 3½-ton	12	3¾x3⁄16
1919	AT-CDO, 5-ton	12	4¼x¼
1919-21	15-45, ¾ ton	12	4¼x¼
1919-21	20-45, 2-ton	12	4¼x¼
1919-21	ATJ or 40D, 3½-ton	12	3¾x3⁄16

WINTON—Passenger

Year	Model	Rings Required	Size Inches
1916-18	22	18	4½x¼
1916-18	22A	18	4¾x¼
1919	24	18	4½x¼
1919-21	25	18	3¾x¼

INSTRUCTION No. 72

ADJUSTING AND REPAIRING CLUTCHES, TRANSMISSIONS AND UNIVERSAL JOINTS

The fundamental principle and purpose of each of these parts, as well as their construction, are explained in the first section of this book. For instance, clutches[1] are explained on page 20, and transmissions on page 25.

We will now deal with adjustment and repairs, using as examples the parts of different makes of cars. Some of the older types of cars will be used, rather than taking all of our examples from the very latest types, owing to the fact that repairs and adjustments are more commonly required on the older types.

Types of Clutches

There are three types of clutches in general use: the cone, the plate, and the multiple-disk types.

The cone types of clutch are those using a **straight cone** or an **inverted cone.** The angle of the cone is usually 17°.

The **facing** of a cone clutch can be **leather** or **fabric.** The latter is being used now, more than formerly.

The plate clutch seems to be gaining steadily in favor.

Of the many different designs in present-day cars, the following are typical: (1) steel against asbestos fabric; (2) steel against molded asbestos; (3) steel against bronze; (4) steel against cork.

There is a strong tendency toward the dry-plate type of clutch, and this tendency seems to be largely due to the fact that the parts, frictional area, etc., of a dry-plate clutch can be made very much smaller than the parts and frictional area of a clutch running in oil. The oil film serves as a lubricant, which reduces the amount of friction and necessitates a very much stronger spring, or an elaborate system of multiple levers.

The introduction of the molded asbestos ring, which has now come into commercial prominence, has resulted in a great refinement in clutch design. These molded rings or disks can be made to closer limits and do not require any stapling at the joint. In some cases the ring is made flat, and in such cases no replacements need be made until these disks have worn practically all the way through. There are no rivet heads to consider.

The multiple-disk clutch, which has a greater number of disks than the plate clutch, each disk requiring multiplying levers to keep an engagement, is found operating both **dry** and **in oil.** Its greatly increased frictional surfaces over the plate clutch necessitate a strong spring, but the disk clutch running in oil is larger and has to have more frictional area than the dry disk type, for the same reasons as have been given in what is said of plate clutches above.

How to Use the Clutch Properly

The clutch on an automobile should be either **in** or out absolutely.

Many good drivers make it a plan to **keep their foot off the clutch pedal** while they are driving. The weight of the foot on the pedal and a little nervous tension in the driver's leg is sometimes just sufficient to hold the clutch out just far enough to "slip it" on a hard or sudden pull.

Another good way to spoil a clutch is to throw it out in traffic until the car comes almost to a standstill, and then to speed up the engine and to slip the clutch in with the gear-shift lever still in high speed.

When the car slows down with the clutch out, the gear lever should be slipped to second speed, and if the car comes to a full stop, it should be shifted to low speed.

Another important point in driving is to learn to **engage the clutch gradually,** and not to "bang" it in with the engine racing.

It is always better to **run on the engine as much as possible,** throttling it down instead of constantly throwing "out" the clutch.

A well-adjusted clutch **takes hold gradually,** does not slip after it has come to a seat, and releases instantly when the pedal is depressed.

CONE CLUTCHES; TROUBLES, ADJUSTMENT, AND REPAIRS

The parts of a cone clutch can be enumerated as follows:

1. **Leather or fabric facing** over the cone.
2. **Main clutch spring,** which holds the tension of the cone to the fly wheel.
3. **Pressure or plunger studs,** also called "clutch leather expanders," which are mounted under the clutch leather at various points and allow gradual engagement of the frictional surfaces. The "grabbing" feature is eliminated by the use of these plungers, of which there are usually six, inserted under the leather, as shown in Fig. **1.**
4. **Clutch rollers** on the shifter yoke.
5. **Ball-thrust bearings** on the clutch shaft.
6. **Clutch brake,** which prevents spinning of the clutch when released.

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[1] See Index under "Specifications of leading cars" for types and make of clutch used on different makes of cars.

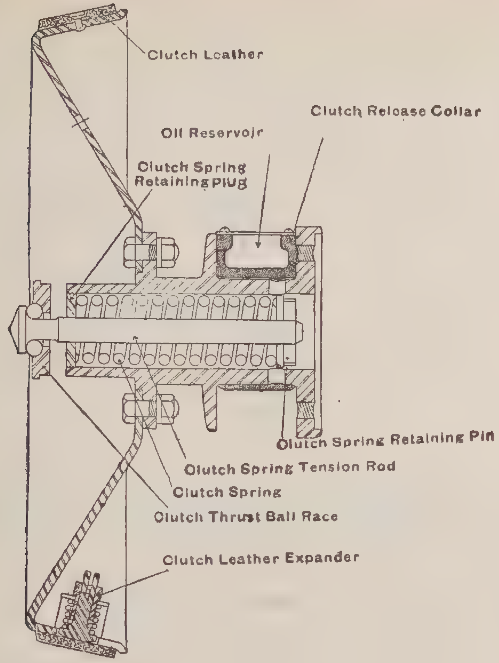

Fig. 1. Typical example of a **cone clutch,** the Chevrolet "490." Note that expanders are placed under the clutch leather so as to present slightly raised points of contact to eliminate "grabbing."

If the clutch takes hold too quickly and causes the car to start with a jerk, it is an indication that the clutch leather expanders need adjusting. To do this, turn each of the expander nuts to the right, until they lightly touch the clips, and then give them a half-turn to the left. This unscrewing allows the expander to act properly under the clutch leather.

The clutch leather will in time "dry" out, resulting in "grabbing," or slipping. Once a month rub a little neatsfoot or castor oil on the leather to soften it. Should the clutch leather become greasy, apply a little fuller's earth to it. Do not use sand or other gritty substances to make a slipping clutch hold.

Cone-Clutch Troubles

Cone-clutch troubles are either fierce engagement or grabbing, slipping, or spinning. The latter makes it difficult to shift the gears of the transmission.

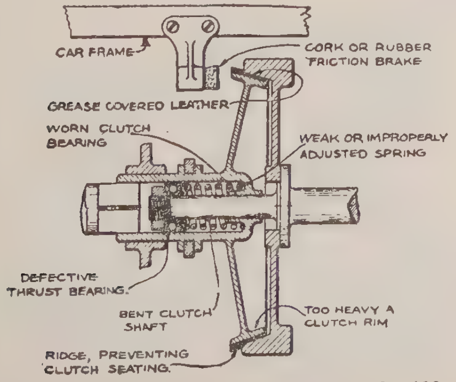

Fig. 2. Various cone-clutch troubles illustrated. (*Motor.*)

Cause of Clutch Grabbing

Clutch leather dry or hard: This can be remedied by applying neatsfoot or castor oil after first cleaning the leather with kerosene, using an oil gun to remove any mineral oil.

A prominent clutch manufacturer states: "We recommend keeping all oil off the clutch leather, and we do not use the common remedy, neatsfoot oil. Better results are accomplished by keeping the clutch face clean, and when an occasion arises where the clutch grabs, **clean it with kerosene, but not gasoline.** The kerosene leaves just enough oil to keep the leather in good condition.

Clutch rivets projecting, as a result of wear of the leather: Remedy by placing a center punch against the rivets and hammering until they are below the surface of the leather. A grating or grinding sound will indicate this trouble.

Clutch lever linkages out of adjustment: The amount of movement between the surfaces of the clutch is small, and it is important that no looseness exists in the pedal connections.

Excessive tension on clutch spring: If this is found to exist, weaken the spring tension. Excessive tension also causes undue strain on the ball-thrust bearings.

Plunger studs improperly adjusted: The six plunger studs, also termed the clutch leather expander studs (Fig. 1), should be properly adjusted.

Clutch release ring bearings may be worn, as a result of lack of lubrication. If run while dry, they are liable to seize and to prevent clutch releasing entirely, in which case new bearings must be fitted (see Fig. 9, page 841).

Cause of Clutch Slipping

Burned or worn clutch lining: Usually results from allowing the clutch to slip when starting, or speed changing, and from using the clutch too much, instead of the throttle, while running. Even though it be worn to a certain extent neatsfoot or castor oil will sometimes improve its operation. Otherwise a new clutch leather must be fitted.

Clutch leather oily and greasy: The cure for this is either to wash the oil off by spraying a pint or so of kerosene, with an oil gun, over the clutch leather, while holding the clutch out, or by wiping off with a cloth moistened with kerosene, and to dress the leather afterwards with neatsfoot oil, if necessary. The oil can also be absorbed by sprinkling powdered fuller's earth or talc over the surface and leaving it standing for a while. Don't use dirt or sand—it will cut the leather.

Leather worn down: If it cannot be raised enough by adjustment of the plungers (clutch leather expanders), a new leather must be fitted.

When the surface of the clutch and seat are new, the latter touch all over, but when worn, they touch on only the high places. If the surfaces touch in only a few places, they naturally cannot transmit the power that is possible with a good contact; they can be forced to transmit it by pressing them more firmly together, but it is better to reface the surfaces.

Clutch-spring tension weak: Tighten the adjustment (see page 841). If no adjustment nut is on spring, place a washer between the spring and its seat. **Also examine the pressure or plunger studs.**

Clutch shift out of line: Sometimes caused by too great a spring tension, causing the balls to break in the thrust bearing and cutting the ball race, lowering the clutch shaft out of line. It may also be due to a bent clutch shaft or the clutch shaft being out of alignment.

Ridge or shoulder worn on the clutch leather (see page 843 for remedy).

Clutch Spinning

When a clutch spins, when thrown out of engagement, it is difficult to shift gears.

The shift of gears by the gear-shifting lever ought to be made without a particle of noise if the clutch is thrown out when shifting. If there is noise, then it is usually due to the clutch not being fully thrown out, or to dragging or spinning, or to the transmission shaft being out of line, owing to worn bearings.

Clutch spinning is often due to excessive friction in the spring-thrust bearing (see Fig. 2), though sometimes faulty alignment of the flywheel and clutch cone prevents the engaging surfaces from entirely clearing each other. A bent clutch shaft might be the cause of this.

Sometimes the fault lies in the clutch. A heavy rim or cone will store up energy and continue to revolve when disengaged.

When a clutch spins from lack of alignment or adjustment, the remedy is obvious, but if the fault is in the design, a clutch brake (see Fig. 2) should either be fitted, or the clutch rim lightened by drilling or machining away metal at or near the outer circumference.

Clutch Brake

Unless the clutch-shaft speed is reduced approximately to the speed at which the main shaft of the gear shafting is revolving at the time, there will be a clash of gears at the time of engagement, with consequent damage to the face of the gears and annoyance to the driver. The clutch brake will overcome this to a considerable extent if it is properly fastened and proportioned.

The **purpose of the clutch brake** is therefore to keep the clutch from spinning when thrown out. See Figs. 2, 10 and 11. It consists of a small spring-mounted fiber pad attached to the left of the frame, against which the clutch cone strikes when disengaged. It should be so adjusted that when the pedal is pressed half-way down, the cone should just begin to come in contact with it, so that by the time the pedal is all the way down, the spring on the clutch brake will be fully compressed. For an example of a clutch-brake adjustment, see page 842.

If the car is not equipped with a clutch brake and it is desired to attach a clutch brake or dampener, to check the revolving of the cone when released, either cork or rubber can be fitted into a metal bracket which can be attached to the car frame.

The position of the brake should be just to the rear of the clutch rim, against which the clutch will draw when the disengaging pedal withdraws the cone.

Cone-Clutch Lubrication

Lubrication of a cone clutch is usually at the **rollers or clutch yoke and ball-thrust bearings;** otherwise oil should be kept from the clutch leather as much as possible, as a leather-faced cone is supposed to run dry, but yet be kept flexible. This can be done by the use of neatsfoot or castor oil, as explained.

If the Clutch Fails to Release

When a cone clutch fails to release, it is usually termed a "frozen clutch." This may be due to rusty or tight pedal connections or to loose pedal linkage connections; clutch yoke rollers run dry sometimes, from too tight a spring adjustment.

The amount of movement between the surfaces of a clutch is small, and it is important that no looseness in the pedal connections or bending of the levers should exist to prevent gradual engagement.

When cleaning or treating a clutch with neatsfoot oil, it can be held out of engagement by using a prop placed against the clutch pedal, as shown in Fig. 3.

The cone part of the clutch with the leather facing on it can then be turned by hand and neatsfoot oil applied, or the oil gun filled with gasoline can be used for cleaning, as shown in Fig. 4.

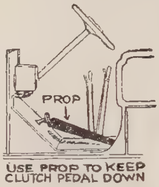

Fig. 3

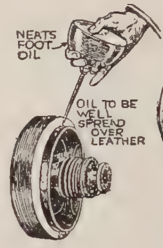
NEATS FOOT OIL
OIL TO BE WELL SPREAD OVER LEATHER

Fig. 4

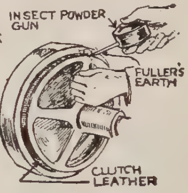

Fig. 5

An insect-powder gun, filled with talc or powdered fuller's earth can be used as a temporary remedy for an oily slipping clutch or brake, if necessary, as shown in Fig. 5.

Cone-Clutch Adjustments

The adjustments on a cone clutch are:

1. Clutch pedal adjustment.
2. Main clutch-spring adjustment.
3. Clutch-leather expanding spring adjustment.
4. Throw-out adjustment.
5. Clutch-brake adjustment.

Clutch-Pedal Adjustment

There are two possible causes or reasons for the necessity of adjusting the clutch pedal:

1. The pedal, when in driving position, with the clutch in, may vibrate back and forth, owing to there being too much clearance between the pedal and toe board.
2. The clutch may be slipping, because of the pedal pressing against the toe board before the clutch is fully engaged.

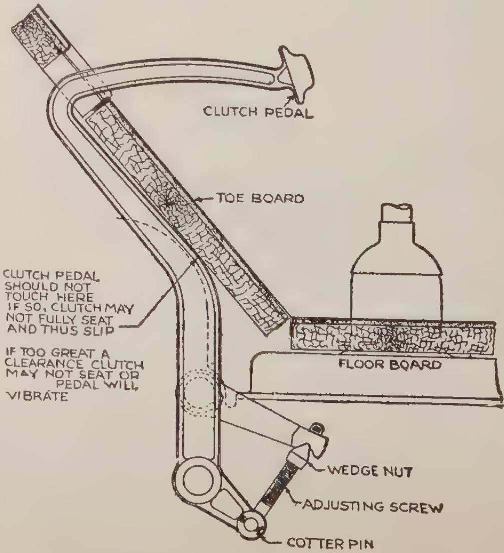
CLUTCH PEDAL
TOE BOARD
CLUTCH PEDAL SHOULD NOT TOUCH HERE IF SO, CLUTCH MAY NOT FULLY SEAT AND THUS SLIP
IF TOO GREAT A CLEARANCE CLUTCH MAY NOT SEAT OR PEDAL WILL VIBRATE
FLOOR BOARD
WEDGE NUT
ADJUSTING SCREW
COTTER PIN

Fig. 6. Clutch-pedal arrangement of the Oakland "34-B."

Adjustment of clutch pedal: There are various methods used to adjust the foot-clutch pedal. The illustration (Fig. 6) is that of the Oakland model "34-B."

To remedy either condition mentioned above, remove the cotter pin and push the adjusting screw out of the hole in the pedal. Hold the wedge nut and turn the adjusting screw to the right or left until the proper adjustment is obtained, and replace it in the hole and put in the cotter pin.

The clearance between pedal and toe board should be approximately 1/16″.

The clutch-pedal adjustment on the **multiple disk type of clutch,** or, in fact, any type of clutch, is for the same purpose as mentioned above, although the construction may vary. For example, the clutch-pedal adjustment of the Cadillac type "57" is shown in Fig. 7.

Adjustment of clutch-pedal clearance of the Cadillac[1] (type "57"): After the car has been run for some time it may be found that the lacings on the clutch disks have become compressed or worn to some extent, and that consequently the clutch pedal strikes the stop screw before the clutch is fully engaged. When this condition exists, a readjustment may be made as follows:

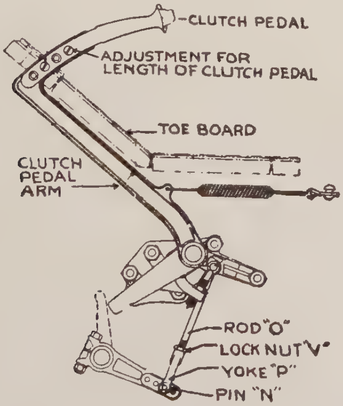

Fig. 7. Clutch-pedal arrangement of the Cadillac type "57." Note that the foot pedal is adjustable as to length.

Remove the pin (N) (Fig. 7), and unscrew the yoke (P) which is threaded on the rod (O), so that when the pin (N) is replaced, the clutch pedal has a movement back and forth of 1¼″ without starting to release the clutch. Secure the pin (N) with a cotter pin, and tighten the lock nut (V).

Adjustment of length of clutch and brake pedals: The clutch and brake pedals are each made in two parts, slidingly adjustable, to accommodate different drivers.

Main Clutch-Spring Adjustment

There are two or three methods of arranging the main clutch springs so that they will hold the clutch cone firmly to the inner surface of the flywheel.

One method is as shown in Fig. 8. Note that the main clutch spring (S) is placed over the clutch shaft between the clutch spider and a collar provided with an adjusting nut.

To adjust: With a screwdriver remove the cover plate, loosen the clamp screw on the clutch-adjusting nut, and turn up the clutch-spring adjusting nut (just below the clutch "throw-out" fork (F), until there is sufficient compression. Then tighten the screw. Also note the clutch leather engaging the spring, for the purpose of expanding the clutch leather (explained farther on).

Care: Keep the clutch-yoke grease tube filled, and be sure it does not clog. Keep the drain hole in the bottom of the clutch housing free, so that oil cannot accumulate on the clutch leather. Turn the grease cup down often, on the "clutch throw-out." The first 50,000 Dodge cars used the clutch as shown above. Later cars use disk clutches of the dry type, described farther on.

The first 50,000 Dodge cars used the "cone "clutch as described above. Later cars use the disk clutch, dry type, consisting of 4 driving and 3 driven members.

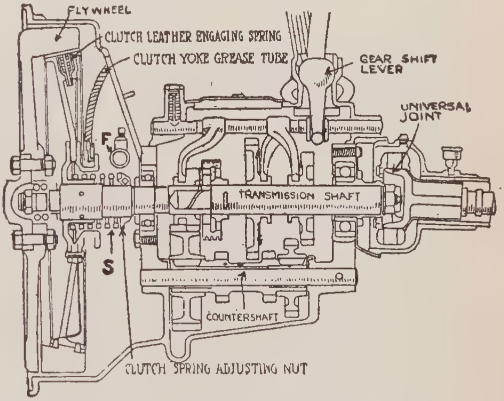

Fig. 8. Cone clutch and transmission used on the early model Dodge cars. Note the position of the main clutch spring (S).

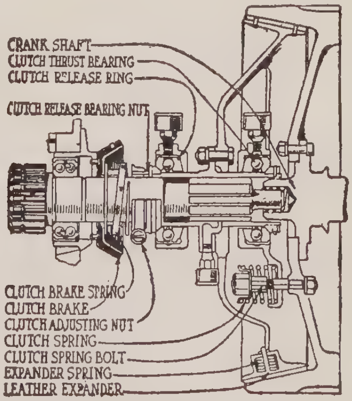

Fig. 9. Note the position of the clutch spring.

Another arrangement of the main clutch springs is shown in Fig. 9. Note the main clutch spring is within the clutch spider.

Here again, the regular remedies for a slipping clutch caused by a worn, oily, or burned leather, apply.

Adjustment: A worn leather may be made to hold by increasing the tension on the four large clutch springs within the clutch spider. In doing this, be careful to turn each nut to exactly the same extent.

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[1] The Cadillac does not use a cone clutch (see page 22).

Clutch brake: When the lining of the clutch brake becomes worn, thus allowing the clutch to **spin** after disengagement and make the shifting of gears difficult, adjust by loosening the clamp bolt and turning the adjusting nut to the left, or counter-clockwise. This will compress the brake spring sooner, and consequently stop the clutch more quickly.

To grease the clutch, loosen the wing nuts and remove the cover of the clutch housing. Give the grease cup on the clutch release ring a turn or two. Press the clutch pedal, and turn the clutch cone around until that grease cup appears, and give it a turn or two. Turn the engine over until the grease cup on the clutch spider appears and turn that down the same amount. Apply a few drops of flowing oil to the clutch release-yoke trunnion bearings.

Note that the **leather expander and spring** for expanding the clutch leather are in this clutch also.

Clutch-Leather Expanding Adjustment

The clutch-leather expanding adjustment, called the "clutch-leather engaging spring" in Fig. 8, and the "expander spring" in Fig. 9, is for the purpose of preventing "grabbing." The expanders are so placed as to present a slightly raised point of contact of the clutch leather to the fly-wheel inner surface.

If the clutch takes hold too quickly and causes the car to start with a jerk, it is an indication that the clutch-leather expanders need adjustment.

The clutch-leather expanders usually consist of six small spring-mounted clutch plungers placed under the clutch leather, which raise it at various points and allow gradual engagement of the friction surfaces. Should these plungers become fast in their guides, or should anything prevent the leather over these plungers from first coming into contact with the seat in the flywheel before the entire surface engages, "grabbing" will result.

They should be **adjusted** so that with the clutch in complete engagement, approximately 1/16″ remains between the adjustment nut of the plunger stud and the guide to the cone, when the clutch is fully engaged.

The clutch leather will in time "dry" out, resulting in either **"grabbing," or slipping.** It is a good idea occasionally to rub a little neatsfoot or castor oil on the leather to soften it. Should the clutch leather become greasy, apply a little fuller's earth to it. Do not use sand or other gritty substances to make a slipping clutch hold. If you do, you are simply inviting a large repair bill.

Cone clutch with cork inserts: On the early models (1914, 1915, 1916) Moline-Knight cars, a cone clutch was used where the leather on the face of the cone had cork inserts regularly placed around the leather. They are backed up by an adjusting screw.

Clutch Throw-Out Adjustment

The throw-out adjustment, or the amount of leverage for the distance to which the clutch is thrown out, is adjusted on the clutch pedal, or, on some clutches, at the shifter yoke collar, also termed the releasing ring. See Figs. 9 and 11.

Clutch release ring bearings (Fig. 9), which, by pressure upon the clutch release ring, disengage the clutch from the flywheel, should be kept well greased or oiled, as the case may be.

Ball thrust bearings should be supplied with oil (see Fig. 2, page 839).

Clutch-Brake Adjustment

The clutch brake, as used on the Studebaker series "20" cars, is shown in Fig. 10. There are two arms, one on each side of the clutch, so arranged as to make the adjusting screws accessible after removing the floor board. The double construction equalizes the pressure on the clutch cone, and prevents any tendency for it to bind on the shaft.

The object of a clutch brake is to facilitate gear shifting and eliminate clashing of gears. Its action is to slow down the transmission counter-shaft gears so that the gears while being shifted, will have the same speed.

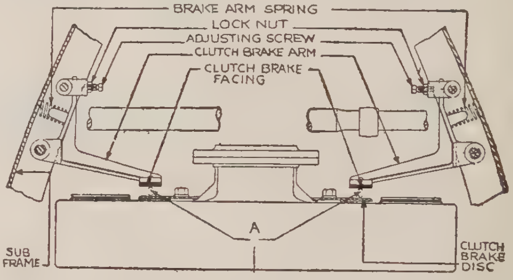


Fig. 10. Clutch brake as used on the Studebaker series "20" cars.

Cars when shipped are so adjusted as to give the best results. When a car has been driven 500 miles, the clutch-cone facing will become slightly compressed, allowing the cone to enter the flywheel farther, which, together with a slight wear of the clutch-brake facing, will increase the gap at (A) (Fig. 10). It will then be necessary to screw out on the adjusting screw, decreasing the gap (A) to 5/16″, taking care to adjust both sides alike.

Removing and Replacing a Cone Clutch

As an example, the Willys "six" is used, as shown in Fig. 11.

To remove the clutch, first remove the two cap screws which hold the spacer shaft (Fig. 11) to the clutch cone. Remove the three nuts on the motor side of the first member of the universal joint, and drive the studs back so that the spacer shaft, with the first member of the universal joint, can be removed.

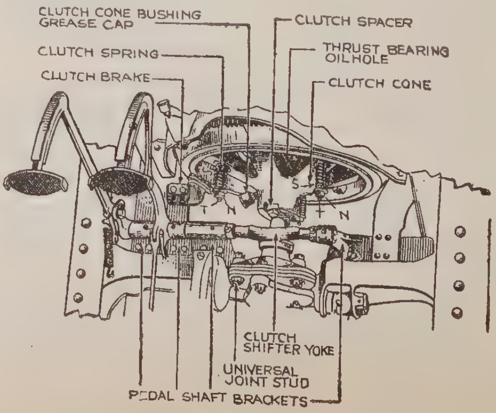


Fig. 11. Cone clutch and parts Willys "six."

Remove the clutch brake and the bolts holding the foot pedals and clutch shifter yoke, so that the shifter yoke and its shaft can be raised slightly. Next remove the nuts holding the three main clutch springs in place and take off the springs (Fig. 11), after which the clutch cone itself can be withdrawn.

In replacing the clutch, the springs (S) can be compressed sufficiently to start the retaining nuts (N), if a pry bar (P) is held back of the clutch spider (R) pressing the studs out (Fig. 12). Be careful to get an even tension on the main clutch springs, which will be reasonably assured if the retaining nuts are screwed on to their respective studs (T) approximately the same distance. Do not fail to fasten the cap screws holding the spacer and universal joint nuts with cotter pins.

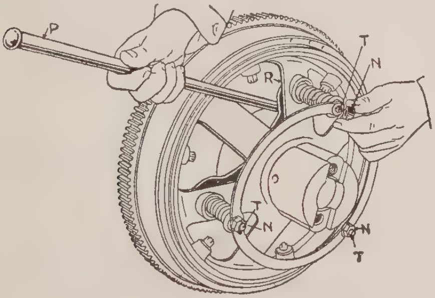


Fig. 12. Replacing clutch springs.

In replacing the clutch brake, it should be set so that when the clutch is thrown out to its limit the edge of the cone bears firmly on the clutch brake, but does not compress the spring solidly.

Fitting New Leather to Clutch Cone

First, be sure that replacement is necessary. See pages 839, 840, and note the causes of trouble.

If the leather is worn or the rivets project, then it will be necessary to remove the clutch in order either to replace the leather or to drive the rivets down below the surface of the leather.

If a shoulder of about 1/16″ or 1/32″ has worn on the leather, a careful trimming of it off with a file or rasp will permit the cone to go farther into the flywheel and may be all that is necessary—together with cleaning the whole surface of the leather and removing oil or glaze, and then applying neatsfoot or castor-oil dressing.

If however a new leather is necessary, then procure it of the dealer of the car if possible. It comes cemented ready to apply, and can be slipped over the cone and can be driven into position with a mallet or a piece of wood.

When the clutch must be relined in an emergency, and the old lining is not available to serve as a pattern, secure a piece of first-class, unstretchable belting, 3/16″ thick, 10″ wide, and 44″ long, as shown in Fig. 13.

If you must make the leather facing, then first remove the old leather by cutting the rivets with a chisel and hammer. Then procure first-class, unstretchable leather belting (or chrome-tanned leather) 3/16″ thick for the new leather. The leather should first be cut as shown in Fig. 13.

Then place the leather over the clutch cone in the correct position, and draw it as tight as possible. The leather, if cut as shown, will lap from 3″ to 4″. Mark on the inner side of the lapped leather the end of the first turn which lies against the cone. Next remove the leather and measure back or toward the long end of the leather ⅝″. Measure back from the unmarked end of the clutch leather 3″, and bevel the leather off, as shown in the illustration. Add 3″ to the corrected length of the leather, and bevel this end as shown.

The leather may now be cemented, and after it is thoroughly dried it may be installed. Always put the rough or flesh side on the outside. For the kind of cement to use, ask a harness maker.

Before a new clutch leather is installed, it should be thoroughly soaked in neatsfoot oil and stretched tightly over the clutch face. Before the leather is fastened to the clutch drum, the "clutch plungers" (or pressure studs) should be forced in below the surface of the clutch cone and held in this position by the clutch-plunger adjusting nuts, which may be screwed up on the stem of the plunger.

In riveting the leather on to the cone, extreme care should be exercised to see that the rivets are properly clinched or turned over on the inside of the clutch cone, and that the heads are driven into the leather of the clutch face until they are well below the surface. Unless this is carefully done, the clutch will "grab" or engage suddenly, with consequent disastrous results.

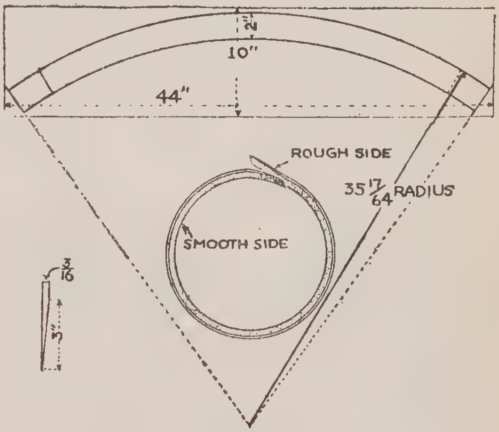


Fig. 13. **Pattern for cutting clutch facing for a Willys "six" cone clutch.** When the old lining is not available to serve as a pattern, secure a piece of first-class, unstretchable belting, 3/16″ thick, 10″ wide, and 44″ long.

To lay out the correct pattern of the facing, draw on a piece of heavy paper the arc of a circle, having a radius of 35 9/32″, and below it the arc of a circle with a radius of 33 9/32″, as shown. The exact length of the belt will be 44 3/16″, but it is well to make it somewhat longer, because it will be safer to be able to trim the ends later on. Put the rough or flesh side of the new clutch leather on the outside.

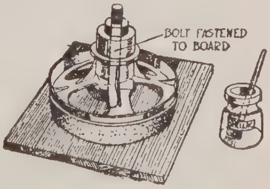


Fig. 14. **A suggested method of forcing a new clutch facing on a cone by drawing the cone into it by a bolt as shown.** A small amount of shellac is applied to the clutch and is allowed to set before the stud nut is loosened. After this, leather pegs are used to complete the bond between leather and clutch. (*Motor.*)

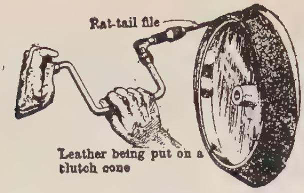

Rat-tail file
Leather being put on a clutch cone

Fig. 15. **Another method to force a one-piece clutch lining on a cone clutch.** Insert a rat-tail file in a bit brace. Force the lining on as far as it will go with the file, which should be a coarse one, and by turning the bit brace, the file will roll the lining into place.

An alternative sometimes used for older makes of various cars is "raybestos" strips, as used for brake lining. It is made in parallel lengths and riveted to the cone in six or eight sections, the edges being cut at a slight angle, according to the diameter of the cone.

Note. A very important point to observe in fitting a new clutch leather or fabric is to have the surfaces absolutely clean, otherwise the clutch facing will be raised if there is any substance under it, and will thus cause the clutch to grab.

If, after relining a cone clutch, the clutch grabs, or if it grabs even though not relined, this is usually due to high places on the facing, or the leather is dry.

If, after treating it with neatsfoot oil, it still grabs and the high spots cannot be determined by the general appearance of the leather, then try this method: Depress the clutch pedal and then insert a piece of white paper between the flywheel and the leather-faced portion of the clutch. Engage the clutch, and then depress the pedal again. When the paper is removed, the high spots will be plainly indicated on it. The leather should then be trimmed to the surface uniform in height.

THE MARMON CONE CLUTCH

The Marmon "34" cone clutch is simply an aluminum wheel having a conical rim engageable with the corresponding surface within the flywheel. Depressing the clutch pedal moves this cone back and disconnects the engine, while a spring action holds the clutch in contact when the clutch is let in.

Smooth application of power is assured by the **five steel disks set within the flywheel,** which give a slipping contact with gradually increasing force until the whole surface of the cone comes into full contact as the clutch is entirely engaged.

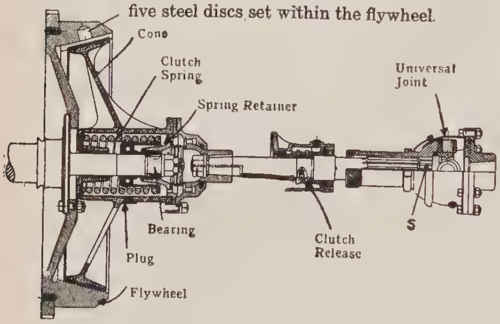


Fig. 16. The Marmon "34" cone clutch.

No adjustment for easy engagement is necessary. The metal and **asbestos fabric** with which the cone is lined usually require replacement after 10,000 to 20,000 miles of running, the life being largely dependent upon the class of service.

To disassemble the clutch, remove the circles of bolts at the universal joint and at the clutch flanges, and take out the drive shaft, thus released. Then remove the cotter and back off the main clutch nut. The spring retainer can then be pulled off its key after inserting ⅜" cap screws in its threaded holes. Then the cone will slide off the pilot shaft. In replacing, care must be taken in fitting the spring retainer on its key.

Relining clutch: The standard facing for these clutches is superior to leather, and to get the best service, renewals should be made with the same material.

To install, clean off all remains of the old facing, lubricate the cone with graphite, and slip the new facing in place. It may be necessary to force it gently, but do not hammer the edge. Soaking the facing in water will aid the facing to slide on easily. Then put rivets firmly in place, making sure the heads are below the surface. This is best done by placing the rivet head against a punch or small steel bar held vertically in a vise, and riveting with the round head of a machinist's hammer.

Replacing: See that the felt washer and hub bushing at the front of the cone are in good condition; then fill the hub with oil and replace, making sure to get all parts back just as they came out.

Clutch release: The shaft back of the clutch has two flanges about which is fitted a split collar, giving a marine type of bearing, which should be filled with oil. The backward thrust to release the clutch is applied to this collar by a yoke linked to the clutch-pedal shaft. The bushings of these shafts and links are self-lubricating. The clutch pedal stop is against the floor-board. Inspection should be made, from time to time, of the shifting collar, to be sure that, from lack of lubrication, this part does not revolve with the shaft when the clutch is released.

Note the play allowed in the splined shaft (S) for the movement of the clutch shaft when the clutch is thrown out.

CONE-CLUTCH REPAIR—THE CHEVROLET "490" AS AN EXAMPLE

Evidence of Trouble

1. **A heavy grinding noise when the clutch is released.** This is usually caused by worn or broken balls in the clutch-thrust bearing.
2. **Actual failure of the pedal to release or move the clutch or to come back into position when pushed out.** This indicates that the clutch-spring retaining plug has become unsoldered and has unscrewed from the clutch hub.
3. **Excessive slipping of the clutch,** that cannot be cured either by application of neatsfoot oil, if dry, or fuller's earth, if slippery.

The first necessitates a complete removal of the clutch, together with the flywheel and clutch-spring tension rod; the second a removal of the clutch hub, and the third the removal of the hub and clutch.

Disassembling the Clutch

1. Remove the floorboards.
2. Remove the wiring running from battery to starter.
3. Remove the three bolts holding the V-brace to the engine base and the gearbox support, and remove the V-brace.
4. Disconnect the brake rods from the pedals.

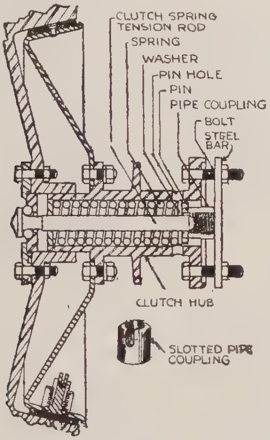


Fig. 17. Showing the **method of compressing the clutch spring.** The steel bar is 5/16″ x 1″ x 4″. The bolt holes are ⅜″ and 3″ between centers. The pipe coupling is ⅝″ inside diameter; the slots are about ¾″ deep.

5. Remove the bolts holding the clutch-release shaft to the gearbox support, and remove the clutch release cross-shaft, together with pedals.
6. Remove the bolts on the rear clutch-hub drive ring.
7. Remove the four bolts holding the gearbox to the gearbox side-arms. (Care should be taken in removing the shims under the gearbox, so that they may be replaced in the same position.)
8. Remove one bolt holding the left gearbox side-arm (on the pedal side) to the engine. (This permits the gearbox side-arm to spring to one side when removing the gearbox).
9. Lift the gearbox up and slide it forward. It may then be removed from the chassis. (A jack should be placed beneath the propeller shaft to hold it in place when the gearbox has been removed. In some cars it is necessary to spring the gearbox arms apart or to force the gearbox out with a jack.)

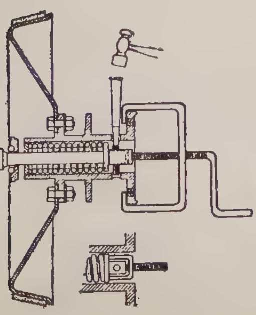


Fig. 18. Showing the method of compressing the clutch spring, **permitting the lock pin to be removed.**

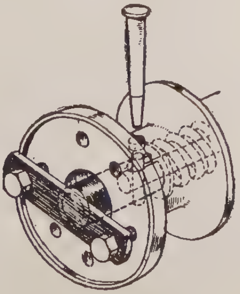


Fig. 19. Another form of clutch spring compressor, somewhat simpler than that shown in Fig. 18.

10. Turn the flywheel until the pinhole (Fig. 17) passing through the clutch hub is at the top, and the clutch-spring retaining pin is in line with the hole.
11. Using either the compressor shown in Figs. 17, 18, or 19, compress the clutch spring. The clutch-spring retaining pin will usually drop out when over the hole in the housing; but, if not, it may be driven out with a drift and hammer.
12. Draw out the clutch spring.
13. Remove the bolts holding the clutch hub to the clutch spider, and remove the clutch hub. (This is necessary, as the hub would otherwise interfere when removing the clutch.)
14. Pull out the clutch. (This will take some little effort, as the gearbox arms squeeze on to the clutch and must be sprung. But it can be pulled out.)
15. Remove the nuts holding the flywheel to the crank shaft flange and with a bar loosen the flywheel and remove it. (It is advisable to mark the position of the flywheel on the flange so that it may be replaced in the same relative position.)
16. Remove the flywheel together with the clutch-spring tension rod, and place it on two boards nailed to the bench.
17. Separate all parts and clean with gasoline and waste.

Clutch Troubles

Clutches of this type give but little trouble if properly used, and the necessity for relining is only occasional. **If slipping** has been experienced and the leather is damp, it is usually because it has been soaked with mineral oil. This may be removed by cleaning the leather with gasoline, after which neatsfoot oil should be applied to keep the leather flexible.

Grabbing: On model "490" there are six clutch leather expanders. These expanders are placed under the clutch leather and present a slightly raised point of contact. Their function is to prevent the clutch from grabbing. If the clutch grabs, the expander should be adjusted. To adjust the expanders, turn each of the expanding nuts in the same direction as the hands of a clock, or from right to left, until they lightly touch the clip, then give them a half-turn in the opposite direction. If this method fails, the chances are that the clutch is dry.

Though a dry clutch will occasionally cause slipping, it more often causes "grabbing." Unless the leather is burned, or worn out, it may be restored by roughing the surface slightly with emery paper, and then dressing it with neatsfoot oil.

Another cause of a sticking clutch is protruding rivets, and these should again be set beneath the surface of the leather. A small shoulder will also cause trouble, and this should be scraped or filed down.

A new leather should never be fitted unless it is absolutely certain that the old leather cannot be reclaimed.

If relining the clutch is imperative, it is best to obtain the new lining from the makers. If this is not expedient, the old lining should be carefully removed and used as a pattern for cutting the new lining. The new leather should be much thicker than the old lining, and of uniform thickness. The most essential point in fitting the new leather is to have it fit tight and true to the cone.

If the clutch has been relined it will not work perfectly until it has been worked in. This usually takes some time and during that period should receive frequent applications of neatsfoot oil.

To Fit a New Leather

1. Soak the leather in water.
2. Secure one end of the leather to the cone by one copper rivet (rough side out). (Never use anything but copper rivets; other metals will score the metal clutch facing.)
3. With only about three-quarters of the leather on the cone, pin the other end to the cone by a rivet. (See Fig. 21.)
4. Force the leather up into the cone. It should fit evenly and with uniform tension.
5. Drill and countersink the rivet holes.
6. Rivet the leather in place. Be certain that the rivet heads are 3/32″ below the leather and well headed on the inner side.
7. Allow the leather to dry slowly. It will otherwise shrink too much and expose the rivets. A coarse file may be used to remove the high spots.

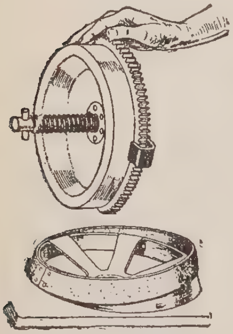


Fig. 20 (upper)
Fig. 21 (lower)

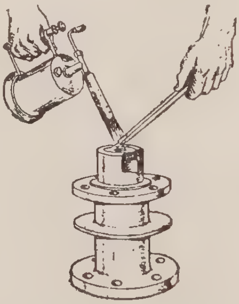


Fig. 22

Fig. 20. The **thrust-bearing assembly** is held together by three old valve springs, placed in the manner shown.

Fig. 21. The **new leather should be fastened at the ends,** and then forced over the face of the clutch.

Fig. 22. When loose, the **plug in the end of the clutch hub** should be sweated back in place.

Clutch-Hub Repair

If the solder holding the clutch-spring retaining plug has become loosened, permitting the plug to unscrew—

1. Clean and scrape both plug and hub end thoroughly.
2. Screw the plug into the hub until the upper surface is slightly below the hub.
3. Heat the end with a torch, as shown in Fig. 22, and run solder into the joint.

Thrust-Bearing Repair; Assembling

1. Examine the balls and races of this bearing, and if they are pitted or show the slightest indication of wear, the entire assembly must be replaced.
2. Place the flywheel on the bench, with gear side up.
3. Force a ball race into the flywheel casting. This must go in evenly and come to a seat evenly, otherwise the bearing will quickly destroy itself.
4. Assemble the balls and clutch-spring tension rod, packing the balls in grease.
5. Slip the clamp shown in Fig. 20 over the end of the stud. This holds it firmly in place and permits one man to put on the retaining springs.
6. Slip three old valve springs over the end of the stud and pin in place, as shown. The clamp may now be removed, and the stud, with the thrust bearing, cannot fall apart in reassembling the clutch.

   An alternative method, and one commonly used in assembling the tension rod and bearings is to place the ball race, balls and tension rod together before placing them in the flywheel. They may be held together by the three valve springs.
7. Lift the flywheel back into place on the engine. Bolt it back in the same position as before it was removed. Do not tighten any one bolt until all are drawn snug. This removes the possibility of having the flywheel out of true, which would ruin the thrust bearings.
8. Remove the pin and three old valve springs from the clutch-spring anchor stud.
9. Force the clutch back into position.
10. Bolt the clutch hub to the clutch spider. Draw all bolts up snug, before any one is tightened.
11. Put the clutch spring back in place and pack with grease.
12. Using the compressor shown in Figs. 18, 17, or 19, replace the clutch-spring retaining pin.
13. Lift the gearbox back into the frame. It will have to be sprung past the gearbox side-arm.
14. Replace the bolt holding the gearbox side-arm to the engine.
15. Replace the bolts on the rear clutch-hub drive ring. Bring all up snug together.
16. Replace the bolts holding the gearbox to the side-arms. (Make certain that the shims are replaced exactly in the same position from which they were removed.)
17. Replace the clutch release shaft with the clutch yoke and pedals.
18. Connect the brake rods.
19. Replace the V-brake, connecting gearbox support with engine.
20. Refill the oil reservoir on the clutch yoke and the grease cups on the clutch cross-shaft. Oil all working parts.
21. Replace the wiring. Start the engine and note whether everything seems to be working properly. If there is a rattle in the clutch drive ring it will indicate that the gearbox is out of line. The shims will have to be shifted, or possibly removed. When perfect alignment is reached the rattle will cease. (*Motor World.*)

PARTS OF THE BORG & BECK SINGLE-PLATE CLUTCH, SHOWING ASSEMBLY

This clutch is termed a "single-plate clutch" because a single dry disk (2) (Fig. 23) is locked to rotate with the flywheel by gradual pressure between two asbestos rings (1) and (3), thus driving the clutch shaft that carries power to the transmission.

The pressure is brought to bear on this disk (2) by the positive lever action of three arms, or bell cranks (L) (Fig. 25A), which act as wedges, these wedges being forced into place by the thrust of the clutch spring (7).

Action of the Various Parts

The friction disk (2) (Fig. 23), and the asbestos rings (1) and (3), and the clutch shaft and its shaft sleeve (8), the only parts not anchored to the flywheel **float in the drum at rest** until they are locked with it by the wedge action at (T) (Fig. 25) of the bell cranks (L) carried on the mounting ring (5).

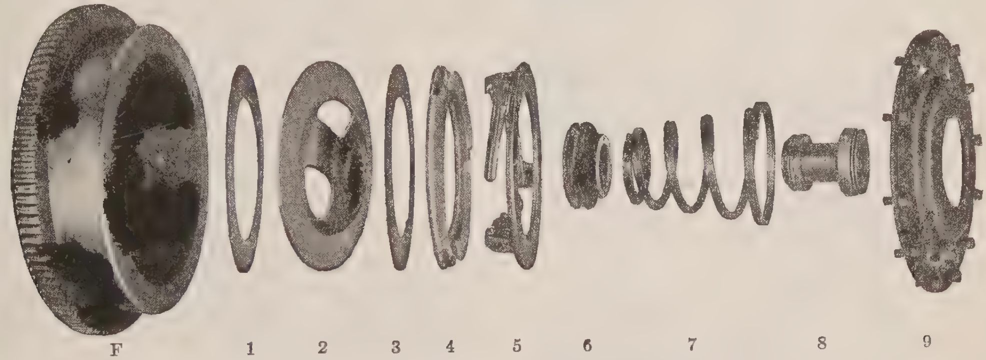


Fig. 23. **Parts of the Borg & Beck dry-plate clutch.** (F) represents the flywheel ready for the clutch parts, which are shown disassembled in the order in which they are to be assembled. Note that inside of the flywheel the dowel pins that carry the thrust ring (4) are shown projecting (see also **P**, Fig. 25).

(1) **Friction ring,** a duplicate of No. 3. These rings take all the clutch wear.
(2) **Friction disk,** or dry plate, keyed to the shaft by 10 splines.
(3) **Friction ring;** copper reinforced woven asbestos.
(4) **Thrust ring;** note the inclined face toward the center, and adjustment inclines.
(5) **Mounting ring;** fastens to the cover with adjustment bolts; it carries the bell-crank levers.
(6) **Retractor collar;** the ends of the bell cranks engage in slots.
(7) **Spring** is compressed between cover (9) and the retractor collar; it operates the bell-crank levers.
(8) **Sleeve** carries retractor collar; note the thrust bearings.
(9) **Clutch cover** bolts to the flywheel; note the adjustment bolts in the slots which are shown as (**A**) in Fig. 24.

Note. Parts 1, 2. 3, and 8 come to rest when the clutch is disengaged.

When the clutch pedal (Fig. 25) **is pressed,** the sleeve (8) and the collar (6) are pulled back, moving the bell cranks (L), and consequently releasing wedge pressure on the thrust ring (4). **When released,** the spring thrust moves the bell cranks forward, exerting the pressure that locks the drive disk (2).

It is to be noted that the thrust ring (4) is an inclined plane, thinner on the inner edge than on the outer. The thrust shoes on the bell cranks mount this inclined surface as the spring thrust is exerted, and gradually increase the pressure on the friction rings (1) and (3). This causes the friction disk to begin to move, at first slowly and then with increasing speed, until the pressure of the thrust ring (4) finally locks it to drive with the flywheel. Because it has finely polished surfaces, this slippage is even and smooth, and the car is not jerked or shaken by a too rapid engagement of the clutch.

An annular ball bearing, mounted on the sleeve (8) and inside of the retractor collar (6), allows the shaft and sleeve to come to rest with the friction disk when the clutch is thrown out. A similar ball-thrust bearing is mounted on the opposite end of the sleeve, and takes the thrust of the clutch spring as the sleeve is pulled backward under the pressure of the yoke of the clutch pedal.

Lubrication: Oil for the sleeve and bearings is provided from the transmission through the hollow clutch shaft and holes bored in the sleeve itself. Care should be taken to see that the oil level in the transmission is not too high; it should come approximately up to the center of the lower, or secondary, transmission shaft.

After about every thousand miles, remove the adjusting bolt and squirt a little cylinder oil into the clutch—just enough to moisten the asbestos rings. Too much oil will cause the clutch to slip until the oil is burned out.

The assembled clutch is shown in Fig. 24. Note that the parts are applied to the hollow flywheel (F) (Fig. 23), first by the friction ring 1, then by 2, 3, 4, and so on, until the cover (9) is bolted to the outer edge of the flywheel. It then appears as shown in Fig. 24. The drive shaft is not shown. It passes through the parts, beginning at 9, and ends in the splined disk (2).

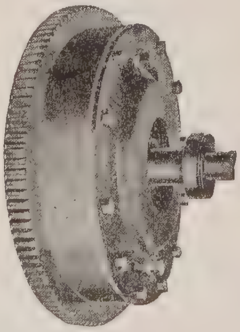


Fig. 24. Assembled clutch.

Note. The foregoing description covers the DX 10-inch and GX 12-inch types of clutches now used with unit power-plant assembly. All other types of Borg & Beck clutches are operated by the same principle of engaging and disengaging action, but have only the outer thrust bearing.

To adjust: Loosen both adjustment bolts (**A**) (Figs. 25, 25A). Hold clutch out by pressing clutch pedal. This permits bolts to slide easily in their slots. Sliding (**A**) bolts to the right tightens the clutch and at the same time increases the (**B**) distance, or the clutch-sleeve setting. Sliding (**A**) bolts to the left loosens the clutch and decreases the (**B**) distance. After obtaining the correct (**B**) distance, tighten the bolts. This completes the clutch adjustment.

When the adjustment bolts (**A**) reach the right end of the cover slots, as a result of repeated adjustment, remove them and replace them in the repeat holes which have been exposed at the opposite end of the slots.

Should it be difficult to slide the adjustment bolts far enough to obtain the specified adjustment position, it indicates that the pedal has been lowered from its original setting. This causes the clutch to be released insufficiently. Correct this condition by changing the pedal adjustment so as to raise it. This provides additional release, and will permit the bolts to slide easily.

Where a clutch brake is used, it is located at the (C) position—that is, ½" farther from the clutch cover than the engaged position, as shown. In this case the pedal should be adjusted to cause contact against the brake facing slightly before the pedal pad reaches the floor-board, as shown at (X). This setting will naturally allow proper clearance under the floor-board when the clutch is engaged.

Where no clutch brake is used, the pedal pad should make contact with the floor-board when the (C) position is reached. Care should be taken not to allow the pedal to release the clutch farther than the proper (C) position. Greater release will cause contact with the metal bearing cap on the forward end of the transmission.

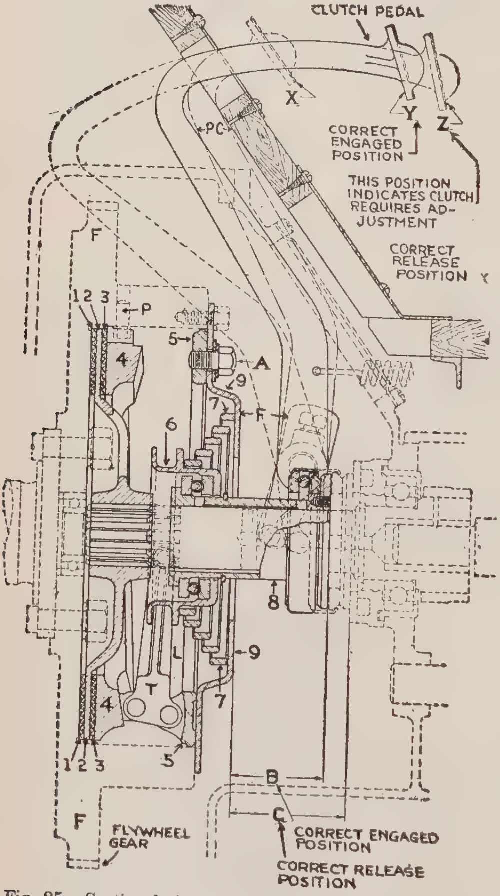


Fig. 25. Sectional view showing assembly of parts and how the clutch is adjusted by the "engaged and release method." Note (B) and (C).

Pedal positions: (X) correct release position; (Y) correct engaged position; (Z) this position indicates that the clutch requires adjustment.

Adjustment of the Borg & Beck Clutch: "Engage and Release" Method

The clutch should be properly adjusted when the car comes from the factory with ½" or more pedal clearance (PC) (Fig. 25) under the footboard and with the adjustment distance (B) (Fig. 25) set correctly for the type of clutch used.

A table showing the proper adjustment distance for all cars carrying the Borg & Beck clutch is given on this and the following page.

After a new car has run several hundred miles it is frequently desirable to make an adjustment to compensate for the "wear-in" of the asbestos friction rings (1) and (3). Thereafter adjustments are not necessary oftener than each 2,000 or 3,000 miles.

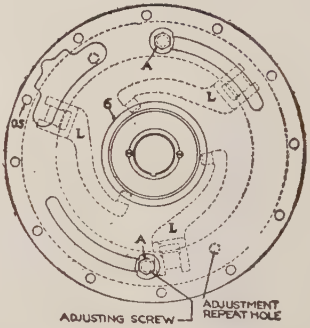


Fig. 25A. **Phantom view of clutch,** showing the bell-crank levers (L) and the adjusting bolts (A). Note the hole (OS); this is an odd-spaced hole in the cover. The mounting ring (5) (Fig. 23) must be assembled so that one lever comes directly under this hole when the adjusting screw (A) is in the left end of the slot.

To adjust the clutch, first release it by pressing the clutch pedal. Loosen both slot-bolts (A), and move either of them to the right or "clockwise," about ½". Let in the clutch, and if the adjustment distance (B), that is, the distance from the clutch-cover plate to the end of the sleeve, is more than it should be, throw out again and tap either slot-bolt back counter-clockwise far enough to get the correct adjustment distance.

The adjustment (A) **also adjusts the foot pedal.** When the clutch slips, it is usually due to the clutch pedal striking the under side of the floor-board. Moving the adjustment bolts to the right automatically lowers the clutch pedal, giving the necessary pedal clearance.

When the bolts (A) **reach the end of the cover** slots (Fig. 25A) as a result of repeated adjustments, screw them out of their mounting holes and set them back into the repeat holes exposed near the opposite end of the slots.

Adjustment Distance

Refer to Fig. 25. The adjustment distance is the distance from the flywheel clutch cover to the end of the throw-out sleeve: distance (B). A number of manufacturers listed below have used clutches of two or more different types. The Borg & Beck nameplate on each clutch indicates the type.

Passenger Cars Using Borg & Beck Clutch

	Clutch Type	Distance "B"	Clutch Type	Distance "B"
Abbott	DA	1 ⅞	......	....
Allen	DU	2 13/16	......	....
Anderson	D	1 ½	......	....
American	DA	1 ⅞	......	....
Auburn	D	2 7/16	DX	2 15/16
Beggs	DA	2 7/16	......	....
Bell	M	2 15/16	......	....
Ben-Hur	D	2 7/16	......	....
Bour-Davis	DA	1 ⅞	......	....
Case	D	2 7/16	DX	2 15/16
Chandler	D	1 ½	DX	2 3/16
Cleveland	M	2 9/16	......	....
Columbia	D	1 ½	DX	1 ⅞
Comet	D	1 ½	......	....
Crow-Elk	M	2	......	....
Davis	D	1 ½	DX	1 ⅞
Detroiter	D	1 ½	......	....
Dixie	M	3 1/16	......	....
Economy	D	1 ½	DX	2 15/16
Elgin	M	2 5/16	DX	1 15/16
Elkhart	D	1 ½	......	....

	Clutch Type	Distance "B"	Clutch Type	Distance "B"
Empire	D	2 7/16		
Franklin	DX			
Geronimo	D	1 ½	DX	2 3/16
Grant	DX	2 3/16		
Hal	G	2 1/16		
Hackett	DA	1 7/16		
Halladay	DX	2 15/16		
Hanson	DA	1 ⅞		
Haynes	D	1 ¾		
Jackson	DA	1 ⅞	DX	2 7/16
Jeffery	D	2 7/16		
Jones	DX	2 3/16	DA	1 ⅞
Jordan	DX	2 7/16	DA	2 7/16
King	D	1 ½		
Kissel	D	1 ¾		
Kline	D	2 11/16	DX	2 15/16
Lexington	DA	2 7/16	DX	2 7/16
Liberty	M	2 7/16	DX	2 7/16
Louisiana	D	1 ½		
Madison	D	2 7/16		
McFarlan	GS	4 7/16		
Maibohm	DX	2 7/16		
Meteor	DA	1 ⅞		
Moon	D	2 11/16	DX	2 1/16
Moline-Knight	DS	4 7/16	DX	2 1/16
Metz Six	DX	2 1/16		
Mitchell	D	2 7/16	DX	1 ⅞
Murray	DA	1 ⅞		
Monitor	D	2 7/16		
Nash	D			
National	GX	2 1/16	DX	2 1/16
Noma	DX	2 1/16		
Norwalk	M	2 ¼	DA	1 ½
Norwalk	DX	2 15/16		
Olympian	M	2		
Paige	DAX	1 5/64	DX	2 1/16
Pan-American	DX	2 7/16		
Pan	DA	2 7/16		
Paterson	D	1 ½	DX	2 3/16
Patriot	DA	2 7/16	DX	2 7/16
Piedmont	D	2 7/16		
Pilot	D	1 ½		
Premier	DAX	1 ¼		
Roamer	D	2 11/16	DX	2 15/16
Rock Falls	DX	2 15/16	D	2 7/16
Ross	D	2 7/16		
Sayers & Scovill	DX	2 15/16	D	1 ½
Standard	D	2 7/16	G	2 7/16
Stephens	D	2 7/16	DX	2 7/16
Templar	DX	2 3/16		
Texas	D	1 ½		
Tulsa	M	3 1/16		
Velie	D	1 ½	DX	2 3/16
Westcott	DX	2 1/16		

Commercial Cars Using Borg & Beck Clutch

	Clutch Type	Distance "B"	Clutch Type	Distance "B"
Acason	GX	2 5/16	GX-1	2 5/16
Acason	DA	1 ⅞		
Acme	DX	2 7/16	GX	2 5/16
Acme	GX-1	2 5/16	SGX-1	2 5/16
All-American	DA	1 ½		
Atlas	M	2		
American	DX	2 15/16		
Bessemer	GX	2 11/16	DX	2 11/16
Bethlehem	GX	2 5/16	DX	2 5/16
Collier	DA	1 ½		
Columbia	DA	1 ⅞		
Comet	D	1 ½		
Commonwealth	DA	1 ½		
Conestoga	DA	1 ½		
Corliss	DA	1 ⅞		
Day-Elder	DA	1 ⅞	GA	1 ⅞
Dearborn	DX	2 15/16		
Diehl	D	1 ½		
Double Drive	DS	4 7/16		
Douglas	D	2 7/16	GX	2 15/16
Fageol	SGS	4 7/16		
Federal	DX	3 9/16	GX	3 7/16
Fulton	DX	2 3/16	DA	2 7/16
Gersix	GX-1	2 5/16		
Grant	GX	2 11/16		
Hahn	DA	1 ⅞		
Harvey	GX	2 5/16	GS	4 7/16
Hawkeye	GX	2 13/16	G	2 7/16
Hewitt-Ludlow	GS	4 7/16		
Huffman	DA	2 7/16		
Indiana	GX	2 5/16	DX	2 5/16
Indiana	DA	1 ⅞	GS	4 7/16
Jackson	GX	2 5/16		
Jones	DA	1 ⅞		
Kearns	DA	1 ½	DX	2 15/16
LaFrance	GX	2 11/16		
Lane	GS	4 7/16		
Little Giant	DA	1 ⅞	GA	1 ⅞
Little Giant	DS	4 7/16	GS	4 7/16
Louisiana	GS	4 7/16		
Maibohm	M	2		
Markt & Hammacher	GX	2 5/16	GS	4 7/16
Menominee	GS	4 7/16		
Michigan H & M. Co.	DA	1 ⅞		
Midland	GX	2 5/16		
Nash Quad	GX	2 5/16		
Niles	GS	4 7/16		
Noble	GX	2 5/16		
Norwalk	DX	2 15/16		
Old Hickory	M	3 1/16		
One Wheel	GS	4 7/16		
Patriot	GX	2 11/16		
Rainier	DA	1 ½		
Rush	M	2		
Sanford	GX	2 5/16		
Sayers & Scoville	DX	2 15/16	D	1 ½
Service	GX	2 5/16	G	2 11/16
Standard	GS	4 7/16		
Stewart	DX	2 3/16	D	1 ½
Texan	D	1 ½		
Tiffin	GS	4 7/16		
Titan	SGX	2 5/16		
Traffic	DA	1 ⅞		
Turnbull	DX	2 13/16		
United	GS	4 7/16		
U.S. Motor Truck	GS	4 7/16		
Wilson	DX	2 11/16		
Winther	SGS	4 7/16	GS	4 7/16

To Clean the Borg & Beck Clutch

It is sometimes desirable to clean the clutch by pouring about one-half pint of kerosene into it through the adjustment bolt hole, and allowing the engine to run for 15 minutes, engaging and disengaging the clutch as it runs. The surplus kerosene can be drained from the clutch by letting the car stand overnight with the front wheels higher than the rear.

Pointers on Operating Clutch

Do not slip the clutch excessively instead of shifting gears. Slipping it makes the clutch do all the work that the transmission was designed to do.

Do not drive with the foot on the clutch pedal. It puts a constant pressure on the throw-out bearing and shortens its life.

Keep the clutch properly adjusted. Many clutches run 30,000 or 40,000 miles without a single adjustment, and very few ever show enough wear to require replacement of parts.

It is, however, to be expected that a failure of lubrication or haste in assembly in the car may cause conditions that should be remedied, and the following suggestions are offered to assist in locating any malfunction in operation that may be encountered:

Clutch Troubles, Cause and Remedy (Borg & Beck)

Slipping is a bad condition that may ruin friction rings, drive disk, bearings, sleeve, in fact the whole clutch, if allowed to continue.

It is usually caused by a continual pedal pressure on the under side of the floor-board which holds the clutch partially "out," thus wearing the friction rings, or it may result from an excess of oil in the clutch.

To remedy: Adjust the clutch by moving the two adjustment bolts, as described on the preceding page. If slipping comes from too loose an adjustment of the clutch, the same remedy will correct it. If there is too much oil, drain the clutch housing and wash it out with kerosene. If this does not relieve the trouble, the clutch disks (1) and (3) are worn.

Slipping of the clutch, followed by chattering and grabbing: This indicates that the asbestos friction rings are glazed and should be replaced, and this necessitates the removal of the clutch.

Dragging, which makes gear-shifting difficult.

Cause: Failure of the clutch to release properly, and so to allow the drive disk on the stem-gear shaft to come to rest. It may come from either of two principal causes: too tight an adjustment of the clutch, or failure of the clutch-brake action. When the clutch is thrown completely "out," the flange nut of the clutch throw-out sleeve is brought up against the brake facing on the hub of the flywheel housing. If the brake facing is allowed to become covered with oil or grease, it will not stop the rotation of the sleeve, and thus causes dragging.

To remedy: Wash off the brake facing with a little gasoline.

Grabbing or stuttering: This condition causes the car to jump and shake as the clutch is let in, and shows uneven gripping of the friction or drive disk by the asbestos friction rings.

Cause: It has been found that this is nearly always caused by imperfect alignment of the clutch in installing.

To remedy: Take the clutch down and secure proper alignment of the stem-gear shaft. If the grabbing comes from a warped drive disk, caused by overheating from slipping, it will be necessary to replace the drive disk and friction rings.

At times, grabbing may be caused by the accumulation of dirt or foreign matter on the asbestos friction rings and drive disk.

To remedy: Wash out the clutch by cleaning it with kerosene, as described on the preceding page. Do not fail to oil the clutch after using kerosene, as explained under "Lubrication" (page 24).

Noise may develop at the three points on the thrust ring where it is driven by the dowel pins (P) (Fig. 25) in the flywheel.

Cause: The fact that the pins were not properly fitted at the time of installation, and the fact that the backlash causes wear in the slots of the thrust ring.

To remedy: Take down the clutch and replace the dowel pins with pins of proper fit for the thrust-ring slots.

Improper lubrication will cause the retractor collar bearing or the throw-out bearing to become noisy.

To remedy: Open up the oil holes in the stem-gear shaft, replacing the bearings, if worn.

These bearings may also become noisy if the bearing seat on the clutch sleeve is allowed to get out of line, or if the stem-gear shaft is out of line.

Cause: This sometimes results from hasty installation or from bad alignment of the throw-out yoke.

To remedy: Straighten the bearings on the sleeve and set the clutch-pedal yoke to bear evenly on the throw-out bearing.

Actual failure of the clutch to operate, or excessive noise when the clutch pedal is pushed out, indicating that the clutch spring or some of the operating members are worn or broken, and necessitating a removal of the clutch.

Ordinarily a washing and adjustment of the clutch will place all parts in good condition. Unless it is positively indicated that a removal is necessary, cleaning and adjustment should always take place before tearing the clutch down.

To Repair Clutch Brake

This brake is designed to stop the spinning of the clutch and to prevent gears clashing when shifting. To examine:

1. Press the clutch pedal down fully.
2. Examine the brake (see Fig. 26 showing the clutch-brake ring), and see whether it actually touches the collar or not. If it does not touch, the transmission must be removed. Note how far it comes from touching.
3. Remove the gearbox. The method of doing this may vary somewhat in the different cases.
4. Examine the clutch-brake friction band. If it is in good condition, it will not be necessary to install a new one, as a metal washer can be placed between it and the shoulder on the main drive pinion. This will raise it sufficiently to touch the brake. The thickness of this washer depends on the distance the clutch brake and flange were apart, as shown in Fig. 26.
5. Unscrew the clutch brake (this is a left-hand thread) and place the metal washer between it and the drive pinion. It is better to reline the clutch brake after washers amounting to ⅛" have been installed.

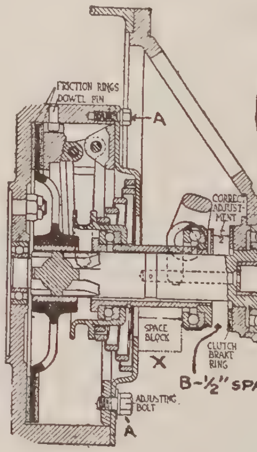


Fig. 26

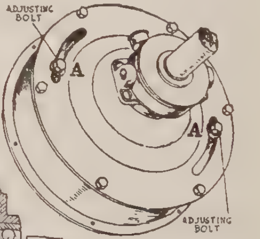


Fig. 27

6. If the clutch brake facing is worn very thin or is glazed, it should be removed and a new one should be riveted on in its place. Copper rivets should be used, and they should be countersunk well beneath the surface of the facing. (See Fig. 29.)

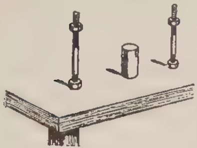
Providing the adjustment of the clutch is correct, and the friction rings are in good working order, the gearbox may now be assembled.

To Remove Clutch

This is necessitated by worn clutch rings, by actual failure of the clutch to operate, or by continued presence of oil after repeated cleanings.

1. Punch the remounting "line-up" marks on the cover and flywheel, so that the cover may be replaced exactly as removed. If the cover should

be replaced wrong, or shifted in remounting, the clutch will not operate properly.



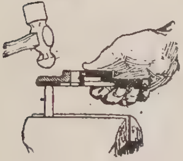


Fig. 28 (upper)
Fig. 29 (lower)

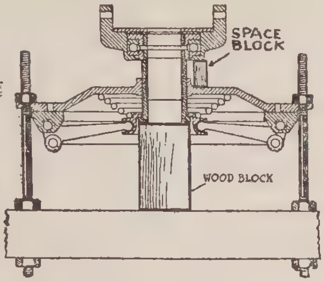


Fig. 30

Fig. 28. Details of a **simple clutch compressor** which can be easily constructed on the bench and used for disassembling and assembling a clutch.

Fig. 29. **The clutch brake friction ring** may be riveted to its flange, but the friction rings of the clutch should run free in their working seats.

Fig. 30. **The clutch compressor in use.** If an arbor press is at hand, it may be used in a similar manner: to hold the clutch in the "out" position.

2. Throw the clutch "out" and lock, by placing a block of wood, 3″ high and 4″ long (space block), as shown in Fig. 30, between the cover and the throw-out yoke.
3. Remove the clutch-cover bolts.
4. Draw out the clutch.

If all working members are in good condition and are not worn excessively, new friction rings should be slipped in place and the clutch should be reassembled. It may however, be necessary completely to dismantle the clutch, in order to replace the spring or some worn member.

To Disassemble Clutch

1. Place the clutch on the compressor shown in Figs. 28 and 30, and tighten the stud nuts.
2. Remove the space block (Fig. 30).
3. Unscrew the retaining collar.
4. Remove the stud nuts of Fig. 30, permitting the clutch to come apart.
5. Examine all parts for wear and replace all worn parts.

To Reassemble Clutch

1. Reassemble the clutch, using the compressor shown in Figs. 28 and 30.
2. Place the space block in position, and remove the clutch from the compressor.
3. Place the friction ring, then the clutch plate, in the flywheel, followed by the other friction ring.

Note. The two asbestos rings should be coated lightly on all sides with cylinder oil. See page 847 about oiling these clutch rings every 1,000 miles.

4. Then put the clutch assembly in place, making sure that the dowel pins, or set screws, are in place on the inside rim of the flywheel, and that they fit into the slots of the driving plate.
5. Replace the clutch cover bolts, making sure that the cover is in the same position as when removed.
6. Replace the transmission, drive shaft, etc.
7. Check up the adjustment of the pedals and clutch as outlined, and see that the clutch brake is working all right.
8. Grease all parts, and replace miscellaneous fittings.

POINTERS ON ADJUSTMENT AND CARE OF A MULTIPLE-DISK CORK-INSERT LUBRICATED TYPE OF CLUTCH

This clutch, as an example, is made with seven driving and seven driven members. They are provided with cork inserts and run in oil.

New corks may be inserted in the disks by the use of a special tool after the corks have been soaked in warm water to make them pliable. They are trimmed off so as to leave a projection of about 1/32″ on each side, and then they are ground to an even surface on the disk grinder.

A more convenient method for the average repairman is to use fine sandpaper. The disks should be trued by rubbing them on a flat surface which has a very thick coating of prussian blue or lamp black. The cork inserts should not project too far over the disk or the clutch will drag; 1/32″ is the maximum.

The clutch spring (S) (Fig. 31) **is not adjustable;** a new and stronger spring is installed if greater tension is required. The position of the pedal will shift toward the floorboard after the clutch has been in service a short time, because the inserts, when brought under the pressure of the clutch spring, will compress slightly.

If the pedal is not adjusted, it will cause a continuous pressure against the clutch and eventually produce slipping. There should be ¾″ clearance between the clutch pedal and the upper side of the floorboard. This is adjusted by loosening the lock nut at the end of the turnbuckle.

The levers of the clutch pedal may be changed to suit the requirements of the driver, there being two holes in the lever on the clutch-yoke shaft for this purpose. Under ordinary circumstances this should be connected to the inside hole, but if the car is to be driven by a lady the outer hole may be used.

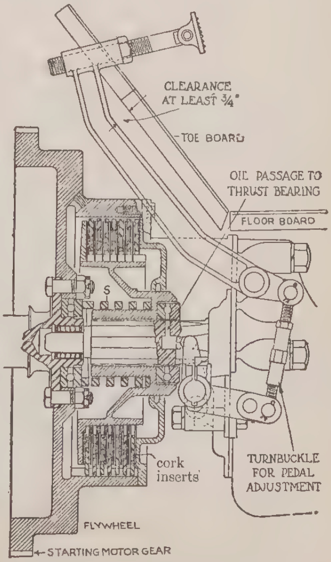


Fig. 31. Sectional view of a multiple-disk cork-insert lubricated type of clutch.

To remove the clutch it is first necessary to take off the gearbox; then the cap screws which attach the clutch-plate cover to the drum of the flywheel are removed, and the entire clutch assembly may be taken out.

To reassemble the clutch it is necessary to compress the clutch spring, which can be accomplished by using two 5/16″ studs about 3½″ long, threaded full length. They should be inserted in two opposite holes in the clutch drum. Then take the driven clutch member and install the disks on it—a plain disk first and then a cork disk, and so on.

Place the clutch plate over the hub of the driven clutch member and insert the spring over the front end of the hub of this part. The lugs on the outer edge of the driving disk should then be run in line. Next coat the gasket on the clutch plate thoroughly with shellac and allow it to dry until it becomes sticky.

The clutch assembly may be entered into the clutch drum of the flywheel and the two studs, mentioned above, can then be inserted in the drum and used to draw the clutch into position. Finally install the cap screws which hold the clutch-plate cover to the flywheel, and after removing the two studs tighten all of the screws firmly.

It is sometimes necessary to remove the main drive gear from the front end of the transmission and to use it as a guide, in order to be sure that the clutch is in proper alignment with the rear bearing in the rear end of the crankshaft which supports the front end of this main drive gear, otherwise there may be difficulty in getting the transmission into place.

HUDSON LUBRICATED MULTIPLE-DISK CORK-INSERT CLUTCH

The Hudson clutch is of the multiple-disk type with cork inserts. It is fully enclosed in the flywheel and runs in what is suitably termed clutch oil. The cork inserts become saturated with this oil, and maintain the velvety action so desirable, while the friction between the corks and steel disks is sufficiently great to prevent any tendency to slip.

Renewing the oil and lubricating the clutch throw-out collar are the only attentions necessary. The fact that the cork inserts become saturated with oil makes it comparatively difficult to abuse this clutch, as compared with other types. However, its action will be affected if instructions in regard to the quality and quantity of lubricant are not strictly adhered to.

Never put more than a half-pint of mixture in at one time. Always drain the clutch to remove the used oil before filling in any fresh oil (half kerosene and half good engine oil).

Clutch oil consists of one half-pint of kerosene and lubricating oil mixed in equal proportions.

Clutch adjustment should be inspected occasionally. The adjustments are shown in the wording for Fig. 32.

Wear on the clutch parts is indicated by the pedal stopping farther away from the toe-board than usual. If the clutch is burned or abused, so that the corks swell up, the pedal will come back farther—nearer to the toe-board.

Do not slip the clutch when driving, except when absolutely necessary, and then only when you know it has sufficient lubrication to stand it. If you feel that you must do so, owing to lack of confidence in your ability to handle the car through congested traffic, remember that the lubrication of the throw-out collar will need more frequent attention.

The clutch throw-out sleeve is lubricated by the large grease cup. Clashing of gears and hard shifting is usually due to faulty lubrication at this point.

Note. **The usual cause of slipping of the lubricated disk type clutch** is a weak clutch spring or clutch pedal-linkage adjustment, which prevents the clutch plates from engaging. If this type of clutch **drags,** it is probably due to oil being too **thick.** If it grabs it is probably the result of lack of oil or improper clutch-spring adjustment.

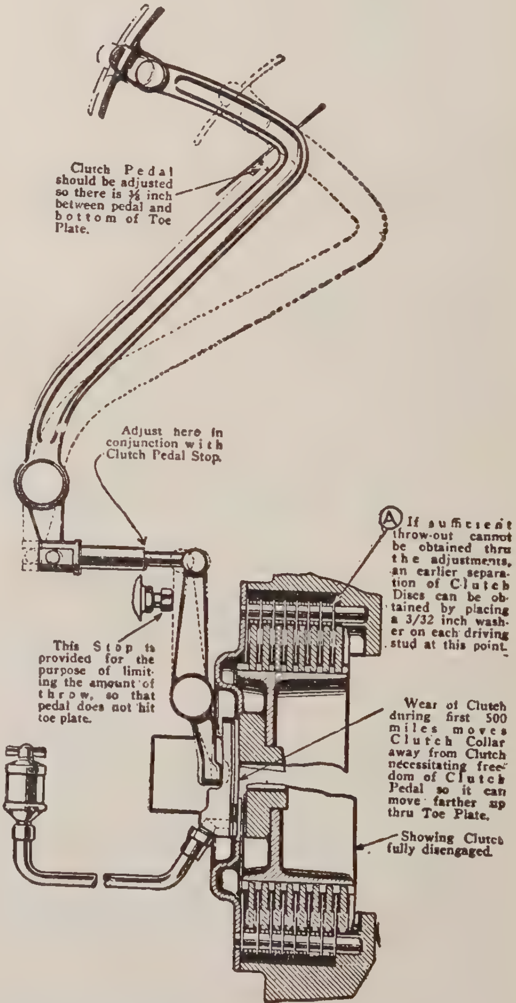

Clutch Pedal should be adjusted so there is ⅛ inch between pedal and bottom of Toe Plate.
Adjust here in conjunction with Clutch Pedal Stop.
Ⓐ If sufficient throw-out cannot be obtained thru the adjustments, an earlier separation of Clutch Discs can be obtained by placing a 3/32 inch washer on each driving stud at this point.
This Stop is provided for the purpose of limiting the amount of throw, so that pedal does not hit toe plate.
Wear of Clutch during first 500 miles moves Clutch Collar away from Clutch necessitating freedom of Clutch Pedal so it can move farther up thru Toe Plate.
Showing Clutch fully disengaged.

Fig. 32. The Hudson lubricated multiple-disk cork-insert clutch.

THE REO MULTIPLE-DISK DRY-PLATE TYPE OF CLUTCH

This clutch is of the multiple dry-disk type, consisting of thirteen steel plates, seven of which are lined on both sides with asbestos. The remaining six plates are of plain steel and are placed alternately between the lined disks. These disks are designed to run dry, and the application of oil, regardless of the kind, will tend to ruin them. Details of troubles and adjustments are given on next page.

Evidence of Trouble

1. **Slipping clutch:** This is often caused by lack of proper clearance between the clutch opening fingers and the release plate. This clearance should never be less than 1/16″ or more than ⅛″ when the clutch is in. This necessitates an adjustment of the clutch opening fingers (see clutch adjustment below).

   Another cause of slipping clutch is too little tension on the clutch springs, contained in recesses in the flywheel, as shown in Fig. 35. The nuts on the engine end should be tightened enough to prevent the clutch from slipping, but not enough to make the pedal difficult to operate. Never tighten the clutch-spring nuts until the release fingers have been adjusted to the proper clearance. Neither of the adjustments mentioned will have any effect if the lining on the disks is worn so thin that the clutch casing seats on the flywheel, as shown in Fig. 35, at (**A**) and (**B**). When worn thus, the clutch must be removed.

   Continual slipping causes the disks to get very hot, warping the steel disks, as shown in Fig. 33, and raising the rivets on the lined disks so that they cause the clutch to chatter, with the possibility of grooving the disk and giving them a permanent warp.
2. **Noisy clutch—particularly when released:** This is due to a worn clutch-thrust bearing (see Fig. 35). A removal of the clutch and replacement of the bearing is necessary.

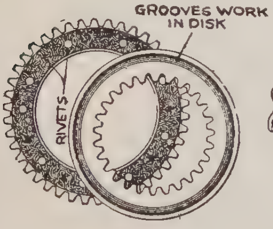


Fig. 33

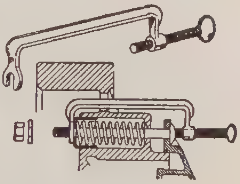


Fig. 34

Fig. 33. **If worn, the facing should be renewed,** and the rivets countersunk below the surface to prevent grooving the steel disks. The steel disks should be renewed if grooved or warped.

Fig. 34. The assembly is facilitated by the use of a simple **compressor,** applied in the manner illustrated. It is cast iron, though a similar one could be forged from bar stock. The main thing is to use a compressor of some sort.

To Remove Reo Clutch

1. Remove the floorboards.
2. Remove the starter driving chain.
3. Remove the two battery wires running to the starting motor.
4. After removing the two bolts holding the right end of the starter, and the single bolt at the left end, remove the starting motor.
5. Remove the short drive shaft, with its universals, that connect the clutch and gearbox.
6. Remove the brake rods.
7. Remove the bolts on the clutch cross-shaft and spring it up.
8. Remove the clutch cross-shaft.
9. Remove the nuts that hold the clutch-spring bolts at the rear of the flywheel. Remove bolts.
10. Pull the clutch out and remove it from the frame.
11. Place the clutch ring assembly on the bench with the clutch rings up.
12. Remove the snap ring, and then remove all friction rings. (Note how the rings are removed, so that they may again be built up in the proper sequence.)
13. Clean all parts with gasoline and scrape out the clutch-ring recesses both on the flywheel and the clutch hub.

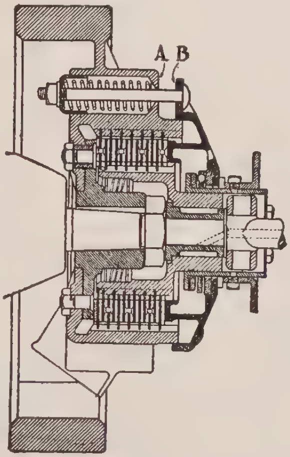


Fig. 35

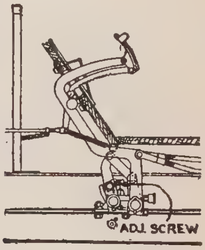


Fig. 36

Fig. 35. Clutch assembly. When the disks are worn out, surface (**A**) touches surface (**B**).

Fig. 36. To adjust clutch-opening fingers, turn the adjusting screw on the clutch pedal until the clearance between the fingers and the release plate is about 1/16″ when the clutch is in. The release plate should then spin freely.

To Repair Reo Clutch

If the asbestos faces of the disks are worn, they must be replaced. The split rivets holding them should be opened down below the surface, if the facing does not have to be renewed.

1. To replace facing: Cut off the heads of the old rivets, taking care that the disks are not sprung out of shape.
2. Examine each disk to see that it is not sprung or warped out of shape, and note whether the steel disks are grooved. If either is the case, the disks must be replaced.
3. Using each disk as a template, drill the rivet holes in its new facings. Countersink the facings slightly for the rivet heads. (The new facings can best be obtained from the car makers, and this should be done if possible.)
4. Using solid copper rivets, rivet the new facing to the disk.
5. Examine the ball and roller bearings of the clutch for wear and the clutch bushing for looseness. Replace with new ones, if any amount of wear is evident.
6. Use little grease in assembling the bearings, as the clutch must be run dry.

1. **When assembling the clutch:** Make certain that the rings are inserted in proper relation to each other. (An asbestos-faced disk goes in first.)
2. Slide the clutch back into place.
3. Using a clutch-spring compressor, as shown in Fig. 34, replace the nuts on the clutch-spring bolts. Do not tighten these nuts yet.
4. Replace the clutch cross-shaft.
5. Reconnect the brake rods.
6. Replace the drive shaft and universals.
7. Replace starting motor, wires, and driving chain.

To Adjust Reo Clutch

1. Adjust the opening fingers on the clutch throw-out collar, so that they strike the collar together. This is done by loosening the clamp bolts, holding them to the cross-shaft, and tapping them into alignment. If this is not done the gears will not shift readily.

2. Adjust the clearance of the opening fingers. This is done by loosening the lock nut on the adjusting set screw, as shown in Fig. 36, and turning the screw in to decrease the clearance, and out to increase it. This screw should be turned out until the clutch release collar spins easily on the drive shaft when the clutch is in.

3. Tighten the nuts on the clutch springs at the rear of the flywheel evenly, and until the clutch does not slip. These nuts should not be so tightened that the clutch pedal works with difficulty.

Maintenance

1. If the clutch starts to slip, adjust it at once.
2. Use no oil on the interior of the clutch, except as placed in the two oil openings in the drive shaft.
3. Do not drive with the foot on the clutch pedal. (*Motor World.*)

ADJUSTMENT OF BUICK "SIX" CLUTCH (1921)

The Buick "six" clutch is of the multiple-disk dry-plate type, consisting of steel plates operating between steel plates lined with asbestos and which are connected alternately to the flywheel and the clutch shaft.

Adjustment: When the facing on the clutch disks wears, adjustment can be made by moving the lock nut and the adjusting on the clutch-release rod to allow more clearance between the clutch-release bearing and the plates. When adjustment is properly made a clearance of 1/32″ should be between the ball-thrust bearing and the rear plate against which it operates.

Lubrication: Neither oil nor grease should be put on the clutch disks. The clutch is lubricated by two grease cups, one located on the clutch-release yoke pin and one on the clutch-release bearing retainer, both of which should receive attention at least once every 500 miles. A few drops of oil applied to the pins on which the disks slide will prevent squeaking.

Clutch and brake pedals require soft cup grease. Remove the floor board and give grease cups one or two turns. Keep filled with grease. There is one cup on each pedal hub.

The clutch release fork pin requires soft cup grease. Remove clutch cover and give grease cup one or two turns.

The clutch release bearing retainer requires soft cup grease. Give grease cup (outside of transmission housing) one or two turns.

The clutch pedal position can be adjusted by means of the set screw at the rear end of the clutch housing.

The proper handling of the clutch pedal and accelerator so as to make the motor "pick up" its load quickly, and at the same time prevent it from "racing" when the clutch is released, requires practice.

In changing gears, and especially when starting the car from a standstill, always let the clutch pedal come back gently. If the foot is suddenly removed from the pedal, it will let the clutch take hold with a violent jerk.

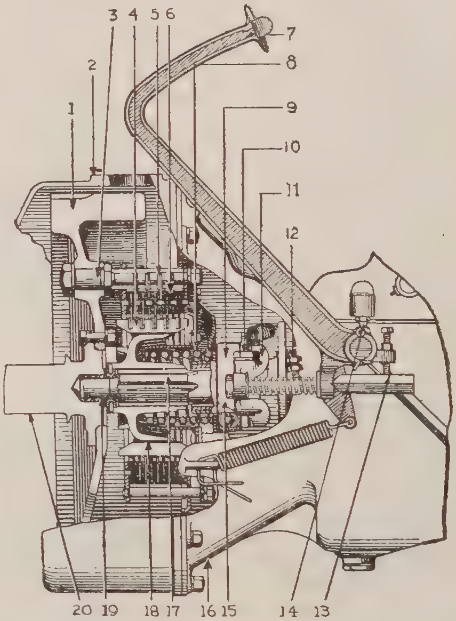


Fig. 37. The Buick "six" clutch.

(1) Fly wheel.
(2) Crank case.
(3) Flywheel driving stud.
(4) Clutch-driven plate.
(5) Clutch driving plate.
(6) Clutch-plate facing.
(7) Clutch pedal.
(8) Clutch spring.
(9) Clutch-release bearing.
(10) Clutch-release bearing retainer.
(11) Clutch-release fork.
(12) Clutch adjusting stud.
(13) Clutch-release adjusting nut.
(14) Grease cup.
(15) Clutch-release rod.
(16) Transmission case.
(17) Clutch gear.
(18) Clutch-driven hub.
(19) Graphited bushings.
(20) Crank shaft of engine.

THE STUDEBAKER "LIGHT SIX" CLUTCH

The Studebaker "Light six" clutch is of the single-disk dry-plate type.

Operation of clutch: The driven member is a single malleable-iron disk placed between two friction plates. Six coil springs are used to exert pressure on the clutch toggle plate, acting upon friction plates and a malleable disk located between the toggle plate and flywheel (Fig. 38).

The clutch is released by the toggle-lever collar being pulled back against the three toggle levers which operate the toggle plate, thereby relieving the pressure on the friction surfaces.

The toggle lever should be adjusted so that, with the clutch pedal released, there is a slight play between the ends of the levers and the toggle-lever collar. This play must be the same for each lever, so that the clutch is released equally at all points.

To make adjustment, first loosen the lock nuts on the toggle-arm adjusting screws. Then turn the screws to the left to increase the play between the toggle levers and the collar, or to the right to decrease it.

Under no circumstances should the levers be tight against the collar when the clutch pedal is released, as the clutch will be partially disengaged, and slipping will result.

In the case of a new car, or after new friction disks have been installed, it may be necessary, after 500 to 1,000 miles of running, to readjust the three levers which may bind on the collar as a result of the friction disks running into a smooth surface and becoming thinner. After the disks have worn smooth, no further adjustment will be necessary for some time.

When disks become badly worn it will be necessary to replace them with new ones, which can be obtained from a Studebaker dealer or branch. These disks require no treatment before or after being installed.

Clutch brake: The braking action on the clutch occurs when the grease retainer nut of the clutch throw-out bearing is brought in contact with the leather-faced flange, which is a part of the flexible coupling spider, keyed to the clutch drive shaft (Fig. 38).

There is no adjustment to the clutch brake, and it requires no care except that of replacing the leather facing when worn.

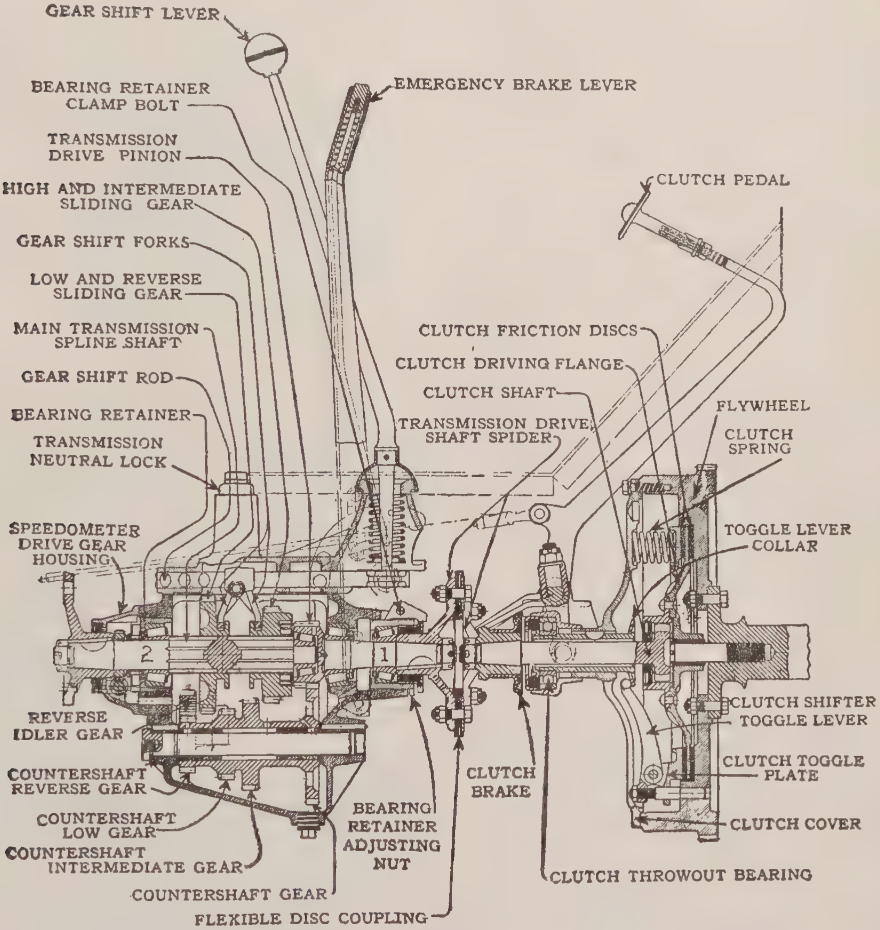

GEAR SHIFT LEVER
BEARING RETAINER CLAMP BOLT
EMERGENCY BRAKE LEVER
TRANSMISSION DRIVE PINION
HIGH AND INTERMEDIATE SLIDING GEAR
CLUTCH PEDAL
GEAR SHIFT FORKS
LOW AND REVERSE SLIDING GEAR
MAIN TRANSMISSION SPLINE SHAFT
CLUTCH FRICTION DISCS
CLUTCH DRIVING FLANGE
GEAR SHIFT ROD
CLUTCH SHAFT
FLYWHEEL
BEARING RETAINER
TRANSMISSION DRIVE SHAFT SPIDER
CLUTCH SPRING
TRANSMISSION NEUTRAL LOCK
SPEEDOMETER DRIVE GEAR HOUSING
TOGGLE LEVER COLLAR
2
1
REVERSE IDLER GEAR
CLUTCH SHIFTER TOGGLE LEVER
COUNTERSHAFT REVERSE GEAR
CLUTCH BRAKE
CLUTCH TOGGLE PLATE
COUNTERSHAFT LOW GEAR
BEARING RETAINER ADJUSTING NUT
CLUTCH COVER
COUNTERSHAFT INTERMEDIATE GEAR
CLUTCH THROWOUT BEARING
COUNTERSHAFT GEAR
FLEXIBLE DISC COUPLING

Fig. 38. Sectional view of the clutch and transmission of the Studebaker "Light six."

TRANSMISSION TROUBLES

Transmissions used on most cars are of the selective sliding-gear type, with three forward and one reverse speed, as explained on page 28.

Most of the transmission manufacturers now mount the counter-shaft on ball or roller bearings instead of on bronze bushings. Several are mounting the gear set separately from the engine and clutch which, however, are continued as one unit.

The usual troubles are:

1. Stripped gears.
2. Bearings worn, permitting shaft to drop out of line.
3. Dogs or gear teeth worn.
4. Dripping oil from the gearbox.
5. Cracked gears, worn teeth, sprung shafts.
6. Gear-shift rod out of adjustment.
7. Gears will not stay in mesh.
8. Usually the teeth of the "intermediate gear" and external and internal "high and intermediate sliding gear" (Fig. 38) wear first.

The cause of dripping oil is either a loose gasket, or too much oil running out at the bearing, or a worn felt gasket that may be sometimes used. The amount of oil usually carried in a transmission is a quantity sufficient to reach to a center line of the secondary shaft (Fig. 39). The lower gears will splash oil to all parts.

Other troubles: When dogs become worn (see part No. 139, page 26) so that they slip out of engagement, they may be dressed up or squared by grinding. Most transmissions now use internal gears, as shown in Fig. 38 ("drive pinion" and "high and intermediate sliding gear").

Noise: In gearboxes where the shaft ends are supported by single-row ball bearings, with no provision for end-thrust adjustment, and are noisy, **replace the bearings.**

Considerable wear in the bearings will change the distance between centers of the transmission shaft. In such a case **replace the bearings.**

Difficulty in shifting gears: There are three reasons for this: (1) a sticking or dragging clutch, caused by heavy oil; (2) the teeth of the shifting gears being burred; (3) considerable wear in the bearings, throwing the shaft out of line, which also causes noise. **Gears should be shifted without a particle of noise.**

Gears do not stay in mesh: This trouble is usually the result of weak or broken springs in gear-shifting shaft, **plunger or lock** (see 31, page 858). **Gear-shifting forks** (26, page 858) fit into collars on the sliding gears, and it is through them that the gears are moved to the different positions.

There are two types of gear-shifting shaft plungers or locks: (1) those placed on the top (31, page 858); (2) those placed on the side (Fig. 40, pg. 857). **A notch is cut in the gear-shift rod or shaft** (23, page 858) and a **plunger** and spring engages in the notch. On some transmissions a **steel ball** is forced into the notch by a spring, the **purpose** being to hold the gear-shift rod rigid so that gears will not move out of mesh after being shifted. The spring can be replaced if the gears fail to stay in mesh.

Worn gears and loose bearings will also cause the gears to fail to stay in mesh.

End play may be discovered by grasping the universal joint behind the gearset and attempting to move it forward or backward. If looseness is found, adjustment is needed. If end play is allowed to develop, the gears are likely to be stripped.

To determine the cause of clashing gears: Remove the cover plate over the clutch and, with the rear wheel jacked and the car in gear, let the clutch in and out. If the clutch continues to spin after it has been thrown out, look to the clutch brake, or see if there is too close an adjustment, or whether heavy oil causes the gears to drag.

Note. Do not allow a nut or any chips of metal to lodge in the transmission case. It will strip the gears if caught between the teeth. This also applies to the engine and the differential.

Do not use waste to wipe out the interior of a transmission. It leaves lint.

Removal and Replacement of a Transmission

Dowel pins and shims: Dowel pins are usually provided on either side of the transmission to insure its alignment. Sometimes, however, it is necessary **in squaring up the transmission with the engine** to insert a thick shim on one side; consequently it is important, when removing the gearbox, to notice whether **there are any shims,** and if there are, they must be replaced when the unit is put back.

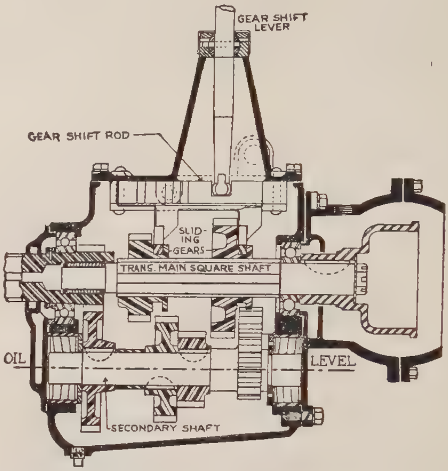


Fig. 39. Sectional view of a transmission. Note the oil-level line.

Bearings: The secondary-shaft in this example (Fig. 39) is carried on two Hyatt roller bearings. The bearing linings are a pressed fit in the case, and when they show wear they may be replaced at slight expense. The end thrust of this shaft is carried by two hardened steel washers, and a slight amount of end play is of no consequence.

Lubrication: The gearbox will usually hold about 2 qts. of oil, and should not be filled above the center line of the secondary-shaft. There are two oil rings provided on the main transmission shaft, and drains carry the oil back to the secondary-shaft bearings. Additional provision to prevent the oil from washing out through the bearings of the main shaft is made by thin steel washers which cover the inside of these bearings.

When replacing ball bearings in a gear-set case or on the shafts, care must be taken to see that the balls or races are not damaged from improper handling. Where the bearing is to be put on a shaft, the force should be applied to the inner race, using a piece of pipe and a hammer. If the bearing is to be forced into the gearset case, the driving effort should be applied to the outer or larger race in such a manner that no strain is imposed on the steel balls themselves.

Transmission-Gear Ratios

This subject is fully treated on pages 8, 9. See page 9 for examples of four-speed transmission.

STUDEBAKER LIGHT "SIX" TRANSMISSION

Type of transmission: The transmission is of the selective sliding-gear type, located at an intermediate position just behind the engine (Fig. 38). It consists of three shafts and a series of gears. Two of these shafts—the main transmission spline shaft and the pinion shaft—are in direct line with each other, the end of the main transmission spline shaft turning in the end of the pinion shaft. The third shaft, operated parallel with the pinion shaft and the main transmission spline shaft, is called the counter-shaft.

Neutral lock: The transmission is equipped with a neutral lock mounted in a hand-control base plate, and, when locked, it holds the sliding gears in neutral position (Fig. 40).

Transmission gears: The main transmission spline shaft carries two sliding gears of unequal sizes. These gears can be slid into mesh with gears of uneqal sizes on the counter-shaft. One of the sliding gears can also be moved into engagement with an idler gear supported by a transmission case, thus obtaining the changes of gear from "low" to "reverse."

Gear shift: See Fig. 3, page 630.

Lubrication of transmission: A heavy transmission oil should be used in the transmission. In addition, it is advisable to see that the transmission case is **thoroughly cleaned** out several times a season, as particles of steel from the gears, cuttings from the bearings, etc., all have a tendency to accumulate and, if not thoroughly cleaned out, will in time cause extra wear on the bearings. This can be done by taking out the cap screws on top of the transmission case cover and removing it altogether

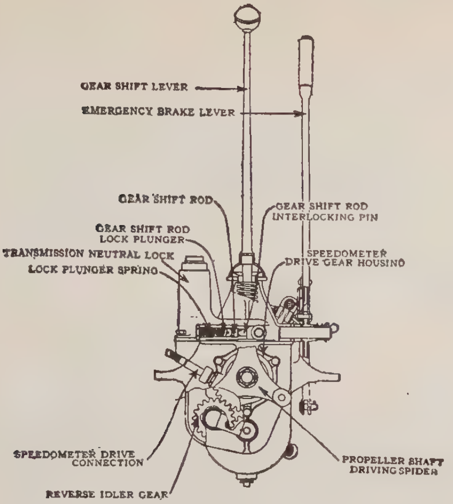

GEAR SHIFT LEVER
EMERGENCY BRAKE LEVER
GEAR SHIFT ROD
GEAR SHIFT ROD INTERLOCKING PIN
GEAR SHIFT ROD LOCK PLUNGER
TRANSMISSION NEUTRAL LOCK
LOCK PLUNGER SPRING
SPEEDOMETER DRIVE GEAR HOUSING
SPEEDOMETER DRIVE CONNECTION
PROPELLER SHAFT DRIVING SPIDER
REVERSE IDLER GEAR

Fig. 40. Studebaker Light "six" transmission; rear view.

with the gear-shift assembly. Unscrew the plug at the bottom of the transmission. After the oil has been drained out, kerosene or gasoline should be flushed over the gears, and the entire case should be washed out with kerosene or gasoline very thoroughly. The plug should then be replaced; new oil should be put in the transmission, and the cover and gear-shift assembly replaced, care being exercised to see that an oil-tight joint is made between the transmission case and the transmission-case cover.

Amount of oil carried in transmission: When the proper amount of oil has been added, it will stand just at the top of the oil-filler plug, which is located on the left-hand side of the transmission.

To adjust the pinion shaft (1) (Fig. 38) for wear, remove the retainer clamp bolt, and turn the retainer nut in the front end of the transmission case in a counter-clockwise direction until all end play is just removed.

Adjustment of the main drive shaft (2) (Fig. 38) is made by removing the bolts which hold the speedometer drive-gear housing to the transmission case, sliding the cover back far enough to give room for a spanner wrench. Then turn the bearing retainer in a clockwise direction until all end play is just removed.

DODGE DRIVE SYSTEM

To Adjust Dodge Clutch

The Dodge clutch is of the multiple-disk, dry-plate type. There are 7 disks held together by a heavy spring (6) (Fig. **A**, page 858). The 4 **driving** disks (9) (covered with wire-woven asbestos) are supported on 6 pins (3), pressed and riveted into the flywheel. The 3 **driven** disks (8) (plain) are carried on 3 pins (7) riveted to the clutch spider (4), which is keyed on the clutch shaft (32). Flywheel pins (3) are located outside, or above the clutch-spider pins (7), so that they can turn independently of the clutch-spider pins when the clutch is disengaged.

All disks are free to slide upon their supporting pins, and are held together by the clutch spring (6) when the clutch is "in."

To tighten the clutch spring: Compress it enough to allow the split washer (Fig. 41), which fits into one of three grooves cut on the clutch shaft, to be moved forward to the next groove. The two halves of this washer must fit securely into the groove so that the clutch-spring rear retainer fits snugly around it.

Care: Keep the foot off the clutch pedal except when using it, otherwise the disk facings and ball-bearing throw-out will wear excessively. Do not slip the clutch unnecessarily, as this causes the fabric to become glazed and to slip. Keep the drain in the bottom of the clutch housing open.

Lubricate the ball-bearing clutch release (12) by keeping the grease cup located on the toe-board to the right of the accelerator pedal well filled, and give it one complete turn every 100 miles. Make sure that the clutch-release grease tube (34) (Fig. **A**) is tightly connected and unobstructed.

Removal of Clutch and Gearbox

(1) Break the universal joint; (2) drop the emergency brake rod; (3) remove the exhaust pipe completely; (4) block up the engine at the rear, just in front of the bell flywheel housing; (5) remove the bolts in the rear engine arms (47); (6) remove the bolts holding the bell housing flange (10) to the crank case; (7) drop the foot-brake rod; (8) disconnect the flexible grease-cup tube running from the floor board to the clutch throw-out; (9) slide the unit to the rear and lift it out.

Disassembly of Dodge Clutch

(1) Remove the two lockscrews in the clutch throw-out yoke (visible from the clutch hand-hole); (2) remove the two nuts on the clutch throw-out yoke; (3) remove the clutch pedal (38) from its shaft and loosen the brake pedal (39); (4) drive out the clutch shaft (32) to the left; (5) lift out the clutch unit; (6) apply the clutch puller (Fig. 41) to the complete clutch disassembly; the puller consists of a cross-member with a bolt terminating in a hook perpendicularly placed at each extremity; the hooks engage pins on the clutch; (7) draw down on the puller nuts until the clutch spring is sufficiently compressed so that the split locking ring may be withdrawn; (8) remove the split locking ring; (9) ease up on the puller nuts, and then remove the clutch spring; (10) clutch plates may now be taken apart.

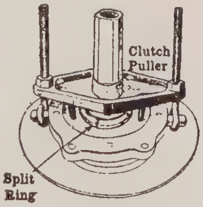


Fig. 41

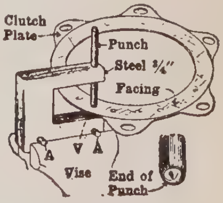
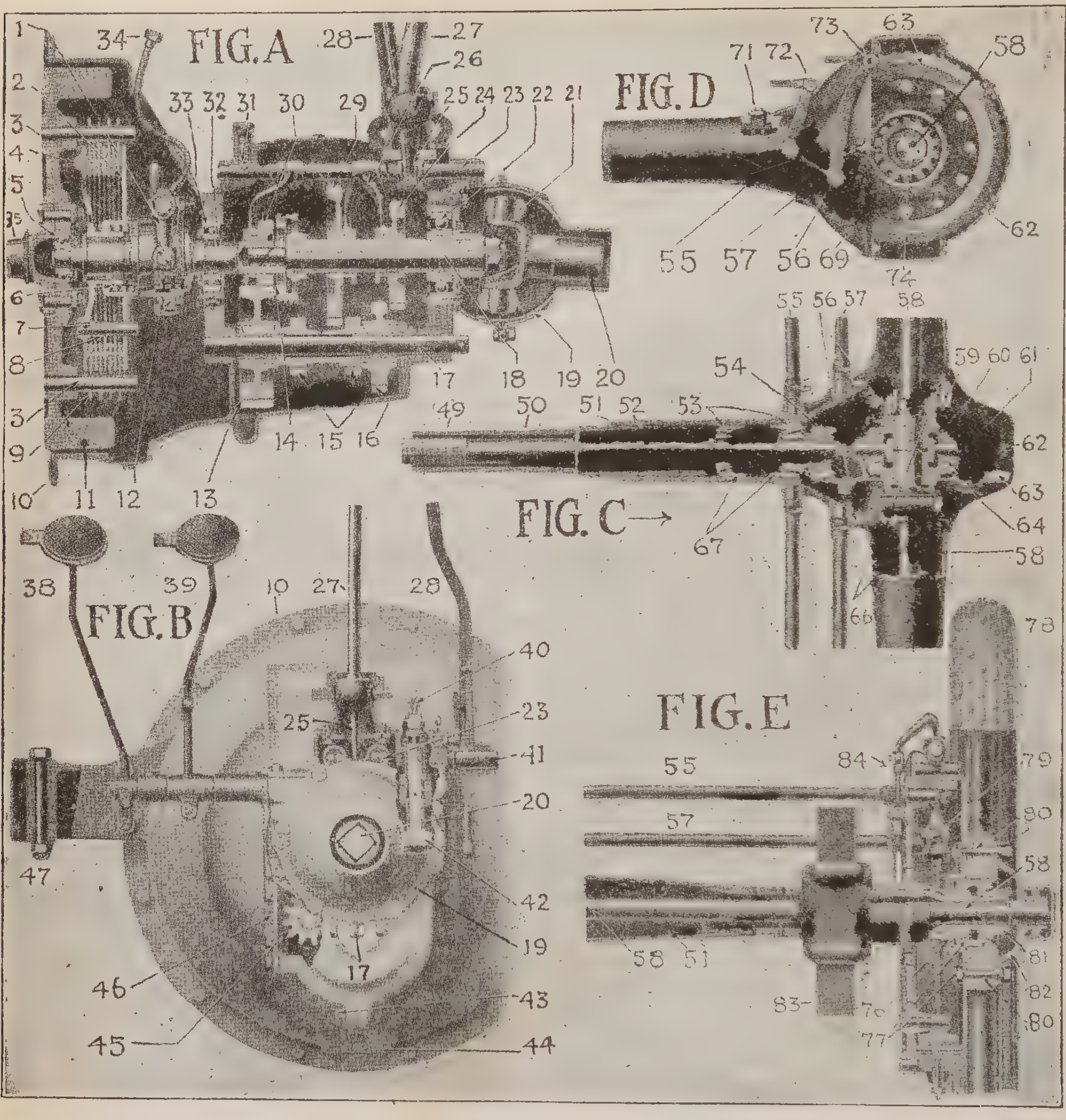


Fig. 42

To Replace Dodge Clutch

The facings come already cut and drilled, so it is merely a matter of riveting a new facing in place on the driving disks (9) (Fig. **A**). A tool especially designed for this purpose is shown in Fig. 42. The punch is made of a valve stem, hardened. In putting in the hollow rivets half of them should face one way and alternate ones in the opposite direction. This tool may also be used to rivet brake linings.



1. Clutch release fork.
2. Clutch pressure plate.
3. Clutch-driving disk pin.
4. Clutch spider.
5. Clutch-shaft front bearing.
6. Clutch spring.
7. Clutch-driven disk pin.
8. Clutch-driven disk.
9. Clutch-driving disk.
10. Housing, bolts to crank case.
11. Flywheel.
12. Ball-bearing clutch release.
13. Counter-shaft drive gear.
14. High-speed internal gear.
15. Counter-shaft low and reverse pinions.
16. Counter-shaft intermediate gear.
17. Counter-shaft.
18. Sliding-gear shaft, or transmission main shaft.
19. Universal-joint housing.
20. Universal hollow shaft; square drive shaft (49) fits inside.
21. Universal joint.
22. Sliding-gear shaft rear bearing.
23. Shifting shaft.
24. Intermediate sliding gear.
25. Shifting-shaft yoke.
26. Gear-shifting fork.
27. Gear-shift lever.
28. Hand-brake lever.
29. Low and reverse sliding gear.
30. High-speed sliding gear.
31. Shifting-shaft plunger.
32. Clutch shaft.
33. Clutch-shaft rear bearing.
34. Clutch-release grease tube.
35. End of engine crank shaft.
38. Clutch pedal.
39. Foot-brake pedal.
40. Speedometer drive shaft.
41. Hand-brake lever shaft.
42. Speedometer drive gear.
43. Transmission drain plug.
44. Clutch drain plate.
45. Reverse idler pinion.
46. Reverse idler-pinion bracket.
47. Support arm.
49. Square end of drive shaft, fits into (20).
50. Torque tube, fits to (19).
51. Rear-axle housing.
52. Drive or propeller shaft.
53. Drive-shaft roller bearings.
54. Drive pinion.
55. Foot-brake operating shaft.
56. Adjusting-ring lock screws.
57. Hand-brake operating shaft.
58. Rear-axle drive shafts.
59. Differential roller bearing.
60. Differential bevel gear.
61. Differential cross.
62. Lubricant level plug.
63. Bevel-driven gear.
64. Differential bevel pinion.
66. Bearing adjusting rings.
67. Drive-shaft bearing adjusting rings.
69. Differential carrier.
71. Adjusting ring lock.
72. Foot brake operating shaft lever.
73. Hand brake operating shaft lever.
74. Differential bearing adjusting ring lock.
76. Grease retainer.
77. Wheel roller bearings.
78. Tire.
79. Brake toggle joint—see page 884.
80. Rear wheel hub bolt.
81. Wheel-bearing adjusting nut.
82. Rear-wheel flange.
83. Spring.
84. Brake mechanism—see also page 884.

Dodge Rear Axle

This will now be considered with special reference to Figs. **A, B, C, D,** and **E,** on page 858.

Noisy Rear Axle

When there is a constant singing or humming noise in the rear axle, with the humming increasing with speed, and the rear axle mesh seems stiff when the clutch is thrown out, it is usually due to the adjustment of the drive pinion (54) to the driven bevel gear (63) being meshed too tight.

When there is noise and back-lash, which is more noticeable when the clutch is "thrown out," and there seems to be a loose, jerky motion in the rear when the clutch is "thrown out," it is probably due to gears (54) and (63) not meshing tight enough.

Remedy: First see if there is oil on the teeth of the gears, by taking out the filler plug and placing your finger on the gear. Often heavy grease will not throw all the way round.

Adjustment: Ordinarily the adjustment of the drive pinion (54) is sufficient. If not, the driven bevel gear (63) must also be adjusted.

Note: On other makes of cars having **"helical" gears** the same rules apply.

In the later Dodge axle, only one adjusting ring is used at (67) Fig. **C**, the adjustment of propeller shaft bearings being made by hexagonal nuts at forward end of bearing retainer, it being necessary to remove the propeller shaft to make this adjustment.

To Adjust Drive Pinion

The whole drive shaft (52) (Fig. **C**) can be adjusted **endwise** to obtain the exact position of the driving pinion (54) which is rigidly attached to it, in relation to the driven bevel gear (63) bolted to the differential. Two adjusting rings (67), fitted against the two Timken bearings (53), can be screwed forward or backward to obtain the proper position of the bevel driving pinion (54). These rings can be reached by removing the ring lock (71) (Fig. **D**). All that need be done is to back off one adjusting ring (67) (Fig. **C**), and screw the other one ahead, in whichever direction it is desired to move the bevel driving pinion (54). Be sure that each is holding its bearing rigidly before replacing lock (71).

Adjustment of Bevel-Driven Gear

To test if the bevel gear (63) **is running quiet,** jack up the rear axle and run the engine, with the gears in direct drive, about 20 m.p.h., as indicated by the speedometer.

After adjusting the bevel driving pinion (54) as explained above, and if it is still noisy, remove the rear-axle cover plate and the two adjusting ring-lock screws (56), and readjust the bevel driven gear (63) to the new position of the pinion.

The large bevel driven gear (63) **can be moved either to the right or to the left in order to insure its quiet engagement with the driving pinion** (54), by operating the two bearing adjusting rings (66) (Fig. **C**) in a manner similar to those used in adjusting the drive pinion. After adjusting, they are locked in place by the adjusting-ring lock screws (56) (Figs. **C** and **D**).

Removal of Rear-Axle Shafts

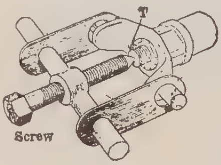
The rear axle is of the seven-eighths floating type,[1] permitting the removal of the drive shaft (58) (Figs. **C** and **E**) without jacking up the car.

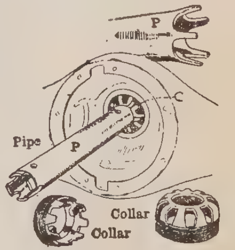
To remove rear axle shafts[1] (58) and flanges (82), simply unscrew the nuts on bolts (80), which hold the flanges to the hub of the wheel and remove them together with the axle shafts. If one axle shaft should stick, remove one on the opposite side, and drive or push the other one out with a long rod.

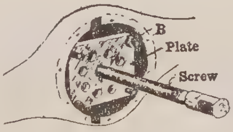
Lubrication of the rear axle: Use 5 pints,[2] if empty, of gear lubricant, or enough to fill the rear axle up to the level of the lower plug (62) (Figs. **C** and **D**). If grease leaks out from the rear wheels, the housing is too full.

To Disassemble Differential

(1) Remove axle shafts (58); (2) remove the inspection plate; (3) take the caps off the bearings and lift them out; (4) remove the cotter pins and nuts on the 4 studs which hold the differential unit together, and disassemble.







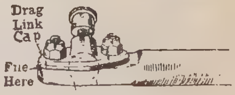


Fig. 43 (upper)
Fig. 44 (lower)

Fig. 45 (upper)
Fig. 46 (lower)

Fig. 43. Puller for front of universal joint.

Fig. 44. **To remove the drive pinion** (54), a plate is bolted to the 4 studs and pressure is applied to the shaft by the screw.

Fig. 45. **To remove the front bearing,** adjust collar (C) and turn to the left with a screwdriver. A special wrench for this purpose can be made of a piece of pipe (**P**).

Fig. 46. The drag link cap is filed to give adjustment.

Dodge Transmission

The Dodge transmission (page 858) main sliding-gear shaft is mounted on ball bearings at either end, and looseness means replacement of the bearings. The counter-shaft is mounted on bronze bearings. If the gearset is kept properly lubricated with clean oil, none of these bearings should need replacement in a good many thousand miles of driving. Not more than 2 quarts of gearset lubricant should be used in the case. The level should be inspected every 1,000 miles and, if it has fallen so low that the gears on the main shaft do not dip well into the lubricant, the supply should be replenished so that they do. The level should be kept ½″ below the main sliding-gear shaft.

REMOVING, DISASSEMBLING, AND ASSEMBLING TRANSMISSION (MITCHELL "F")

Removing the transmission from the car: Remove the two bottom floor boards and lift out the front-seat cushion as well as the stool on which it rests. This will completely expose the transmission.

Disconnect the rear universal-joint member and, placing a jack under the transmission, raise it just enough to take the load off the transmission hanger links. Remove the two large hanger link nuts on top of the frame cross-member.

The transmission, still connected to the torsion tube, can be lowered to the ground by lowering and then removing the jack. Take out the 8 cap screws holding the transmission to the torsion tube; the transmission can then be taken out from under the car.

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[1] Semi-floating type now used. **To remove rear-axle** shafts, first remove rear wheels.

[2] 4 pints in semi-floating type.

Disassembling the transmission: With the transmission out of the car, remove the cover and clean out the lubricant. Removing the drain plug at the bottom of the transmission case will aid in this operation.

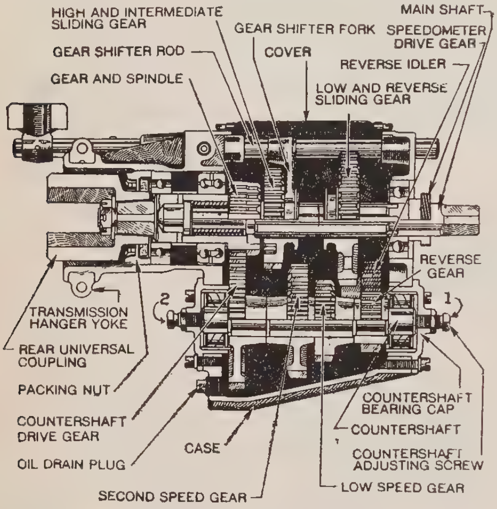


Fig. 47. Mitchell model "F" transmission used as an example.

Drive out the rear main-shaft ball bearing when the splined main shaft can be removed through the rear opening. In doing this the sliding gears will come off the main shaft and can be lifted out through the cover opening.

Care should be taken not to let the sliding gears drop as they come off the main shaft, since they may fall on the counter-shaft gears and get chipped. The small roller bearing supporting the front end of the splined shaft in the gear and spindle and the grease retainer may come out with the shaft, or may stay in the gear and spindle. Watch for them to see that they do not fall into the bottom of the transmission case and become misplaced.

Remove the pins holding the gear-shifter forks on their rods, and the rods can then be pulled out through the front of the case and the forks removed through the cover. In removing the rods it will be necessary to pull them out against the action of the spring locks which prevent the gears from coming out of mesh.

Remove the nut holding the universal-joint coupling to the front end of the gear and spindle and remove the coupling. Remove the lock holding the front-bearing packing nut and unscrew this nut.

Loosen the lock screws holding the large main gear and spindle double-row ball-bearing in place, and the gear and spindle complete with its bearings can then be removed by forcing it into the case and lifting it out through the cover opening.

Remove the front and rear counter-shaft bearing caps by taking out the cap screws which hold them in place. The counter-shaft roller bearings should be removed with the caps. The counter-shaft can then be moved back, tilted, and taken out of the case through the cover opening.

The gears can be removed from the counter-shaft only by the use of an arbor press. They should not be removed unless it is necessary to replace them.

The reverse idler gear can be removed by taking out the cotter pin in the end of the spindle and forcing the spindle into the case which removes the gear from it, when the gear and spindle may both be lifted out through the cover opening.

Assembling: When replacing the gear and spindle in the transmission case, do not set up the main-bearing lock screws tight enough to bind the bearing. They should be set up just tight enough to keep the bearing from turning in the case.

When reassembling the transmission and torsion tube, be sure that the speedometer drive gear on the transmission main shaft meshes with the small pinion in the front end of the torsion tube.

Adjusting the transmission: The only adjustment on the transmission consists of the two screws (1 and 2) (Fig. 47) located in the centers of the counter-shaft bearing caps. In reassembling the transmission, the counter-shaft should be so located in the case that the main counter-shaft drive gear is in full mesh with the large external gear on the gear and spindle. The adjusting screw should then be set up so that there is no end play on the counter-shaft, but allowing the counter-shaft to rotate freely without cramping or jamming.

The tension on the gear-shifting lever can be varied, and any tendency to rattle can be lessened by adjusting the splined nut found where the lever enters the floor boards. Remove the lock and unscrew this nut to decrease tension, or screw it down to increase tension and remove rattle. The ideal adjustment is such that there is little or no rattle and the lever does not bind or cramp in shifting gears.

Lubricating the transmission: The transmission is lubricated by filling it to a little above the center line of the counter-shaft with a high-grade semi-fluid lubricant of about the consistency of 600-W steam-engine oil. It will take about 2 quarts of oil to fill the transmission case to this point.

UNIVERSAL JOINTS

There are two types of universal joints in general use: the mechanical angular type, shown in Figs. 48 and 49 and the flexible-coupling or fabric type shown in Fig. 50.

The Spicer Universal Joint

A very popular type of universal joint is the Spicer, shown in Figs. 48 and 49. This universal joint can be used with an angular-drive or straight-line drive system, as explained on page 24.

The forward universal joint is provided with a dust cap (D) and a felt washer (W) on the rear end of the sleeve into which the end of the drive or pro-

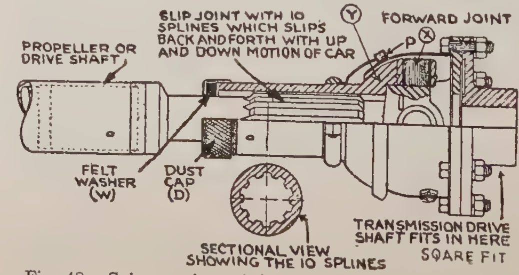

SLIP JOINT WITH 10 SPLINES WHICH SLIPS BACK AND FORTH WITH UP AND DOWN MOTION OF CAR
Y
FORWARD JOINT
P
X
PROPELLER OR DRIVE SHAFT
FELT WASHER (W)
DUST CAP (D)
SECTIONAL VIEW SHOWING THE 10 SPLINES
TRANSMISSION DRIVE SHAFT FITS IN HERE
SQARE FIT

Fig. 48. **Spicer universal joint showing the forward,** or splined end of the drive shaft in place. The right end of this forward joint is connected to the transmission shaft.

peller-shaft slides. This cap should be turned to the right occasionally in order to keep the felt washer tight and prevent the leakage of grease. Both joints have flax packing (P) between the two parts of the pressed-steel casings.

This packing can be tightened by loosening the casing-adjusting screw (S) and turning the casing-adjusting nut or ring in a right-handed direction.

If the packing in the front universal joint is allowed to leak grease, the joint will not only suffer from lack of lubrication, but the grease will be thrown up on to the emergency brake, rendering the brake inoperative.

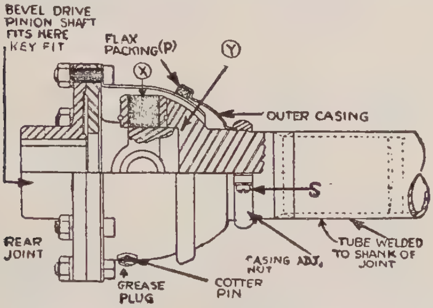


Fig. 49. This is the **rear universal joint** which is connected to the rear end of the drive shaft at the right end of the joint, and to the bevel-pinion drive shaft at the left end. Note that the splines are not used in this rear joint.

Lubrication: Every 1,000 miles remove the grease-hole plugs and fill with heavy gear oil or light cup grease. Too much grease will work out; about one-third full is the correct quantity.

Note. An "O" will be found on upper end of the propeller shaft tube (Fig. 48); a corresponding "O" will be found on the shank or rear end of the forward universal joint. When the propeller shaft and the universal joint are assembled, these two "O's" must be in line (as shown in Fig. 48), that is, the **yoke (Y) and journal (X) of the forward universal joint must be parallel to corresponding yoke and journal of the rear universal joint** (Fig. 49), otherwise the rear transmission bearing will be subjected to undue strain and excessive wear, and a jerky motion will be given to rear wheels.

Assembling: When the universal joints have been disassembled and are assembled again, care should be taken to see that the holes in the flange and the inside casings are matched up in such a way as to bring the **oil hole** (which is closed by a threaded plug) opposite an open space in the joint, and not opposite one of the lugs, which would prevent the introduction of grease through the hole. By removing this plug the user of the car can at any time inject additional oil or grease by the use of an ordinary grease gun, if the holes are matched.

Many of the joints are now fitted with a spring of suitable strength to give just the right pressure on the packing between the inner and outer casings. These require no attention from the operator. (Address of mnf'r.: Spicer Mfg. Co., South Plainfield, N.J.)

The Fabric Flexible Universal Joint

A type of flexible joint, connection, or coupling, as it could be termed, is shown in Fig. 50. This joint is generally used with drive shafts of the straight line drive, or what is nearly so, as explained on page 24. What angular movement there may be is the result of the flexibility of the flexible disks. These joints can be used with angular-drive systems (see page 24) where there is not too great an angular movement.

On each end of the driving, or propeller shaft, spiders (S) and (S1) are securely attached. Another spider (S2) is attached to the transmission shaft at the forward or driving end, and still another (S3) at the rear end which is attached to the drive pinion shaft.

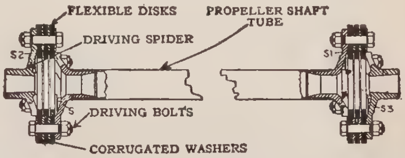


Fig. 50. The Thermoid-Hardy flexible connection, or joints that are used at each end of the propeller or drive shaft, instead of universal joints.

Three flexible disks, made of thermoid composition, are placed between the spiders and held securely by means of bolts and corrugated washers.

Note that with the use of these joints a splined shaft, as shown in Fig. 48 is not necessary.

By removing a few bolts the shaft may be removed.

Make sure that all bolts are kept tight, otherwise the holes in the fabric may tear out. New disks can be obtained at supply houses. Lubrication is not necessary.

The popularity of the fabric universal joint (Fig. 50) is to a large extent attributable to the poor lubrication methods used on many of the form-metal universal joints.

The lubrication systems, in some cases, were designed correctly enough, but, when assembled in the car, they were not within observation of the owner or driver and consequently received but scant attention. This could result in only one thing, and that was rapid wear with its accompanying knocks and lost motion. Some of the molded universal joints have been very much improved in this respect, and the Lincoln, for instance, makes provision for lubricating the front universal from the front gear case.

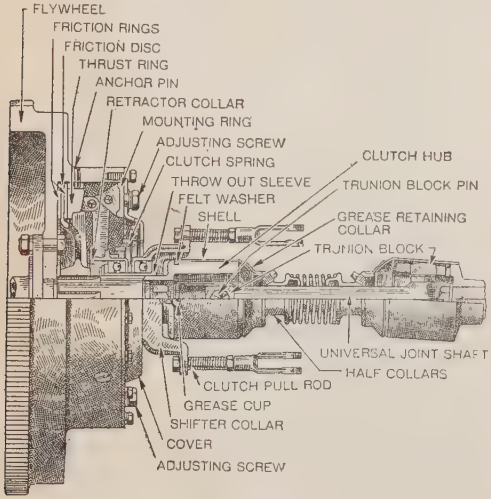
Disconnecting a Universal Joint and Clutch Mitchell Model "F" as an Example

Purpose of universal joint: Owing to the fact that the transmission is rigidly fastened to the front end of the torque tube and swings with it, there exists a certain amount of disalignment between the transmission and the clutch. For that reason a rigid drive or connection cannot be used, and a universal joint is employed. By means of hardened steel blocks sliding in hardened steel jaws the universal joint is given a flexible action which takes care of disalignment. See Fig. 51.

Removing the clutch and universal joint from the car: Disconnect the front universal joint member by compressing the grease retaining collar spring, taking out the half-shells and sliding back the cuff or housing. Slide the spring, rear grease-retaining collar, and cuff forward on the universal-joint shaft, and remove the whole universal-joint assembly.

Disconnect the clutch pull-rods by removing the clevis pins. Place two wood blocks 1⅜" thick between the clutch cover and the ends of the clutch pull-rods, thus relieving the cover of spring, pressure when the 12 capscrews holding the drive in the three anchor pins, and the rings can then be readily removed.

Remove the nut holding the clutch hub on the crank shaft, when the whole clutch assembly can be slipped off the end of the crank shaft, the friction rings and disk remaining in the flywheel. To remove the friction disks, as when renewing them, drive in the three anchor pins, and the rings can then be readily removed.



.Fig. 51. Mitchell universal joint and clutch.

Disassembling the clutch: With the clutch removed from the car, exert pressure on the retractor collar and, removing the locking wire and blocks from the flange nut, unscrew this nut (left-hand thread), and the whole clutch can be disassembled as the pressure on the collar is released.

Adjusting the clutch: To adjust the clutch, loosen the two adjusting screws in the slotted holes in the clutch cover. Depress the clutch pedal, and push these screws ⅛″ to ¼″ in a clockwise direction to overcome slipping, and counter-clockwise to overcome dragging. Release the clutch pedal and tighten the adjusting screws.

When the screws have reached the end of their slots, a new pair of threaded holes will have entered the beginning of the slots. Transfer the screws to the new holes, and continue to adjust as occasion requires. When these holes, too, have reached the end of the slots, all possible adjustment will have been taken up and new friction rings should be put in the clutch.

After the clutch has been properly adjusted, it would be well to see that the clutch pedal does not strike the under side of the floor board, as this will cause the clutch to slip. If such is the case, it can be corrected by adjusting the clutch pull-rods until the clutch pedal operates freely through the floor board. (See also Index for Borg & Beck clutch.)

Lubricating the clutch and universal joint: The grease cup on the clutch pull-out yoke should be filled and turned down completely once a week, or every 500 miles.

Cup grease should be packed into the front and rear universal-joint housings through the plugs in the half-shells. This can be conveniently done with a grease gun, and should be done every 1,000 miles.

Removing Universal Joint Chevrolet "490" as an Example

For another example of removing a universal joint the Chevrolet 490 is shown as illustrated below. Note the procedure as explained under the illustration.

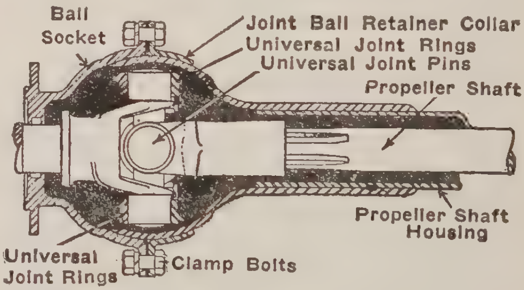
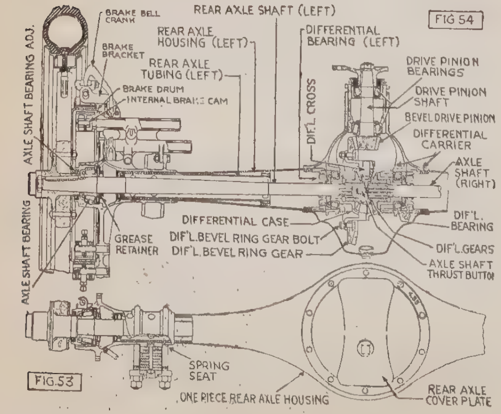


Fig. 52. The Chevrolet "490" metal universal joint. **To remove,** first remove the axle from under the car, take out the five cap screws holding the joint ball-retainer collar, and pull the ball joint from the socket. Remove the four clamp screws holding the two universal-joint rings together, and separate the rings. The nut holding the universal-joint yoke to the transmission shaft can then be removed and the yoke pulled off the shaft.

PARTS OF A REAR AXLE



Figs. 53, 54. Names of parts of a rear axle (one-piece type housing). See also page 875.

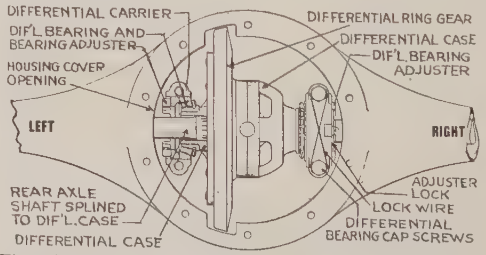


Fig. 55. One-piece rear axle housing showing differential carrier integral with housing.

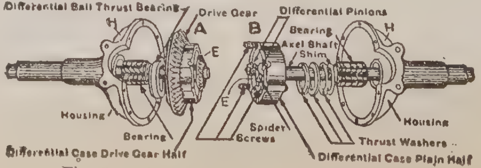


Fig. 56. A two-piece, or divided rear axle

INSTRUCTION No. 73

REAR WHEELS, DIFFERENTIALS AND REAR AXLES FOR PASSENGER CARS: Types; Adjustments, and Repairs[1]

TYPES OF REAR AXLES

This subject is also treated on pages 15 and 16. **Types in general use** are the "plain live" (used on the Ford (pages 1096, 1097); the "semi-floating," which is used most (about 42 per cent of the cars use this type); the "three-quarter floating," which is extensively used, and the "full-floating."

To find the make and type used on different cars see Index, "Specifications of Passenger Cars."

The S. A. E. distinctions between the types of rear axles are as follows:

Dead axle: An axle carrying road wheels with no provision in the axle itself for driving them.

Live axle: General name for type of axle with concentric driving shaft. See also pages 15, 16.

Plain live axle: Has shafts supported directly in bearings at center and at ends, carrying differential and road wheels. (The plain live axle is practically obsolete.)

Semi-floating axle: Has differential carried on separate bearings, the inner ends of the shafts being carried by the differential side gears, and the outer ends supported in bearings.

The semi-floating axle shaft carries torsion, bending moment, and shear. It also carries tension and compression if the wheel bearings do not take thrust, and compression if they take thrust in only one direction.

Three-quarter floating axle: Inner ends of shafts carried as in semi-floating axle. Outer ends supported by wheels, which depend on shafts for alignment. Only one bearing is used in each wheel hub.

The three-quarter floating axle shaft carries torsion and the bending moment imposed by the wheel on corners and uneven road surfaces. It also carries tension and compression if the wheel bearings are not arranged to take thrust.

Full-floating axle: Same as three-quarter floating axle except that each wheel has two bearings and does not depend on the shaft for alignment. The wheel may be driven by a flange or jaw clutch.

The full-floating axle shaft is relieved from all strains except torsion, and in one possible construction, of tension and compression.

Advantages of the semi-floating axle (by Packard Motor Car Co.): In the semi-floating axle, the wheel hubs can be made slightly smaller and, because of the location of the bearings, the stresses in the rear axle can be kept lower than in the full-floating type.

There is a slight advantage also in the bearings, as the full-floating type have to use a bearing with a smaller ball, since it must fit around the rear-axle tube. In the semi-floating type, the bearing has a smaller bore, and therefore larger balls can be used, as the bearing has only to go over the axle shaft.

Another advantage is that the rear wheels can be more readily removed when replacements are necessary, wheels being replaced oftener than shafts. Still another advantage claimed is that of lubrication, as the outer bearings can be lubricated from the inside, and an oil retainer can be placed on the outside, while the full-floating type must have a separate supply of lubricant for the rear-wheel bearings.

Rear-axle ratios (see pages 8 and 9). **Types of drive** (see page 6).

TIMKEN REAR-WHEEL BEARINGS; ADJUSTMENT AND LUBRICATION

As an example of the semi and full-floating types of rear axles, and the method of attaching the axle shafts to the rear wheels, and of how the bearings are placed, we will use the Timken rear axles and wheels.

Rear-axle housing is made in "one-piece" or "two-piece" type. Fig. 53, page 862, shows a one-piece type, and Fig. 56, a two-piece type. The halves (H) are termed **right and left halves.**

The bevel-gear housing (Fig. 54) is that part where the bevel gears are enclosed. The **differential carrier** is that part which carries the differential. On some it is bolted to the axle housing, as in Fig. 19, page 871, and on others it is integral with the axle housing, as in Figs. 54, 55. The **rear-axle tube** is shown in Fig. 54, one right, the other left. **Rear-axle shafts** (semi-floating in this example) are right and left. The **rear-axle housing cover** is the plate over the one-piece housing. The **rear-axle spring seat** may be under or on top of the housing. Other parts are shown in Figs. 53, 54.

Removing Rear-Axle Shafts

On "full-floating" and "three-quarter-floating" type of rear axles, the axle shafts can be withdrawn without removing wheels.

On most of the "semi-floating type" of rear axles, the axle shafts can be withdrawn without removing rear-axle assembly, but wheels must first be removed and then the outer wheel bearing nuts and bearings (see pages 15, 16, 864, and 883).

On a "plain live axle" having a two-piece or divided rear-axle housing, the complete rear-axle assembly must be removed in order to remove the rear-axle shafts. See pages 880 and 1096.

Removing Differential

On those types of floating rear axles having a "one-piece" housing and a **cover plate** and where the "differential carrier" is **integral with the rear-axle housing,** the differential can be removed by removing the axle shaft, then removing the differential bearing caps from the carrier integral with the axle housing (Fig. 55), after which the differential can be withdrawn at the rear of the housing.

On those types of rear axles having a one-piece housing with "differential carrier" bolted to rear-axle housing (Figs. 18, 19, page 871), the differential with drive pinion can be removed by withdrawing axle shafts, loosening differential carrier, and removing complete assembly (Fig. 19, page 871), through the **front** part of the axle. Then the differential can be disassembled and adjusted on the removed carrier.

On those types of rear axles having a "two-piece" or divided rear-axle housing which is bolted together in the center, the complete rear-axle assembly must be removed from the car in order to remove the differential, as shown in Figs. 56, page 862 and 41, page 880, Fig. 28, page 921, and Fig. 39, page 1096.

Semi-Floating or Fixed Hub Types[2]

Timken fixed-hub or semi-floating rear axles are used on light and medium-weight passenger cars. In this type of construction the wheel is keyed to the axle drive shaft, the shaft revolving in a bearing mounted in the housing just inside the wheel. See Fig. 1, page 864. This bearing should be cleaned, greased, and adjusted at least once a year; more often if the service is severe.

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[1] See Index under Truck axles.

[2] See also page 883 for later types with oil seals.

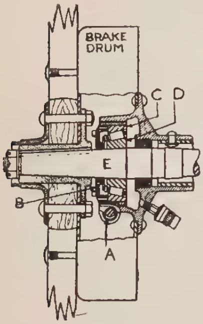

Fig. 1

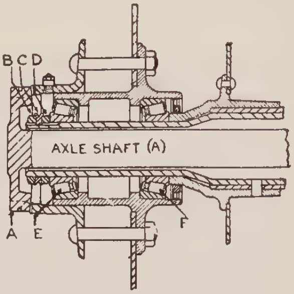

Fig. 2

Fig. 1. Timken **rear-wheel hub** as used with the **semi-floating rear axle** (see also page 883).

Fig. 2. Timken **rear-wheel hub** as used with the **full-floating type of axle.**

To clean the bearing, remove the wheel from the axle shaft, using a wheel puller if necessary.[1] Now release the locking finger (**A**) which prevents the bearing adjusting ring (**B**) turning, and unscrew this ring from the housing, carrying with it the bearing cup (**C**). The ring having been removed, **pull out the axle shaft** (**E**) on which is pressed the bearing cone (**D**), and the rollers. With a stiff brush and gasoline or kerosene clean off all old grease from the bearing cup, cone, and rollers, and from the end of the housing into which the adjusting ring is screwed. In order thoroughly to remove all old grease, the bearings should occasionally be placed in a solution of washing soda and water and brought to a boil.

Lubrication of bearings: After carefully cleaning and drying the bearing, cover well with good, clean cup grease free from acid and dirt, grit, and other solid matter. Also pack the end of the housing with grease.

Adjustment: Now replace the shaft with the bearing cone and rollers and screw on the adjusting ring carrying the bearing cup. The **adjustment** of the bearing is made by turning up this ring.

In adjusting wheel bearing, remember that the two drive shafts, right and left, come in contact in the center of the differential spider (see Fig. 3, page 865). If the bearing on one side is adjusted in too far, while the bearing on the other side is too far out, the spline end of the shaft will project through into the other side of the differential. This will either lock the differential or cause the end of the shaft to be twisted off. Care must be used, therefore, to take up the same amount on both right and left-hand bearings.

Screw up the bearing adjusting ring (**B**) (Fig. 1) until all end play is taken out of the shaft and until the shaft turns stiffly when revolved with a wrench placed on the nut on the shaft end. Then back off the ring one notch and lock in this position by means of the locking finger. The wheel may now be replaced, care being taken to tighten up well on the nut on the end of the shaft and to lock it with a cotter pin.

Full-Floating Type

Timken full-floating rear axles are used on heavy passenger cars. In this axle the entire weight of the car is carried on the axle housing; each rear wheel has two bearings mounted in the hub similar to the front wheel (Fig. 2). These bearings should be cleaned, re-greased, and adjusted at least once a year—more often if the service is severe.

To remove the bearings, take off the hub cap (not shown) jack up the wheel, and pull out the axle drive shaft (**A**). Wipe the grease from the end of the housing tube and the lock nuts. Now take off the outer lock nut (**B**), the thin lock washer (**C**), and the inner lock nut (**D**). The wheel may now be removed. Kneel directly in front of it and, grasping the rim with both hands, pull toward you. Be careful not to allow the outer bearing (**E**) to fall to the floor, which may bend or otherwise damage the cage.

To clean parts: With a stiff brush and gasoline or kerosene, clean all the old grease from both outer and inner bearings and from the inside of the wheel hub. Occasionally both bearings should be placed in a solution of water and washing soda and brought to a boil. This cleans off any grease behind the rollers which may not have been removed by the brush.

Lubrication of wheel bearings: When the bearings have been thoroughly cleaned and dried, replace the inner bearing (**F**) on the axle tube, covering it well with good clean grease free from all acid, grit, or solid matter. Care should be taken to see that there is no dirt on the paddle. Repack the space in the hub between the two bearings and cover the outer bearing with grease.

Replacing wheel: Now replace the wheel, and, holding it firmly in position, slide the outer bearing on the tube end, pressing it firmly into the hub. Screw up the inner lock nut, turning it up tight against the bearing so that the wheel binds, at the same time revolving the wheel to be sure all working surfaces on the bearing come into contact.

Now back off the nut enough to allow the wheel to turn freely, but not enough to give any noticeable looseness or end play. Replace the lock washer and screw up the outer lock nut tightly against it.

Bearing adjustment: Before replacing the axle shaft, be sure that your bearing adjustment is right. The wheel should be loose enough to oscillate, that is, when spun, it should come to a stop and then start to turn back in the opposite direction, but not loose enough to have any amount of shake. Check this adjustment after tightening up the outer lock nut, as it is sometimes possible, when using a large wrench, to turn the nut so tightly against the inner nut as to destroy the adjustment.

Lubrication of wheel hubs, etc : Having obtained a good bearing adjustment, cover the end of the tube and the lock nut with grease, and slide in the drive shaft. Fill the hub cap with grease and screw it on the hub, being careful to get it tight.

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[1] See Index under "Wheel pullers."

Cautions

1. **Don't jam lock nuts so tight that the wheel binds.** A wheel should oscillate when given a slight spin (in other words, come to a stop and turn slowly back in the opposite direction).

2. **Don't allow the lock nuts to be so loose that you can shake the wheel and feel the play in the bearings.** Too loose an adjustment will damage a bearing just as rapidly as too tight an adjustment.

3. **Don't take rollers, cone, cage, or cup from one bearing** and substitute these parts in another bearing even though it bears the same number. After a bearing has once been used, the parts differ from an unused bearing one to two one-thousandths of an inch—not enough to see, but enough to cause trouble and expense if parts are substituted. If a bearing must be replaced, because of damage, replace the entire bearings.

4. **Don't hit the cage with a hammer to drive a bearing on a spindle;** you will bend the cage and damage the bearings.

5. **Don't use a screwdriver or other sharp tool back of the cage to pry a bearing off a spindle**—you will bend the cage. If a bearing cone sticks, be sure the tool is placed behind the edges of the cone. A slight pressure is sufficient to release the cone from the spindle.

6. **Don't let bearings fall on the floor;** you may bend the cage which keeps the rollers in line.

7. **Don't use grease or other lubricant that contains acid or has acid-forming qualities.** Use only a good grade of clear medium cup grease having no solid matter in suspension.

8. **Don't drive cups in hubs or other retainers, nor cones on spindles, with a hammer** where a pressed fit is required.

ADJUSTMENT OF TIMKEN REAR AXLES;[1] GEARS, PINION, AND DIFFERENTIAL BEARINGS[2]

There are three conditions which make adjustment of gears and bearings necessary—objectionable noise, excessive back lash in the gears, and a loose pinion or differential bearings.

Timken-Detroit fixed-hub or semi-floating rear axles are built in two sizes—current series, 5151 and 5152 (Fig. 3) for light cars, and 5301 and 5302 (Fig. 4) for cars of medium weight. **Full-floating axles** for heavy cars are built in one size only—current series 5762 (Fig. 5). The construction of these three axles is shown in detail in Figs. 3, 4 and 5. The **principles of adjustment** are the same in any case; the figures show the slight differences in the details of design.

To adjust for elimination of noise,[2] remove the clamp bolt and lock at (**A**), and turn the sleeve (**B**) containing both the pinion bearing and the pinion shaft one notch to the left. Replace the clamp bolt and lock, and run to see if the noise is lessened or increased. If the noise is less, turn the sleeve to the left until the quietest point is found; if it is increased, turn the sleeve to the right until the best point is found. Do not forget to replace the clamp bolt and lock each time before running to test your adjustment.

To take up excessive back lash,[2] remove the cover (**F**). Now loosen the differential-bearing cap bolt-lock wire (**G**), and disengage the lock (**H**) from the adjusting rings (**J**) and (**K**). When this has been done, loosen the right-hand adjusting ring (**J**) and tighten the left-hand ring (**K**), thus forcing the ring gear against the pinion. Turn both rings the same number of notches until the proper amount of back lash, approximately five one-thousandths of an inch, has been obtained. After adjusting, be sure that the lock is replaced and is held by the wires before replacing the cover.

To adjust the pinion-shaft bearing, loosen lock nut (**C**) and then tighten up on adjusting nut (**D**) until the shaft will turn freely but with only very slight end play. The end play should be about five one-thousandths of an inch after tightening the lock nut. Tighten up the lock nut (**C**) and peen over the washer (**E**), so as to lock both nuts.

If noisy gears result from this adjustment of the bearings, eliminate the noise by the adjustment described above.

Adjustment of the differential bearing is made by tightening up on the adjusting rings (**J**) and (**K**) after releasing the lock (**H**). Tighten up on these rings until the differential turns freely, but without end play. If excessive back lash results from this adjustment, take up as outlined above for elimination of back lash.

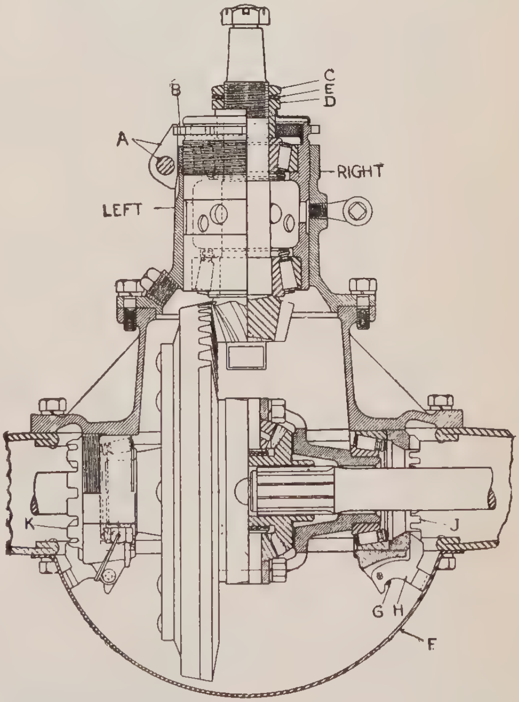

Fig. 3. Timken fixed-hub or semi-floating rear axle, types 5151, 5152 for light cars.

Lubrication: The **pinion and ring gear** and the **differential gears and bearings are lubricated** by the oil in the axle housing. Keep the housing filled to the level of the oil hole in the bowl with a good quality of **light steam cylinder oil.**

To lubricate the drive-pinion bearings, keep the sleeve (**B**) well filled with a good quality of heavy lubricant free from acid, grit, or other solid matter.

Lubricant can be introduced into this sleeve through the street ell at the side of the carrier casting, and this point should receive special attention when the axle is first put into service. Be sure that the sleeve is filled to the height of the lip, and put in additional lubricant from time to time to make up for any leakage.

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[1] **Timken axles** (Figs. 3, 4, 5, and Fig. 6, pages 865, 866, and Fig. 7, page 867) **could represent either a semi-floating or a full floating axle because the differential supports the inner ends of axle shafts.** The next principal feature which determines whether it is a semi-floating or full-floating axle is found in the type of hub used. See also pages 15 and 863.

If the semi-floating wheel hub (Fig. 1, page 864) **is used,** it is termed a semi-floating axle.

If the full-floating wheel hub (Fig. 2, page 864) **is used,** it is termed a full-floating axle.

[2] See also page 910 for later types.

Gears are properly adjusted:

1. When the axle is quiet.
2. When the gear teeth engage for their entire length.
3. When there is but little back lash between the gears.
4. When there is no end play in the pinion shaft.
5. When all adjustments are securely locked.

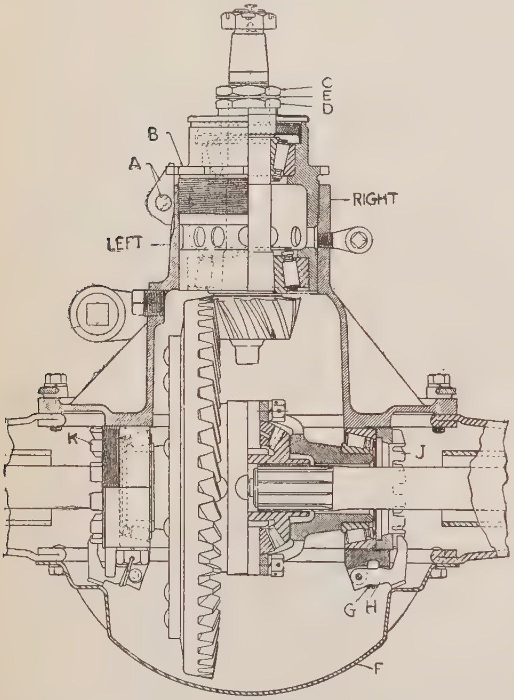


Fig. 4. Timken fixed-hub or semi-floating rear axle, types 5301, 5302 for cars of medium weight.

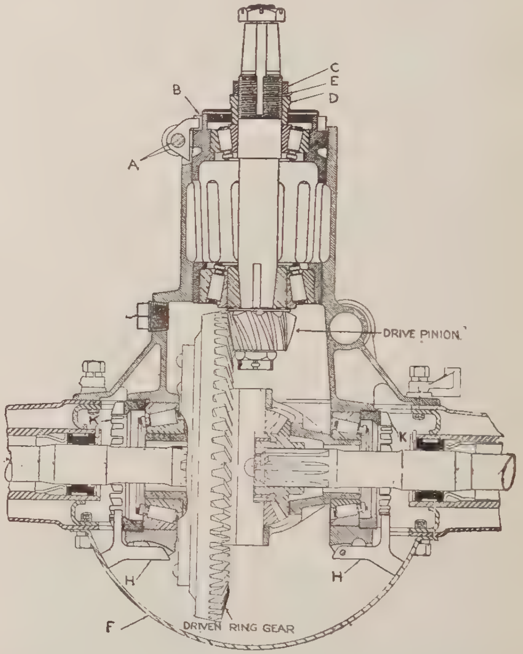


Fig. 5. Timken full-floating rear axle, type 5762, for heavy cars.

OLD TYPE REAR AXLES (TIMKEN)

The preceding instructions are intended to cover particularly the Timken-Detroit axle now being produced.

The following description and figures cover the adjustment of axles as formerly designed, where these designs differ to any extent from the present type. See Figs. 6 and 7.

Gear and Bearing Adjustment of Timken Rear Axle Shown in Fig. 6

1. **Before making adjustments for elimination of noise or back lash,** take up all looseness, if any, in the bearings. To do this, remove bolts (**A**) and locking key (**B**). Turn the slotted ring (**C**) toward the right, while holding ring (**D**) in its original position, until the bearings are free from end play, at the same time allowing the pinion shaft to turn freely.

To take up differential bearings, remove the locking wire in cap screws (**L**) and loosen the screws one half-turn. Release locking finger (**J**) and turn the right-hand adjusting ring (**F**) toward the differential until the bearings are free from end play, at the same time allowing the differential to turn freely.

2. **When adjusting to eliminate noise,** remove bolt (**A**) and locking key (**B**) as directed above, and turn rings (**C**) and (**D**) one slot toward the left and repeat until the quietest point is found. If the noise increases, adjust in the opposite direction. Always turn rings (**C**) and (**D**) together when adjust-

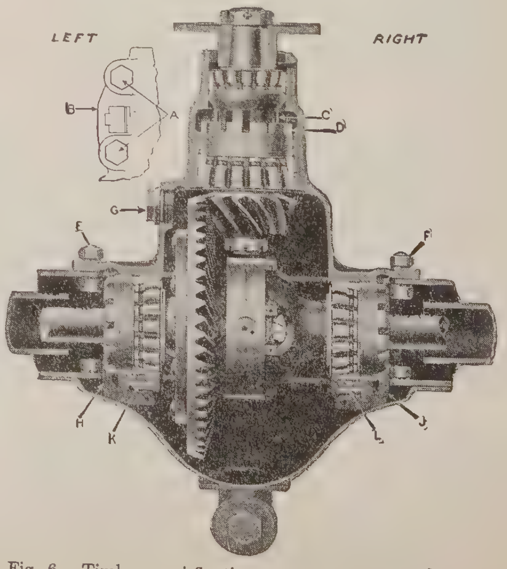


Fig. 6. Timken semi-floating rear axle, as referred to in the text. Models are 5230, 5240, 5241, 5752, and 35C axles. The cars which formerly used this axle are as follows: Hudson (5241); Jordan (5241); Westcott (5240); Chalmers (35C).

ing for this purpose, by using a tool broad enough to engage the slots in both rings.

3. **When adjusting to take up back lash in the gears,** remove the wire and loosen cap screws (K), (L), one half-turn. Release locking fingers (H), (J). Back the adjusting ring (F) away from the differential and turn the adjusting ring (E) toward the differential (right-hand thread on both) until the gear is forced toward the pinion, so that it has about .005″ back lash, or barely perceptible looseness.

If the gears are so far out of mesh that no results can be obtained through the method described above, or if new gears have to be placed in the axle, remove peep-hole plug (G) for observation, and set the gears with backs flush, as a starting-point, and proceed again as directed above.

If noise results from taking up loose bearings, proceed as in paragraphs 2 and 3 as required.

After making adjustments, make sure that all locking keys, cotters, wires, etc., are replaced and that all bolts and cap screws are properly drawn up. If a car is run to try the effect of any adjustments, all bolts and cap screws must be properly tightened.

Gear and Bearing Adjustment of Timken Rear-Axle Shown in Fig. 7

1. **To eliminate noise,** loosen nut No. 1 at (A) and then loosen nut No. 2. Remove the cover at (B), and loosen clamp bolt No. 4. Turn the slotted adjusting cup toward the left one notch, and tighten up nut No. 2, then nut No. 1, just enough to let the shaft run freely without end play. If this lessens the noise, loosen nuts No. 1 and No. 2, and turn the adjusting cap another notch, and repeat this operation until the quietest point is found. If the noise increases, adjust in the opposite direction. When final adjustment is made so that the pinion shaft has no end play, back off nut No. 2 one quarter-turn and tighten up on nut No. 1. Bend the washer over one flat of each nut, tighten up clamp bolt No. 4, and replace the cover.

2. **To take up back lash,** back the adjusting ring at (D) toward the differential, and turn the ring at (C) against the bearing cap which will force the ring gear toward pinion. These rings have a right-hand thread and are threaded to bearing carrier. Before turning the rings, loosen the cap screws in the bearing cap one half-turn after removing the locking wires. The proper amount of back lash should be approximately .005″, or barely perceptible looseness. When proper adjustment is made, make certain that the locking pins are in the back slots of the rings, tighten the cap screws, and replace the locking wires.

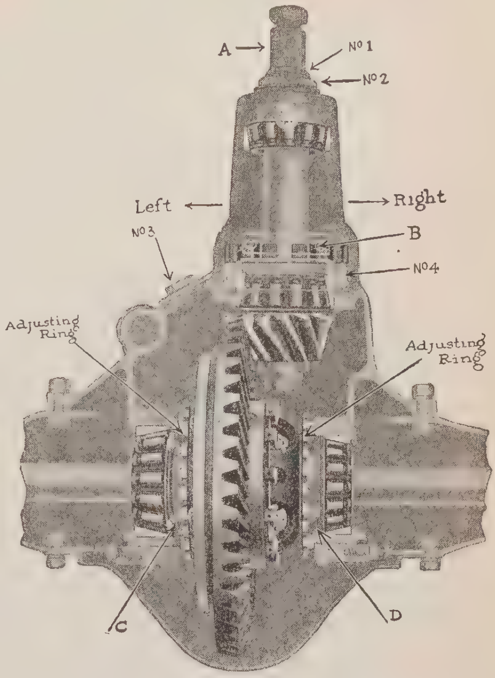


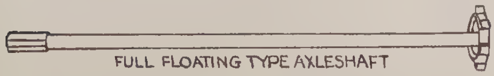
Fig. 7. Timken full-floating rear axle, as referred to in text. Model numbers are 5741, 5742, 5395, 5396, 538, and 574. Cars which formerly used this axle are as follows: McFarland (5742); Hal (5395); Daniels (5396); Dorris (5396).

3. **To take up looseness in bearings on the drive-pinion shaft,** loosen nut No. 1, tighten up nut on No. 2 enough to let the shaft run freely without end play, back off one quarter-turn, and tighten up nut No. 1. If noisy gears result, proceed as in paragraph 1. For taking up looseness in differential bearings adjust rings (C) and (D) away from the differential, after loosening the cap screws and locking the wires, as directed in paragraph 2. **Adjust each ring until the differential runs free without end play,** and if back lash results, proceed as indicated in paragraph 2.

If gears are so far out of mesh that no results can be obtained through the method described above, or if new gears have to be placed in the axle, remove the peep-hole cover No. 3 for observation, and set the gears with backs flush, as a starting-point, and proceed as above.

THE TIMKEN AXLE SHAFTS

From the differential the power is carried to the wheels by the axle shafts. They must be strong—strong enough to resist the greatest possible torsion under any conditions of travel. Yet they should be as light as is consistent with perfect safety.


FULL FLOATING TYPE AXLESHAFT

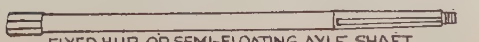

FIXED HUB OR SEMI-FLOATING AXLE SHAFT

Fig. 8

Where the shaft enters the differential it is enlarged, the end is **splined,** and steel is left back of the splines—a very important matter.

At its wheel end the shaft of the **full floating axle** is enlarged to form an integral (not welded) disk or "driving dog" (Fig. 8), which fits into the driving plate of the hub and turns the wheel (Fig. 2, page 864). In the fixed hub or **semi-floating** type of axle shaft, the wheel end is keyed (Fig. 8) to the wheel (Fig. 1, page 864).

TIMKEN ROLLER BEARINGS

The subject of bearings is treated on page 19. An explanation of the Timken roller bearing which takes a thrust or radial load is given below.

The different places on a car where roller or ball bearings are generally used are the front wheels, the transmission, the pinion drive shaft, the differential, and the rear wheels.

The parts of a Timken roller bearing are shown in illustration below (Fig. 9), and are as follows: (1) the cup or outer race; (2) the roller bearings; (3) the cone or inner race.

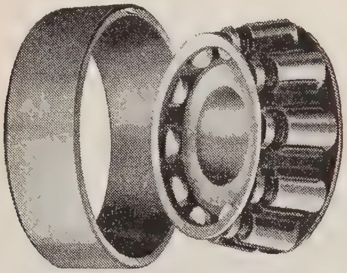


Fig. 9. **Timken tapered-cone type of roller bearing.** Used for wheel bearings, axle bearings, and different parts of the car. The part to the left is called the cup or outer race in which the rollers revolve. Note that the cone, or inner race, is the part underneath the rollers. This part fits onto the shaft and the cup fits into the bearing space.

The cone should have a **floating-fit** on all **non-rotating shafts,** such as front-wheel spindles and full-floating rear-axle sleeves.

The cones should have a **press fit** on all **rotating shafts,** such as semi-floating rear-axle drive shafts, pinion shafts, worm shafts, belt-pulley shafts, and transmission shafts; except where it is necessary to move the cone on the shaft to make adjustment, in which case the cone should have a light-press fit. (Be sure that all cones are seated firmly against the shoulders on the shafts.)

Cups: The ideal mounting for all Timken cups is a **press fit** in such mountings as wheel hubs, pinion housings, differential housings, belt pulleys, worm-shaft housings, and transmissions. Where the cup must be moved to make adjustment, it should have a **light press fit.** (Be sure that all cups are seated solidly against the shoulders in their mountings.)

On mountings where shim adjustment is used, the cups are usually pressed into a retainer or cup-holder which, when installed, is bolted to the housing with shims between the flange of the retainer and the housing. Adjustment on such mountings is made by moving the retainer farther into the housing until all end play is taken out of the bearings.

This can be done by removing the retainer and taking out one or more shims. If adjustment is made too tight, causing a bind in the bearings, one or more shims should be added.

The subject of direct mounting and indirect mounting of bearings on a worm shaft is explained under the discussion of truck rear axles (Timken), as is also the subject of how to compute the worm-gear ratio.

The adjustment and lubrication of the front and rear wheel bearings, transmission, and differential are given in the explanations of the different Timken axles and wheels in this instruction, and also in the instruction dealing with front wheels and under the truck rear-axle subject.

ADJUSTMENT OF COLUMBIA THREE-QUARTER FLOATING REAR AXLE

The Columbia rear axle, illustrated below, is the model 50,000 Columbia three-quarter floating type of rear axle, as used on passenger cars weighing 3,200 to 4,000 lbs., equipped for road service. Some of the cars using this axle are the Cole, King, Premier, National, Du Pont, Kenworthy, and Ogren.

To remove axle shafts: Unscrew the six acorn nuts on the axle flange and pull out the shafts (Fig. 10).

To remove the differential assembly: Having first taken out the axle shafts, remove the ten cap screws on the face of the carrier, as indicated on **2,** Fig. 10, remove the cam brackets which extend over the face of the carrier and which come off freely after the cap screws are out, and the carrier will then fall out of the housing. All brake connections may remain intact during this operation.

To adjust drive pinion bearings: This is required only when the drive pinion shaft is loose, that is, when you can move the drive pinion shaft forward or backward. This can be determined by prying between lock nuts and carrier (Fig. 10). This adjustment is made with the two nuts (Fig. 10) where it reads: "Never loosen these two nuts unless end-play has developed."

To adjust drive pinion: Remove the locking plate (2, Fig. 10) on the neck of the carrier, held in position by two screws and lock washers, loosening the locking bolt next to this plate which clamps the pinion adjuster in the neck of the carrier. Insert a flat tool, usually a blunt screwdriver, into the notches on the pinion adjustment and turn either to right or left as you wish the pinion closer to or farther away from the ring or master gear.

Turn the pinion adjustment to the right, if you desire to move the drive pinion forward (toward front of vehicle), or to the left, if you desire to move the drive pinion backwards and thus bring the back faces of the drive pinion and ring gear to proper position. Move the adjustment only one or two notches (not complete turns) in one direction or the other until the quietest running position has been secured. Replace the locking plate and tighten the locking bolt.

Adjustment for noise: Put the pinion closer for "drive noise," and farther away for "coasting noise," see "Gear Contact."

To adjust ring gear: Do not make this adjustment unless absolutely necessary and after having tried the other adjustments. The thrust of the drive pinion always forces the ring gear toward the **left** rear wheel (left as when seated in car); consequently the adjustment is usually towards the **right-hand** rear wheel in practically every case, owing to excess wear on the left-hand differential bearing. This adjustment is made by turning the left-hand differential bearing adjustment (**A**) (Fig. 10). Sometimes the adjustment may have to be made on the right-hand adjustment (**A**) (Fig. 10); this should not be done however, unless you can pry against the ring gear and it shows a slight end play toward the right.

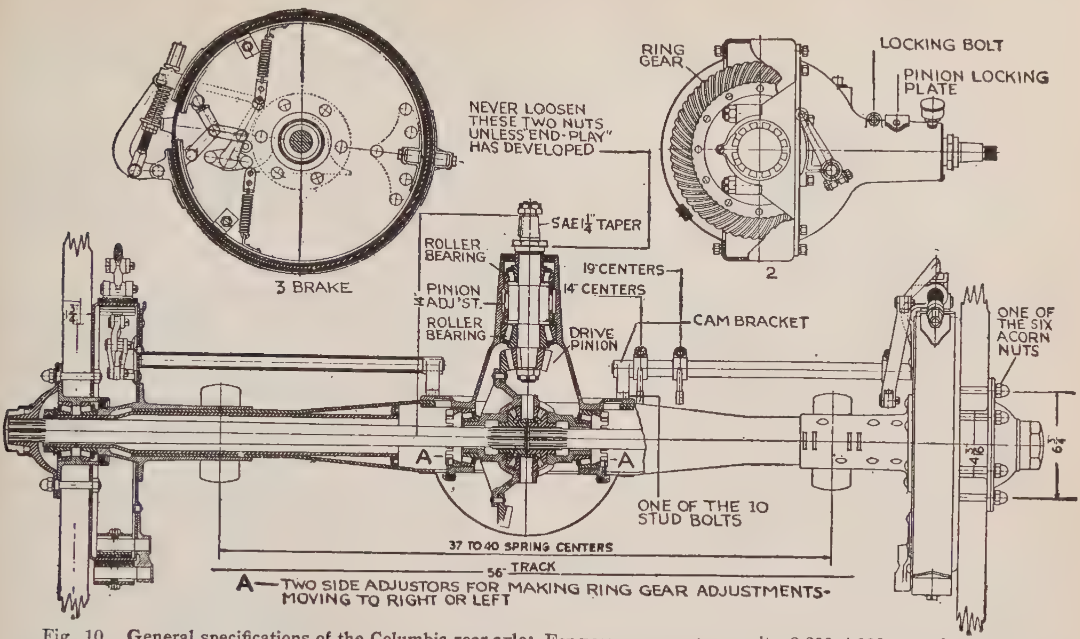


Fig. 10. **General specifications of the Columbia rear axle:** For passenger cars: capacity 3,200–4,000 pounds, equipped for road without passengers; three-quarter floating type; one-piece rear-axle housing, with full-length reinforcing tubes; heavy-duty tapered roller bearings; alloy steel spiral bevel gears, case hardened and heat treated; adjustment provided for pinion and differential; alloy steel pinion shaft and drive shafts scientifically heat treated; sixteen-inch adjustable internal and external brakes. See page 891 for description of the brakes. **Lubrication:** Use Whitmore's No. 9 in summer and Whitmore's No. 33 in winter, or Mobiloil "C," or Polarine "A," or Enarco medium.

Note. To reach the differential bearing adjusters (**A**) (Fig. 10), it is first necessary to remove the locking wires and to loosen two cap screws and remove the caps (not shown in the illustration).

If it has been finally determined that the ring gear must be moved to secure proper gear contact, the whole assembly must be moved, by releasing the adjuster locks on each side and then backing off one of the adjusters (A) a notch or two in the direction you wish to move the ring gear, following this by screwing **in** (toward the ring gear) on the adjuster (**A**) on the **opposite** bearing. Thus you are moving the whole assembly and maintaining the bearing adjustment.

The differential ring gear is always placed on the left side of the differential (left side as when seated in the car), because the crank shaft and propeller shaft revolve clockwise, and thus drive the rear wheels forward. See Fig. 10, and also Fig. 3, page 6. Owing to this fact, the thrust is always to the left side of the differential, and thus there is more wear on the left bearing.

BEVEL GEAR CONTACT

Proper gear contact and properly lubricated gears will assure the efficient transmission of the engine's power to the rear driving wheels, providing that the differential and pinion bearings are performing their functions properly.

In order to understand more clearly the meaning of **"gear contact,"** the following terms are illustrated and described.

Terms Used in Describing Gear Contact

Pitch line: A line drawn near the middle of the tooth (see Fig. 11).

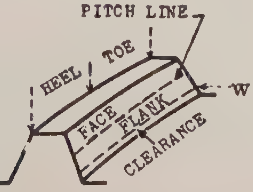


Fig. 11. Descriptive terms as used in connection with gear teeth.

Working depth: That part of a tooth which is opposite the end of the tooth with which it meshes, see (W) (Figs. 12 and 11).

Clearance: The distance from the working depth to the bottom of the tooth (see Figs. 12 and 11).

Face: That part of a tooth which lies between the pitch line and the end of the tooth (see Fig. 11).

Flank: That part of a tooth which lies between the pitch line and the working depth (see Fig. 11).

Toe: The inside or smaller half of a tooth (see Fig. 11).

Heel: The outside or larger half of a tooth (see Fig. 11).

Backlash: The difference between the thickness of a tooth and the space into which it meshes (the play) (Fig. 12).

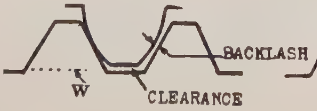


Fig. 12

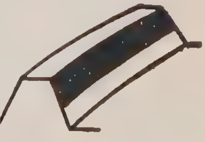


Fig. 13

Fig. 12. Explanation of backlash, clearance, and working depth (W).

Fig. 13. Full-face contact (shown in black).

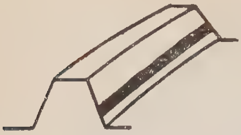


Fig. 14

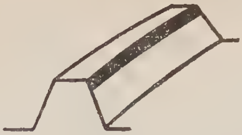


Fig. 15

Fig. 14. **Flank contact** (shown in black).
Fig. 15. **Partial face contact** (shown in black).

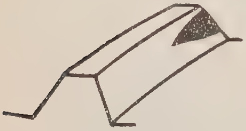


Fig. 16

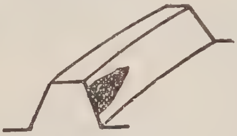


Fig. 17

Fig. 16. **Toe contact** (shown in black).
Fig. 17. **Heel contact** (shown in black).

Gear Contact as Applied to Columbia Rear-Axle Gears[1]

The complete driving assembly is adjusted, locked and tested at the Columbia plant, then tested and readjusted if necessary by the manufacturer, under the vehicle; consequently it is not often necessary for the user to adjust any of these parts, except possibly the bearings.

The pinion shaft and gear revolve in a fixed carrier and may only be moved directly forward or backward. The **ring gear** also revolves in the same fixed carrier and may only be moved directly toward one rear wheel or the other. The **bearings** hold these parts from moving in other directions, consequently, proper **gear contact** may be secured by moving the pinion or ring gear in the proper directions, as the axis of each should remain fixed.

Familiarize yourself with the names of the gear-tooth faces (Fig. 11), so that you may understand the other illustrations (Figs. 12 to 17).

Backlash: All contacting gears must have a certain amount of play or space between the teeth, that is, the tooth of one gear must never entirely fill the space between two teeth of the mating gears (see Fig. 12). This avoids excess wear, breakage, noise, or decreased efficiency. Too much "backlash" is just as destructive as too little. The practical limits of "backlash" to which gear manufacturers work are .005″ minimum to .015″ maximum (five to fifteen one-thousandths of an inch). There may be slight variations from these figures.

The desired gear contact under load is a full-face contact along the entire length of each contacting tooth (see Fig. 13). If the gear cutting, heat-treating, and mounting has been perfect, the proper "backlash" is shown when gear teeth show good contact—running from 75 per cent to full-face contact of tooth.

Flank contact (Fig. 14) is caused by the pinion gear being **adjusted too far back** (toward the rear of the vehicle). This condition often **decreases** the "backlash" and usually causes a grinding noise.

Partial face contact (Fig. 15) is caused by the pinion gear being **adjusted too far forward** (toward the front of the vehicle). This condition **increases** the "backlash" and may cause tooth chipping.

Toe contact (Fig. 16) is caused by moving the ring gear **too far toward the right** rear wheel. This also **decreases** the "backlash," and may cause tooth chipping or breakage.

Heel contact (Fig. 17) is caused by moving the ring gear **too far toward the left** rear wheel and **increasing** the "backlash" to undesirable limits.

Never adjust gears until you know the existing tooth contact. To determine this, remove the rear cover plate and thoroughly clean the pinion and ring gear of oil. Mix powdered red lead with light oil to the consistency of paste and paint a number of the teeth on the ring gear.

Jack up the car (both wheels) and run in high gear for a few minutes, then throw into reverse and run for a minute or so, applying the brakes at intervals to make **close** tooth contact, then examine the teeth on the ring gear and the paint will clearly show the tooth contact existing.

Then remove the inspection **plug (oil-filler plug)** and actually view the contact when possible, by throwing light on the pinion gear while the cover plate is removed. If not correct, cautiously proceed to adjust the pinion gear or ring gear, as previously explained.

ADJUSTMENT OF SALISBURY REAR AXLE; THREE-QUARTER FLOATING TYPE

The trade name or term applied to this construction would be "Pressed Steel Type," and is **three-quarter floating** in design.

To remove the axle shafts: This can be accomplished without the use of the jack, as the full weight of the car can still be left on the wheels, or with the axle shafts removed, since there is no possibility for the wheels to come off. Remove the wheel-drive flange (F) (Fig. 18) by unscrewing nuts (N). The flange with the axle shaft can then be pulled out.

To remove the wheel for any purpose, such as for replacing the wheel bearing, this can be done after the flange and axle shaft are removed. The wheel, with the hub and bearing, is held in place on the axle tube by lock nuts and washers. With these removed, the wheel with hub and bearing can be pulled off.

To remove the bearing from the hub, first remove the spring wire, and the bearing lock nut can then be unscrewed and the bearing removed.

The differential gear carrier (Fig. 19) **as a unit can be removed from the axle proper,** after first disconnecting the propeller shaft and universal joint, by removing the carrier screws which bolt it to the housing. First, however, the axle shafts must be pulled out.

In order that the spiral bevel ring gear (G) (Fig. 18) **and drive pinion (P)** may operate correctly, they must be in perfect alignment, that is, the differential axis must be in the same plane as the pinion axis; at the same time there must be a correct amount of back lash between the pinion and the gear. To that end two means of adjustment are provided.

The differential on which the ring gear (G) (Fig. 18) **is mounted may be moved toward either side,** as required, by turning one of the adjusting nuts (A) to the left, and turning the other to the right an

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[1] From Columbia Axle Co.'s Service Manual, by permission. Copyrighted, 1922.

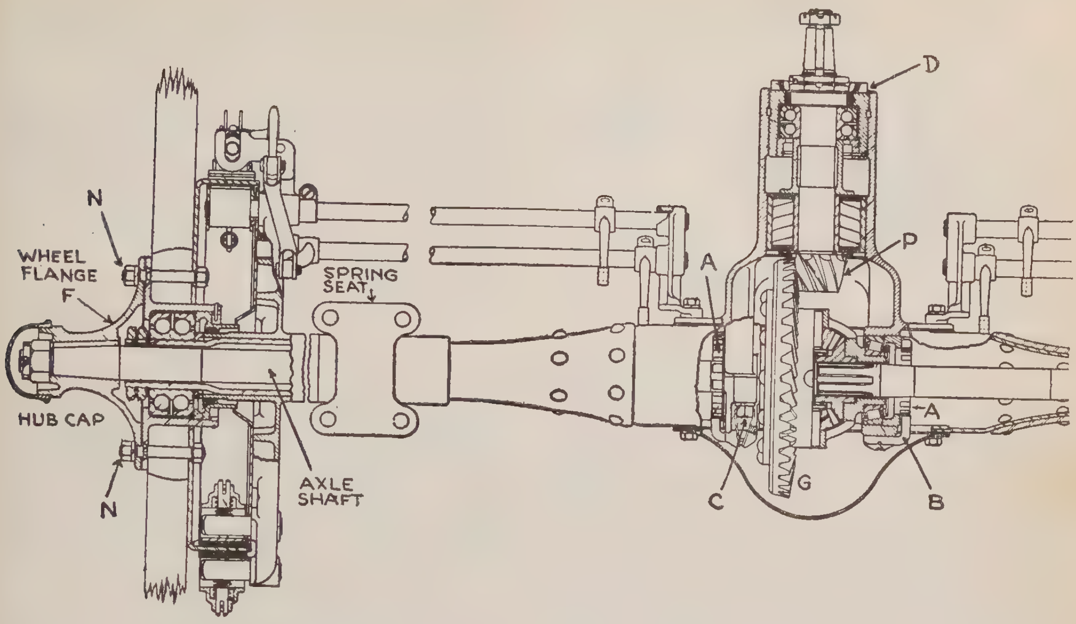

Fig. 18. Salisbury rear axle; three-quarter floating type.

equal amount, after the locking fingers (B) have been removed, and the screws (C) in the bearing caps have been loosened.

The drive pinion (P) may be moved forward or backward by turning the adjusting sleeve (D) in which the pinion shaft is mounted. Moving the pinion-shaft adjusting sleeve or the differential adjusting rings one notch is equivalent to approximately four one-thousandths (.004″) inch at the point of contact between the pinion and ring gear.

The amount of back lash necessary to insure quietness of action is ordinarily between ten one-thousandths (.010″) and twenty one-thousandths (.020″) of an inch, depending upon the cut of the gears and the variation which takes place in their manufacture. The proper amount of back lash or clearance should be arrived at, however, only after it is known that the ends of the teeth on the pinion are flush with either the inner or outer ends of the teeth on the ring gear.

To arrive at the proper running position of these gears, in order that their teeth may have a full line contact and at the same time operate with quietness, see explanation given on pages 870, 874.

Brakes on Salisbury Rear Axle

There are four points of adjustment on each set of brakes (Fig. 20). The adjusting screws (E) and (H) are the means of providing the proper **clearance at the rear of the internal and external bands** when released, and should be adjusted to allow an opening between the brake drum and the linings on the brake bands of not more than 1/32″.

The adjusting nuts (K) which control the setting of the **lower halves of the external bands** are next to receive attention in the proper order of adjustment. The jam nuts must be loosened and the adjusting nuts regulated to give a maximum clearance of 1/32″ around the lower halves of the bands. Should the linings touch the drums at any point, as a result of their not being a true circle, a screwdriver should be inserted and the band forced away. When the adjusting nuts are properly regulated, they should be relocked by the jam nuts.

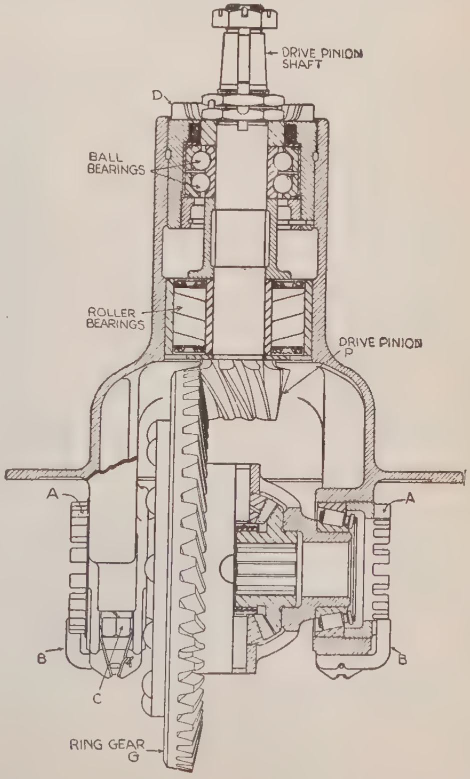

Fig. 19. Differential gear carrier unit. The words "differential gear carrier," or "gear carrier," refer to the unit in which the gears are carried. On this axle, note that the entire unit is removable.

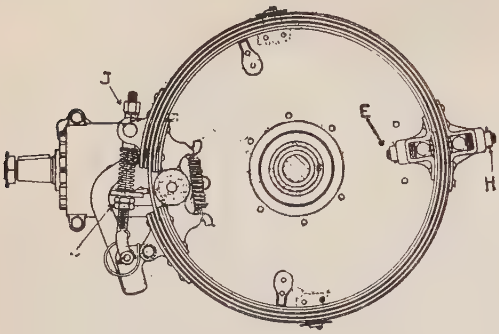

Fig. 20

The clearance between the top halves of the external bands should be regulated to a maximum of 1/16" by means of the nuts (J). This difference in clearance of 1/32" between the upper and lower halves is rendered necessary by the action of the bell cranks, which tend to tighten the upper half to the drum sooner than the lower half is tightened.

When the brakes are released, the pedal should be close to the floor board and the centers of the eyes of all levers on the cross-shafts in the frame should be from 1" to 1¼" to the rear of the shafts. The levers carried on the brake spiders should be as far back as allowable with the rods furnished, and these rods should not be shortened when the brake linings wear. This would disturb the proper setting of the brake levers and would prevent proper brake action. All adjustments should be made at the bands where the wear occurs.

ADJUSTMENTS OF THE OLDSMOBILE MODEL "47" REAR AXLE

The rear axle used on the Oldsmobile model "47" car is a three-quarter floating type, in which the differential is carried on separate bearings, and the inner ends of the axle shafts are supported by the differential side gears. The outer ends of the axle shafts are supported by the wheels which are mounted on large roller bearings and revolve on a race or bearing fastened to the axle housing. With this type of construction it will readily be seen that the drive shafts are subjected only to the driving torsion, and the bending moment imposed by the wheel on corners and uneven roads. The axle housing supports all the load of the rear end of the car.

Torsion tube and third member: The drive pinion shaft is mounted in a set of two bearings (see Fig. 21). At the pinion end is a large radial bearing, in which the shoulder of the pinion rides. This is the pinion bearing and serves to give the alignment to the shaft and pinion. A little farther up the shaft is mounted a double radial bearing which takes all thrust imposed upon the propeller shaft by the action of the pinion in the ring gear. All of these bearings and the adjusting mechanism are incased in a strong housing to which is attached a long tube entirely enclosing the propeller shaft. The tube assumes the torque imposed on the axle.

The differential assembly is mounted on two large Hyatt roller bearings, designated in Fig. 21, as (**M**). The side thrust on this bearing that is naturally set up by the wheels on uneven roads is taken up by the differential thrust bearings (**F**) and (**I**).

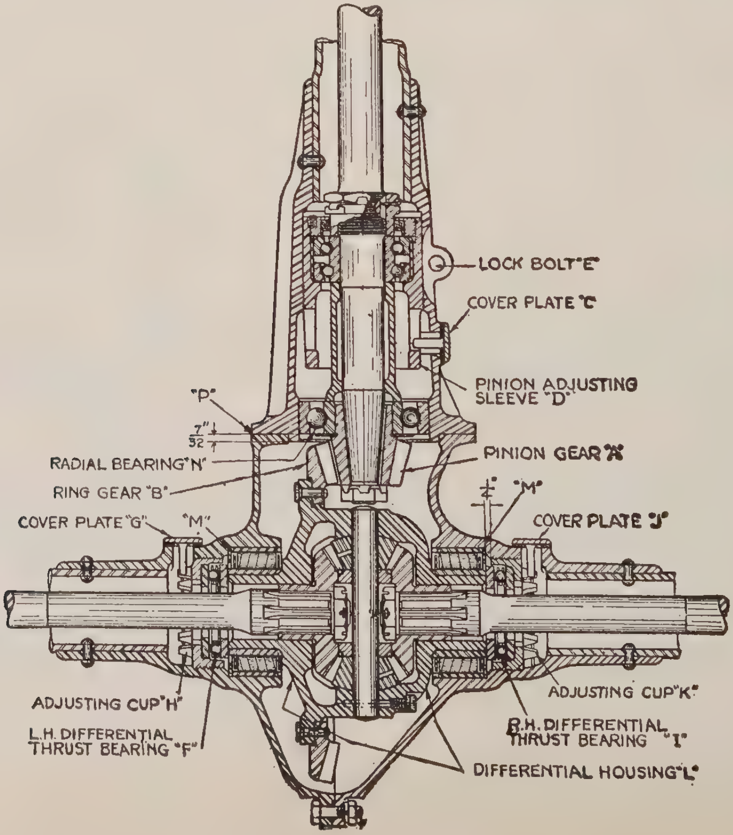

Fig. 21. Oldsmobile (model 47) rear axle

The axle shafts are driven directly by the two differential gears, through which the splined ends of the shafts pass, being securely fastened by large castle nuts and special washers. The outer ends of the shafts are tapered and keyed into the hubs of the wheels, the hubs being held from slipping off the shaft by a nut, which is held in place by a star washer, one lip of which is bent up against the nut. This star washer has a spline which fits the keyway and keeps it from turning.

Adjustment Instructions

Adjustment of axle or differential gears: First find out under what conditions the noise appears, and investigate to see whether the axle is properly filled with heavy or semi-fluid oil. The capacity is one quart up to the level of the filling or inspection plug.

1. **Noise occurs on straight pull ahead:** The difficulty generally results from the teeth of the pinion gear (A) bottoming in the ring gear (B). This may be relieved by loosening the lock bolt at (E) and then opening the cover plate at (C), in the third member housing, and turning the pinion adjusting sleeve (D) outward two notches, or more if necessary, a notch at a time. Do not touch the adjustment of the differential-bearing cup.

2. **Noise occurs on straight coast ahead:** The difficulty is generally the result of the teeth of the pinion gear (A) not meshing deep enough in the ring gear (B). This may be overcome by loosening the lock bolt at (E), and then opening cover plate at (C) in the third member housing and turning the pinion adjusting sleeve (D) inward two notches or more, if necessary, a notch at a time. Do not touch the adjustment of the differential-bearing cup.

3. **Noise occurs on turning corner to right or left:** This is generally the result of end play at the differential thrust bearing (F) or (I). Open the cover plates (G) and (J), and then loosen or back off the adjusting cup (K), four or five notches toward the outer end of axle. Then tighten or turn the adjusting cup (H) against the differential housing (L) until all back lash has been take up between the pinion (A) and the ring gear (B). Now back off or loosen cup (H) by turning out three notches toward the end of the axle. Now tighten the adjusting cup (K) by turning toward the center until it is snug, with the wheels revolving.

4. **Adjusting after installing new ring gear:** With the two halves of the axle disassembled from each other, screw both the adjusting cups (H) and (K) toward the outer end of the axle housing, or until the distance from the inner edges of the cups (H) and (K) to the 1/16″ metal stop rings (M) for the Hyatt bearing is ¼″. With the adjusting cups in this position, no difficulty will be experienced in assembling the two halves of the case with the differential and axle shafts assembled. Firmly bolt both halves together and then assemble the third member in position and tighten. The axle is now ready for adjustments as in paragraphs 1, 2, or 3. above.

5. **Installing new pinions:** In installing a new pinion gear (A) where it has not been necessary to remove the pinion shaft, leave the adjustment of the ring gear as it is, and adjust as explained above in paragraphs 1 and 2, as may be necessary, depending on whether the noise occurs on coasting or on straight pull ahead.

6. **Installing new pinion when necessary and to remove pinion shaft from third member:** Reassemble so that the rear side of the radial bearing (N) in which the pinion (A) revolves is set approximately 7/32″ from the extreme end of the shoulder on the flange of the third member. The backs or ends (see Fig. 28, page 874) of the teeth on the ring and pinion should be flush when assembled. To get this, measure from the face of the pinion-housing flange on the gear case at (P) to the bottom of the teeth at the outside diameter of ring gear (Q) (Fig. 28). Adjust the pinion so that a like dimension is obtained from the face of the pinion housing to the flange to the point of the tooth at the outside diameter (R) (Fig. 28).

Following are a number of suggestions relative to adjustments and inspection. **Read carefully.**

When axle is torn down: Inspect all bearings and parts very carefully when removed, and when reassembling use only the parts which are in good condition.

Single-row ball bearings may have a slight angular movement, or a rock as the action of a ball joint, but must not have any radial looseness or movement up and down.

Clean bearings thoroughly with gasoline, and make sure that the races and balls are in good condition and free from all foreign matter. The bearing should spin freely and quietly.

Roller bearings should be washed in gasoline, and races and rollers should be inspected for defects or foreign matter. These bearings should not have more than .003″ movement radially.

The thrust bearings at the end of the differential should also be cleaned and inspected.

The life of the gears in a way depends on the bearings, and a worn or defective part replaced is money well spent.

The gear housing must be free from all chips, dirt, etc., for a little foreign matter here will ruin the entire unit in a very short time.

When assembling, make sure that every part is in its place and securely locked.

Preliminary adjustment of gears: The backs or ends of the teeth on the ring and pinion should be flush when assembled (see Fig. 28). To get this, measure from the face of the pinion-housing flange on the gear case to the bottom of the teeth at the outside diameter of the ring gear. Adjust the pinion so that a like dimension is obtained from the face of the pinion-housing flange to the point of the tooth at the outside diameter.

Adjust the differential to the left, so that the pinion can enter freely, and then assemble the third member to the axle.

Shellac the point between the two halves of the gear housing and make sure that the faces at the pinion-flange connection are flush. If they are not, there will be a leakage of oil.

Adjustment of gears: Move the differential to the right or left, as required, to get from .005″to .008″ back lash (Fig. 31, page 874).

Through the oil-filler hole in the gear housing, paint both sides of the four teeth in the three equally spaced locations on the ring gear. Use thin white lead.

By turning the bevel gear around several times the lead will be wiped off of the gear tooth, showing where the contact or load is taken on the tooth. The contact to work for is as shown in Fig. 23 or a contact showing slightly heavier on the toe than on the heel, but over the full length on the tooth.

Fig. 24 shows a heavier contact at the heel of the tooth. This denotes too much back lash between ring and pinion, and will eventually break off the heel. To overcome this, move the differential toward the pinion, but be sure to have some back lash.

If the contact still shows heavy at the heel, change gears, as some part of the axle is out of alignment.

Fig. 25 shows a heavy contact at the toe or small end of the tooth. This is not bad, but the load should not be centered here as it will eventually break off the toe. To correct, move the differential away from the pinion, but under no circumstances should a gear be run with heavy contact at the heel resulting from too much back lash.

Fig. 27 shows contact at the top of the tooth, and Fig. 26 shows it on the flank. Either of these will cause noisy gears. To overcome, adjust the pinion toward the center line of the axle for Fig. 27, to get full-depth contact, as shown in Fig. 23. Noise almost always can be eliminated by the adjustment of the pinion.

Testing after Adjusting the Mesh of Gears

After this has been accomplished, install the axle under the car, connect to power plant, and, with wheels off the floor, start the engine. Apply the brakes slightly, adjusting these so that there is an equal amount of friction at both wheels. Watch the tooth contact through the filler hole in the gear housing. If correct results have not been obtained, paint the gears again and readjust the gears as mentioned previously. The car may be run not to exceed one mile without oil as a check on the adjustment.

If further adjustment is necessary, it should be made, as the gears must have contact over the full length of the tooth to carry the load. Oil will not deaden the noise, but is a lubricant.

Gear Contact as Explained in the Oldsmobile Instruction Book

The following illustrations and legends will make clear the meaning of terms used in connection with these explanations.

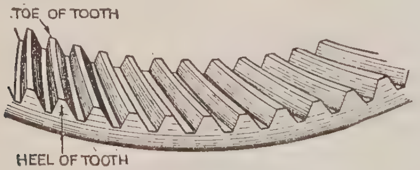

Fig. 22. Section of spiral-tooth ring gear.

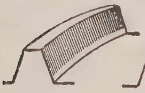

Fig. 23

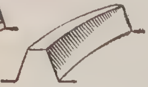

Fig. 24

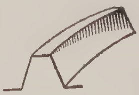

Fig. 25

Fig. 23. Shows correct contact. Gears set up this way give best results for noise and wear.

Fig. 24. Shows heavy contact on heel of tooth. Gears set up this way will eventually break off at the heel. To correct, move the ring gear toward the pinion, but make sure that there is back lash, as gears cannot run tight.

Fig. 25. Shows heavy contact on toe of tooth. Gears set up this way will eventually break off at the toe. To correct, move the ring gear away from the pinion.

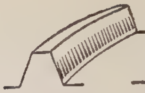

Fig. 26

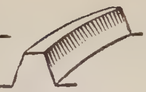

Fig. 27

Fig. 26. Shows heavy contact on the flank of the gear tooth. Gears set up in this way are noisy. To correct, pull the pinion out until contact comes to the full working depth of the gear tooth without leaving the lowest point of contact. See Fig. 23.

Fig. 27. Shows heavy contact on face of gear tooth. Gears set up in this way are also noisy. To correct, move the pinion in until the contact reaches the lowest point on the gear tooth. See Fig. 23.

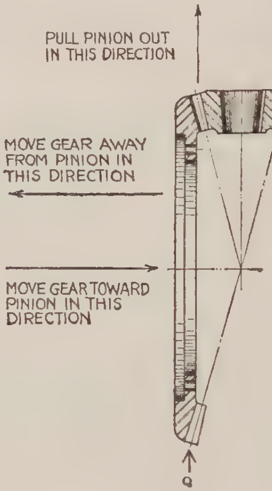
PULL PINION OUT IN THIS DIRECTION
MOVE PINION IN TOWARDS GEAR IN THIS DIRECTION
"R"
MOVE GEAR AWAY FROM PINION IN THIS DIRECTION
MOVE GEAR TOWARD PINION IN THIS DIRECTION
Q

Fig. 28

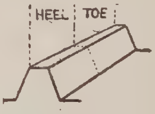

Fig. 29

Fig. 28. See text for explanation.

Fig. 29. The heel of the gear tooth is the large end, and the toe is the small end.

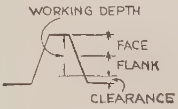

Fig. 30

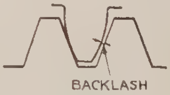

Fig. 31

Fig. 30. Showing the working depth, face, flank, and clearance.

Fig. 31. Backlash.

Putting the Rear Axle Together (Oldsmobile "47")

When putting the axle together make an inspection of the following points:

1. **Before the ring gear is mounted on the differential,** inspect the ring-gear seat of the differential case to determine whether it runs true with the bearing hubs. If it runs out more than .002", face it off in a lathe to make it run true.
2. **When riveting ring gear on the case,** make certain that it is riveted tight. Ring gear should not run out more than .008", using the bearing hubs of the differentials as centers.
3. **When driving the pinion on the shaft,** see to it that it does not ride the key; also that it is driven on tight. The pinion must not run out more than .004" on the shaft.
4. **Inspect all bearings for wear:** Bearings which are pitted or chipped should be replaced by new ones. Ball bearings and straight roller bearings should not have more than .003" play between the inner and outer races.

5. **Outer races of bearings must be a snug fit in bearing holes,** and the inner races must also be a tight fit on the shafts or differential hubs.
6. **Make sure that all parts which go on the inside of the gear housing are thoroughly cleaned.** Any chips, grit, or other hard substances grind out the bearings and gears very quickly.
7. **All studs and nuts must be a good fit in the threads** so as to hold the gears and bearings in place. If these are loose, they will let the gears vibrate.
8. **When all the parts mentioned above are looked after,** assemble the parts in the axle.

   Paint four teeth on the ring gear in three different places, with a thin coat of white lead, and start to adjust the gears until all paint is wiped off of the portions shown shaded in Fig. 23. Wherever the paint is wiped off is where the contact occurs.
9. **After the axle is adjusted:** Put it under the car and jack up the rear wheels; paint the teeth of the ring gear again, which can be done through the oil-level hole; apply the brake load while running the car jacked up in this manner, and note where contact occurs. If it changes much from what it was when assembled, it shows that there is looseness in the axle, and it must be corrected.
10. **After all this is done,** the car may be taken out for a one-mile test without grease in the axle housing, except on the bearings, which should be packed when assembled. This will tell what can be expected as far as noise is concerned. Grease will not deaden the noise very much, it only acts as a lubricant. If you find it advisable to make further adjustments to make the axle quieter, before filling up the case with oil and turning the car over to a customer, paint the gears up again and make certain that you have contact as illustrated in Fig. 23.

   Full tooth contact is required to carry the load.

Unless there is something radically wrong with the rear axle, it need not be taken apart. However, if the gears are worn or damaged they should be replaced. In the majority of cases the only work necessary on the rear axle consists of replacing the lubricant and adjusting the gears.

ADJUSTMENTS OF STUDEBAKER "LIGHT SIX" REAR AXLE

The rear axle consists of a bevel-drive pinion, and ring gear, differential gears, and rear-axle shafts, all of which are enclosed in an oil-tight case. The rest of the rear axle is made up of rear wheels, bearings, brakes, and tires.

The rear axle is of the semi-floating type. Axle shafts are provided with end-thrust adjustments (in case of wear on the bearings) located at each end of the axle housing (Fig. 32). Note that at the inner end of each axle shaft is a hardened steel thrust-button. This serves to prevent wear on the axle shaft at this point, and also minimizes adjustment of the bearings.

To remove end play: Any excessive end play in the shafts may be taken care of by removing the rear wheel (in the tool kit is a puller provided for this purpose); then take out the clamp bolt (Fig. 32), and turn the adjusting nut to the right until proper adjustment is reached.

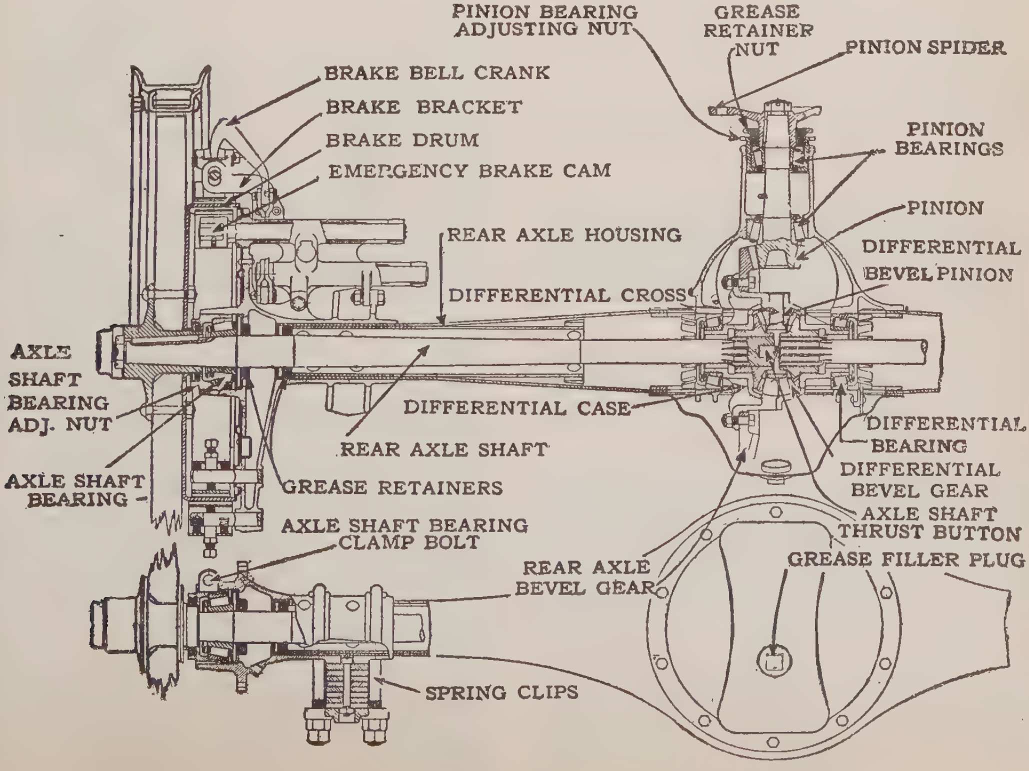

Fig. 32. Longitudinal section of Studebaker "Light Six" rear axle.

Care should be exercised to see that the same distance is maintained between the outer face of each adjusting nut and the end of the rear-axle housing. If this is not done, the rear wheels may be shifted out of line with the front wheels.

Adjusting bevel-drive pinion and ring gear: If wear develops between the bevel-drive pinion and ring gear, it will necessitate adjusting the bevel-drive gear and pinion closer together (Fig. 32). This adjustment may be made by removing the differential case cover, cleaning out all old grease, and loosening the two differential clamp nuts. The differential adjustment nuts can now be moved either out or in, whichever way the bevel gear is to be moved. When one adjusting nut is turned out, the other is turned inward the same amount. This does not affect the tightness of the Timken bearings, but simply moves the whole differential sidewise.

In reassembling parts, be sure that the bearing retainer lock is properly put in place.

The end-play adjustment of the drive pinion may be taken care of by removing the clamping bolt and retainer lock, and turning the bearing cage in a counter-clockwise direction, until proper adjustment is reached (Figs. 33 and 32).

The differential consists, essentially, of a case, made in two halves, bolted together, and a spider or cross with four arms which are clamped between the two halves of the case. A small bevel pinion runs on each of the arms of the spider and meshes with a side bevel gear carried in each half of the differential case. The case is mounted on Timken bearings and carries a bevel driving gear on its outer circumference. Axle shafts, which drive the wheels, extend through the case and fit into the side bevel gears which are bored out and splined to receive them.

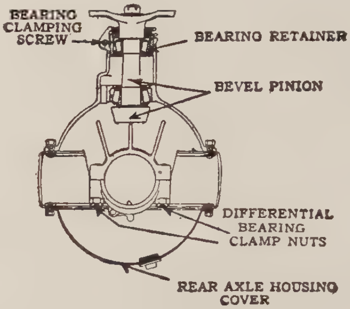

Fig. 33. Section of rear axle through pinion.

Care of differential: It is advisable, at least once a season, to clean the differential thoroughly. This can best be done by removing the cover at the rear of the housing and washing it out with gasoline. Repack with fresh lubricant (light grease or heavy oil), being careful to replace the cover with the gasket in perfect condition. It should be lubricated regularly through the plug in the cover with a good light transmission grease or a very heavy oil. Grease can be inserted through the plug hole only with a grease gun. This tool is in the regular tool kit accompanying the car.

ADJUSTMENTS OF MITCHELL MODEL "F" REAR AXLE

The Mitchell "F" rear axle is of the full-floating type and carries Timken roller bearings inside and outside.

Note: This could be termed a seven-eighths floating axle; see pages 15, 16.

Removing the rear axle from the car: Run a rope under the rear end of the frame, and with a block and tackle raise the rear end of the car clear of the ground.

The rear axle will be held up by the rear springs, so that the caps of the spring saddles on the axles can be readily removed. While the car is raised and there is plenty of room to work, disconnect the brakes by removing the clevis pins where the brake rods join the levers on the axle.

Lower the transmission as in removing it from the car, disconnecting the front universal joint (see page 862). The complete universal joint will drop with the transmission.

Lower the car until the wheels rest on the ground and the rear springs have dropped far enough so that the spring seats clear the axle. Roll the axle back on the wheels until it is in back of the spring seats, when the car should again be raised until the fenders clear the wheels and the axle can be rolled out free of the car. It is well to block the car in that position to avoid the danger of it dropping.

Disassembling the rear axle: The following instructions are for the complete disassembly of the various units which make up the rear axle. In making any specific adjustment or repair, only as much of the work as may be necessary for the job in hand should be done.

With the rear axle clear of the car, remove the transmission from the forward end of the torsion tube by taking out the eight cap screws which hold it in place. Remove the torsion tube from the rear-axle housing by taking out the eight cap screws which hold it in place. The grease retainer will remain in the torsion tube and the propeller shaft can be drawn out at the rear of the tube. It will be found convenient to mount the rear axle assembly on horses at this point.

Removing wheels: Take off the nuts holding the driving flanges to the rear wheels and pull out the flanges together with the drive shafts. Care should be taken not to tear the paper gaskets between the flanges and the wheels, as these gaskets are necessary to prevent the escape of lubricant from the wheel hubs.

If it is desired to remove the flanges from the drive shafts, the hub cap should be removed and the large nut under it taken off, together with the washer under the nut. The flanges may then be pressed off the drive shafts in an arbor press.

Removing wheel bearings: With the shafts and flanges out, the nuts on the ends of the rear-axle tubes controlling the adjustment of the wheel bearings will be exposed. Remove the nuts and tongue washers after taking out the lock springs, when the wheels complete with roller bearings, grease retainers, and brake drums can be pulled off the ends of the rear-axle tubes.

The grease retainers and bearings can then be taken out of the wheels. Unless they are worn or damaged, the bearing outer cups should not be removed from the hubs, as they are pressed in at the factory.

Removing differential: Remove the cover from the back of the differential and clean out the grease by scooping it out of the bottom of the rear-axle housing and draining the remainder off through the drain plug. Remove the lock wire holding the differential-bearing cap nuts from turning, and remove these caps together with the differential adjustment locks.

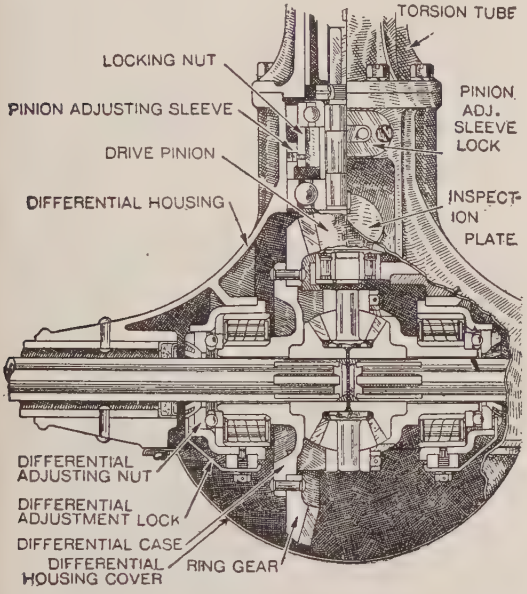

Fig. 34. Mitchell model "F" rear axle.

Back off both adjustments to give the differential end play and, cramping the differential assembly slightly to the right, so that the rivet heads will clear, lift the assembly out of the axle through the rear opening. The differential can be completely disassembled by taking out the eight cap screws holding the two parts of the split case together.

The ring gear being riveted to the differential case, it should not be removed unless it is necessary to replace the gear due to wear or breakage. In cutting off the old gear, great care must be taken not to spring the flange on the differential case to which the gear is riveted. Before mounting the new gear, swing the case between centers on a lathe and check the face of the flange to see that it runs true. If it does not, a light truing cut should be taken off the face of the flange. In riveting the new gear in place, care should again be taken not to spring the flange. To make sure, the case with the gears mounted should be again swung in a lathe and tested to see that the face of the gear runs true.

Removing drive pinion: Remove the locking plate holding the pinion adjusting sleeve in place, and screw this sleeve out through the front of the rear-axle housing. The pinion with its shaft and bearings will come out with it.

Remove the locking ring from the pinion-bearing lock nut and take off the nut and the grease retaining washer. The pinion which is integral with the pinion shaft can then be removed from the adjusting sleeve, together with the large rear bearing, and the bearing can be removed from the pinion shaft. The small roller bearing at the rear of the pinion can be removed by taking off the locking ring and sliding the bearing off the end of the shaft. Take the small front bearing out of the adjusting sleeve. The set screw holding the bearing-sleeve lock nut in place can be removed and the nut taken out of the sleeve.

Removing the rear-axle gears alone: With the axle in place under the car, the ring gear together with the differential can be removed from the rear-axle housing, as described in the foregoing instructions, after the drive shafts have been taken out.

To remove the pinion it will be necessary to drop the transmission, disconnect the torsion tube where it joins the rear-axle housing, and unscrew the pinion adjusting sleeve, together with the pinion and bearings, through the front of the torsion tube.

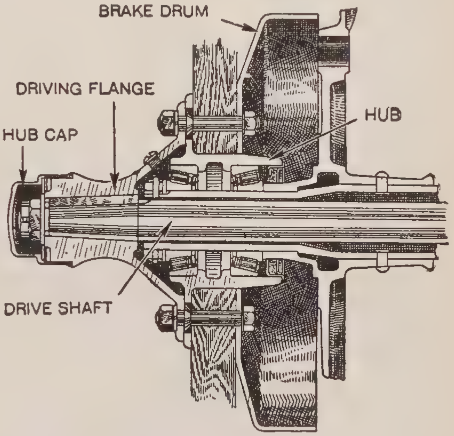

Fig. 35. Mitchell rear wheel hub showing bearings, flange, and brake drum.

Adjusting the rear-wheel bearings: Examine the two bearing cups in the hub to see that they are in good condition, and free from dirt or grit. Cover them with a thick coat of cup grease, and put the inner bearing in place.

Place the grease retainer in the hub and tap it lightly until it is driven in flush with the hub.

Place the wheel on the end of the axle tube and slide it in position, being careful to see that the brake drum is centered in the brake bands. Place the outer bearing in position, put on the lock washer, and then the nut, and draw it up until it is flush with the end of the tube. If the wheels revolve freely and there is no end play, the adjustment is correct and the nut on the end of the tube can be locked with the locking ring.

With both wheels thus mounted, put in the drive shafts and flanges, and fasten them with the nuts and lock washers to the wheel-flange bolts.

Adjusting the pinion bearings: In reassembling the drive pinion with its bearings and adjusting sleeve, put the small front bearing in the adjusting sleeve so that the projecting side of the inner race is about flush with the end of the sleeve having a thread on the outside. This face of the bearing is usually marked "Thrust Here." Screw the adjusting-sleeve lock nut in the adjusting sleeve so that it clears the small bearing by at least ¼″.

Mount the large bearing on the pinion shaft with the projecting side of the inner race toward the pinion. This surface of the bearing is usually marked "Thrust Here." Slide the tubular inner spacer on the pinion shaft following the large bearing.

Mount the pinion adjusting sleeve with the small bearing in place on the pinion shaft, followed by the grease-retaining washer and the pinion-bearing lock nut, which should be drawn down tight and locked in place with the locking ring, making sure that the adjusting-sleeve lock nut is not bearing against the small ball bearing when the pinion-shaft lock nut is tightened.

By prying through the openings in the pinion adjusting sleeve, screw the adjusting-sleeve lock nut back against the small bearing until there is no end play between the bearings, but they rotate without cramping. Lock the lock nut in place with the small set screw. This is the adjustment for taking up wear in the pinion bearings.

The small bearing on the end of the pinion shaft can then be mounted in place and locked with its locking ring.

Adjusting the driving gears: With the differential bearing caps mounted in place, the ring gear can be moved to the right or left by screwing and unscrewing the serrated adjusting nuts. The pinion is moved into mesh by turning the pinion adjusting sleeve to the left (as the operator faces the front of the car) and vice versa. The ideal adjustment is attained when the two gears mesh along the full length of the pitch line of their teeth and the back faces of the teeth are flush with just a few thousandths back lash. Before locking the adjustment it should be checked by revolving the ring gear a few times to be sure that none of the washers have moved out of place and give a false adjustment.

In general, movement of the pinion in and out of mesh causes small change in the back lash, but a large difference in the pitch-line bearing. If the pinion is out of mesh too far, the bearing of the teeth will be out toward the point of the ring-gear teeth, above the pitch line. If the pinion is too far in mesh, the teeth mesh at the root of the ring-gear teeth below the pitch line.

Movement of the ring gear in and out of mesh causes comparatively small difference in the pitch-line bearing, but causes a large change in the amount of back lash. With the ring gear **too far out of mesh,** the ring-gear tooth will bear at its outer side, showing there is too much back lash. With the ring gear **in mesh too far,** the ring-gear tooth will mesh at its inner side, showing that there is not enough back lash.

When the gears are **properly adjusted** and the adjustment is checked by rotating them, the adjustment of the pinion should be locked by mounting the locking plate, being sure that the finger on the lock goes down through one of the openings in the pinion adjusting sleeve. The ring-gear adjustment should be locked by locking the serrated adjusting nuts with the locking fingers fastened to the bearing caps with set screws.

Lubricating the Mitchell rear axle: Once every season, or every 5,000 miles of running, the lubricant in the differential should be removed and the differential should be cleaned out. Fill the differential with about three pints of semi-fluid lubricant of about the consistency of 600-W steam-engine oil. The old lubricant can be removed through the rear-axle housing cover and drained through the drain plug in the bottom, while the new lubricant can be poured in through the opening in the cover after the cover has been mounted on the rear-axle housing. At that time some lubricant should be poured in through the pinion-adjustment lock plate to lubricate the pinion bearings.

Lubrication of the Mitchell rear wheels: Once every season, or every 5,000 miles, the rear wheels should be removed from the axle, cleaned out, and packed with fresh cup grease. If grease leaks out around the brakes, it is a sign that the level of the lubricant in the differential is too high, or that the cup grease in the wheels is thinned out. In the former case some of the lubricant should be drained off, while in the latter case, fresh lubricant can be added through the plug in the driving flange.

DIFFERENTIALS: DISASSEMBLY AND ASSEMBLY

The principle of operation of a differential is explained on pages 17 and 18.

The type of differential gear in general use is the bevel-gear type with helical or spiral teeth. The differential or compensating gear assembly is shown in Fig. 36.

The differential **ring gear** (see Fig. 13, page 18, and Fig. 3 page 6) is always **placed on the left side** (when seated in the car).

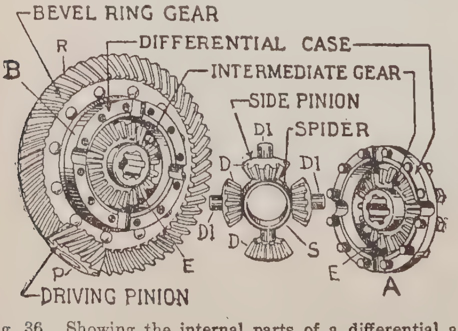

Fig. 36. Showing the **internal parts of a differential** and how the axle shafts fit into each of the intermediate gears and how part (A) is bolted to part (B). Note the pinion shafts (D1) to which the differential bevel gears (D) are fitted, and which rotate on these pinion shafts.

The bevel pinions (D) are then meshed with the two intermediate and larger bevel gears (E), the latter being connected to the axle shafts.

The drive pinion (P) is connected with the drive shaft, and the driving power is thus applied to the large ring gear through the differential housing, to the intermediate bevel gears (E), to the axle shafts, and thence to the rear wheels.

The action of the differential, or compensating gears (D) is explained on pages 17 and 18.

Note in this example and in the case of most all other differentials, that the large bevel-ring gear (R) and the drive pinion (P) are of the bevel type of gears with helical or spiral cut teeth instead of straight teeth.

When replacing a driving pinion (P) with one of a different diameter or a different number of teeth, it is always necessary to replace the driven ring gear (R) also, because the teeth will mesh too tight at either the big end of the tooth or the little end of the tooth, owing to the fact that the teeth are cut at a different angle when not mated.

When replacing drive pinion (P), it is of course necessary to remove the drive shaft on which the drive pinion is mounted.

Replacing driven-ring gear (R): Ring gears are usually riveted to the differential housing. Thus it is necessary to remove the assembly for this operation.

Either the cold or hot rivet can be used. At the factories where they have special power riveting machines, the work is done with cold rivets and in one-tenth of the time. The average blacksmith or repairman, however, will probably find it better to heat the rivets, which is often done where there is only a hammer to work with.

In placing a ring gear on a differential, one of the greatest causes of noisy gears is the fact that the differential flange to which the ring gear is attached is often out of true and should be carefully trued up before fastening the ring gear to it. See page 873 for adjusting after installing.

Removing differential. There are two types of **rear-axle housings,** the **one-piece type** (Fig. 54, page 862) and the **two-piece type** (Fig. 55, page 862). The differential can be removed from axles of the one-piece type by removing axle shafts and then removing the rear-axle housing cover plate (Figs. 53, 55, page 862). On the two-piece type, as shown in Fig. 41, page 880, and Fig. 39, page 1096, the rear-axle assembly must first be removed. See also page 863.

REMOVING THE DIFFERENTIAL (CHEVROLET "FB" AS AN EXAMPLE)

The Chevrolet model "FB" uses a semi-floating type of rear axle. Note that the axle shaft is keyed to the hub (Fig. 37) and the bearing runs between the housing and wheel hub, and not on the axle shaft.

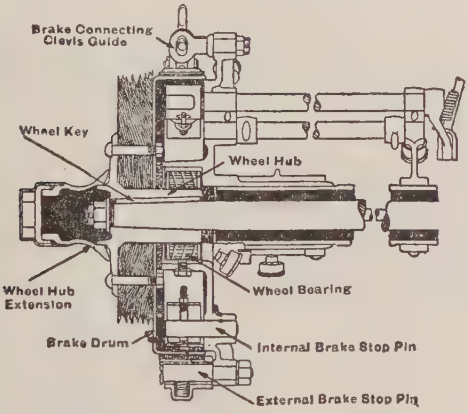

Fig. 37

To remove the differential it is first necessary to remove the various parts as explained below.

To remove the rear axle assembly: Place two jacks under the rear spring brackets and raise rear of car enough to take the weight off the springs.

Remove the clips and bolts holding the springs to the axle and disconnect the brake pull rods, which operate between the foot pedals, hand-brake lever, and rocker shaft on the propeller-shaft housing.

Disconnect the brake pull rods from the operating levers on the rear-axle housing by removing the yoke pins. **Slide the axle assembly from under the car.**

Remove the four propeller-shaft housing bolts, clamping the housing to the axle housings, and lift the assembly off (see Fig. 38).

Remove the hand hole plate shown in Figs. 38 and 39. Clamp the housing in a vise with the hand hole on top. Remove the thrust-bearing adjusting cage lock bolt.

Turn the propeller shaft so that the hole in the pinion-shaft adjusting nut is in line with the milled slots in the end of the thrust-bearing cage.

Secure a small steel pin ⅜" square and 1" long, and place it through the slots into the hole in the shaft. With a large adjustable wrench gripping the splined end of the propeller shaft, turn counterclockwise or from left to right. This will cause the thrust-bearing adjusting cage to turn with the propeller shaft. Continue to turn until the cage is free, permitting the entire assembly to be removed through the drive-gear end of the housing. Should there be any difficulty in unscrewing the cage, insert a large screwdriver into the split clamp at the point where the thrust-bearing adjusting-cage lock bolt was removed, and open the jaws of the clamp slightly.

To remove the propeller shaft, remove the small wire passing through the head of the adjusting-nut lock screw. Remove the lock screw. Unscrew the pinion-shaft adjusting nut as far as it will go. Pull out the cotter pin holding the drive-gear nut and remove the nut. Slip a flat piece of steel between the back of the drive pinion and the lower end of the propeller-shaft housing. With a lead hammer or a piece of wood held against the end of the propeller shaft, drive the pinion shaft.

The bearings and spacing washers can then be taken off the shaft. The rear wheels are keyed on the tapered ends of the axle shafts and held in place by a castle nut and cotter pin.

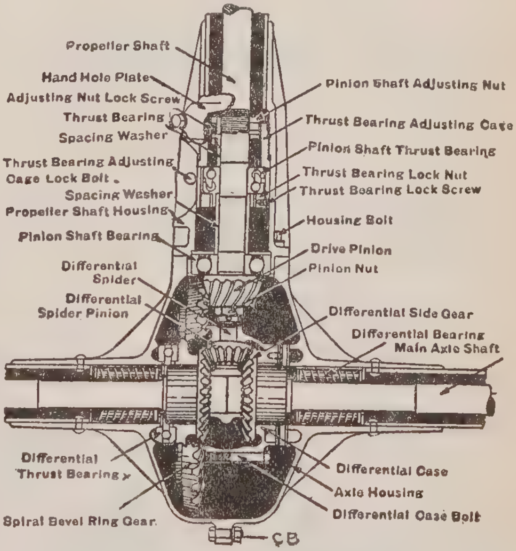

Fig. 38. Sectional view of Chevrolet model "FB" rear axle and differential and drive pinion. To lubricate, use 600W oil.

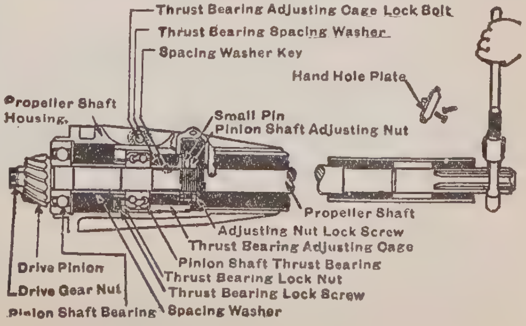

Fig. 39. Sectional view of Chevrolet "FB" propeller shaft.

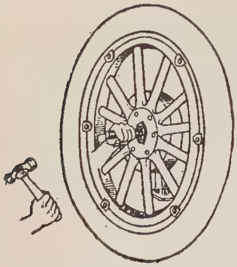

Fig. 40. Method in removing the Chevrolet rear wheel.

To remove the rear wheels, remove the hub caps. On model "FB" also remove the hub extension by using the hub cap wrench and turning counter-clockwise. Remove the cotter pin holding the nut on the shaft. Loosen the castle nut, but do not remove it entirely.

With a bar held against the castle nut, as shown in Fig. 40, deliver several sharp blows on the bar. When the wheel is free on its key remove the castle nut and the wheel can be pulled off.

The axle housings (**H**) (Fig. 41) are in two halves, right and left, held together by a number of clamping bolts (**CB**) (Fig. 38). Remove these bolts and slide the axle housing off the shafts.

In order then to remove the differential, note that the differential gear case is in two halves (**A**) and (**B**) (Fig. 41), held together by clamping bolts or screws, which when removed permit the cases to be separated.

The two parts (**A**) and (**B**) can then be separated, after which the axle shafts with the two halves can be withdrawn.

The differential gears (**E**) are keyed and pinned to the axle shafts. After removing the pins, the gears (**E**) can be pressed off the axle shafts.

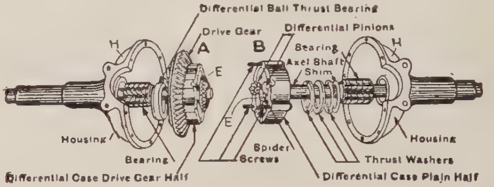

Fig. 41. Illustrating how the **differential case is divided** into two parts (**A**) and (**B**), and which parts must be separated in order to remove the differential. The axle shafts are then removed from the gears (**E**).

DISASSEMBLY AND ASSEMBLY OF A MAXWELL "25" REAR AXLE AND DIFFERENTIAL

The Maxwell "25" rear axle is a semi-floating type of axle.

Evidence of Trouble

1. **Any excessive grinding or humming** indicates that the gears are either worn, broken, or poorly adjusted.
2. An intermittent catch, occurring perhaps only every 100 miles, indicates that parts of one or several teeth are broken, and are catching in the gears.
3. Actual failure of the axle to operate. (Any of these necessitates a **removal of the axle from the car,** tearing down and replacement of defective parts, with readjustment.)

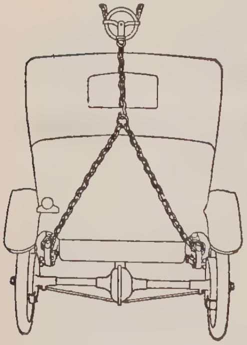

Fig. 42

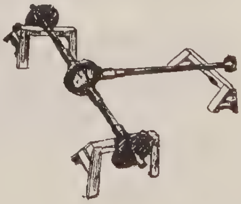

Fig. 43

Fig. 42. The car is readily lifted by a chain block and sling. One man can do the work, and the car is held without danger of falling.

Fig. 43. Three horses form a serviceable **axle stand,** though a special stand could readily be made. Never attempt to dismantle or assemble a part on the floor, but get the work up where it is accessible and clean.

To Remove Axle

1. Block the front wheels.
2. Raise the rear of the car as shown in Fig. 42.
3. Disconnect the brake rods at the point of connection to the brakes.
4. Remove the clips holding the axle to the springs.
5. Draw the axle and housing out to the rear. The drive shaft slips out from the universal, and must be caught to prevent possibility of injury to the splined end.
6. Place the axle on three horses arranged as shown in Fig. 43.
7. Remove the hub caps.
8. Remove the axle nuts.
9. Using puller shown in Fig. 44, remove wheels.

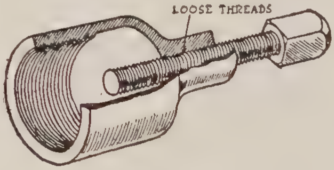

Fig. 44 (upper)

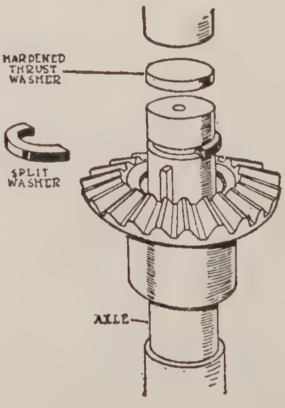

Fig. 45 (lower)

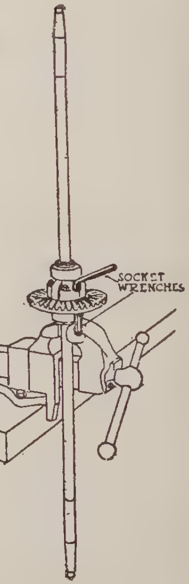

Fig. 46

Fig. 44. The feature of this **rear-wheel puller** is that the screw is hardened tool steel, loosely threaded into the cap. The end play permits a sharp blow on the screw to loosen the sticking wheel.

Fig. 45. Do not attempt to remove the **side bevel gear** from the axle drive shaft until the **split washers** have been removed in the manner shown.

Fig. 46. The differential may be most readily assembled and adjusted, if caught in the vise in this manner. Two socket wrenches are used to do the work.

10. Remove the torque tube and drive shaft. Save the gasket.
11. Catch the grease in a pail.
12. Remove the nut from one end of the axle truss rod.
13. Remove the differential-housing bolts.
14. Pull off the differential-housing halves.
15. Place the differential in a vise as shown in Fig. 46; pull the cotter pins from the bolt ends and remove the differential casing nuts, allowing the two halves to come apart.
16. Remove the split washers from the end by driving the gear down, as shown in Fig. 45.
17. Remove bearings and all parts; wash and clean with gasoline.

General Repairs

1. **After cleaning, examine all parts for wear.** Go over the gear teeth, to see if any are broken or worn. Also note whether the drive-shaft bevel gear has been wearing evenly along the teeth. The face of the teeth should be bright all over. Any breakage or perceptible wear necessitates a replacement of the gear.
2. Draw the drive shaft from the torque tube. Clean and examine the bearings.
3. If the axle has been disabled by a collision, the shaft should be caught between lathe centers, tested, and trued up, if bent.
4. If any serious bend is found in either of the shafts, the two halves of the rear-axle housing should be bolted together, tested for alignment in the lathe, and straightened.
5. When the large ring gear on the differential must be replaced, its bearing on the differential casing should be trued up in the lathe, as shown in Fig 47.

The Reassembly

1. Replace the shaft bearings, differential housing halves, and shaft gears, making certain that the split washers are in place.
2. Replace the differential cross-gears on the differential cross and holding shaft in a vise, as shown in Fig. 46, and bolt the halves together. (Be certain that the thrust washer is in place between the ends of the shafts.)
3. When the halves are bolted together, there should be about 1/64″ end play between the two halves of the shaft. If they are tight, take the differential apart and file a little from the end of each shaft.
4. Rebolt the halves, and holding as shown in Fig. 48, turn the two shafts in opposite directions. The axles should turn easily all the way around.

   Note. If sticking is noted in any place, catch the assembly in a vise, as shown in Fig. 46, and with the tang of a file, find by feeling which cross-gear is causing the sticking. If new cross-gears have been installed, try changing the sticking gear for a new one from stock. (Or if new side gears have been installed, try changing the side gear.)
5. Replace the cotter pins in the differential casing. Clip the ends over, away from the cross-gears.
6. Using horses as shown in Fig. 43, slip the halves of the rear-axle casing in place, after packing all bearing and gears with non-fluid oil.

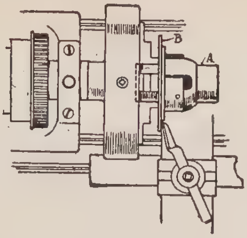

Fig. 47

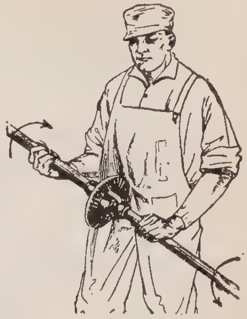

Fig. 48

Fig. 47. Breakage of the ring gear usually springs the **differential housing flange.** By catching the entire housing in the lathe and **trueing it up** by the surface (**A**), the ring gear seat (**B**) may be refaced with a light cut.

Fig. 48. In **testing the adjustment of the differential gears,** grasp the assembly in this manner, and turn the axles in opposite directions. They should turn freely all around.

7. Bolt the halves together. (Do not pull one nut up tight until the others are snug.)
8. Now get the torque tube and drive shaft ready for assembly. The shaft should turn freely in the housing. All bearings should be packed in grease.

   Note. If a new drive-shaft pinion has been fitted, make certain that the bent ends of the cotter pin in the end of the drive shaft do not interfere with the thrust bushing (see Fig. 49).

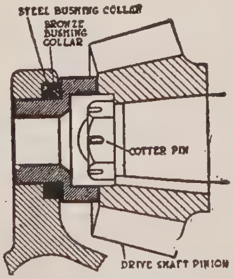

Fig. 49. The cotter pin in the drive-shaft pinion lock nut should not interfere with the **thrust bushing,** and the bushing collars should be inserted in the manner shown.

9. Fill the axle housing with a good grade of non-fluid oil until the ring gear dips well into the oil.
10. Place first the bronze washer on to the drive-pinion thrust bushing, then the steel washer, and insert the bushing into the rear-axle housing.
11. Replace the torque-tube gasket and slip the torque tube and drive shaft into the axle. Bolt in place.
12. When all bolts are tight, the drive shaft should turn freely under the action of a pipe wrench. If any sticking is noticed, additional gaskets should be placed between the torque tube and the axle. If any slack exists in the gears, the gasket should be replaced by one made of thinner paper.
13. Make certain that the brake levers work freely. Oil well. Note whether the brake bands are wearing evenly and are in good condition. Reline, if necessary.

14. Replace the wheels. Fill the hub caps with medium cup grease.

    (Note. It is always advisable to grease the rear springs with graphite and grease at this point.)

15. Roll the axle beneath the car and, with one man guiding the drive shaft, slip it into the universal. The splines may not line up at first, and hence it may be necessary to crank the engine slowly by hand until the two slide together.

16. Let the car down on to the axle; bolt the spring shackles to the axle; reconnect the brake levers.

    (Note. For the first 200 miles, at least, fill and screw down the grease cups two or three times, to make certain that all bearings have an abundance of grease.)

The points on the differential assembly that should be particularly watched are indicated on the illustration to the right (Fig. 50). (*Motor World.*)

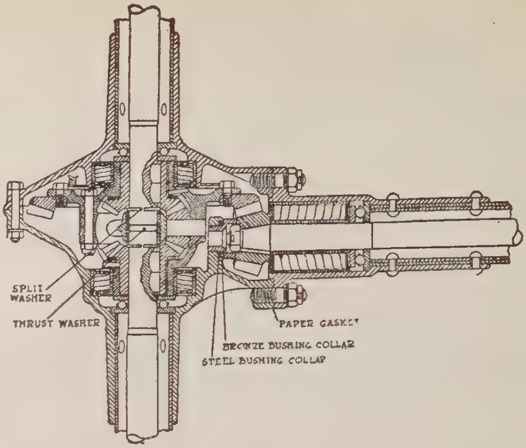

Fig. 50

THE POWRLOK OR "M AND S" DIFFERENTIAL

With an ordinary differential as shown on page 18, when one rear wheel gets into a soft spot it will turn or spin. With this differential, nothing of the kind happens because the angle of the worms (D) and (M) is such that, while the side gears on axle shafts (A) and (B) can drive the worms, the **worms cannot drive the gears on axle shafts** (A) and (B). As a consequence, the differential is locked, or the axle is like a solid axle, so far as the movement of the wheel in relation to the differential is concerned.

When both wheels are firm on the ground and can travel freely, the differential is enabled to act in the usual manner when turning corners, etc., by reason of the fact that the **gears on the axle shaft (A) and (B) can drive the worms.**

This device (Fig. 51) prevents skidding to a great extent and insures positive traction at all times.

(Mfd. by the Powrlok Co., Cleveland, Ohio.)

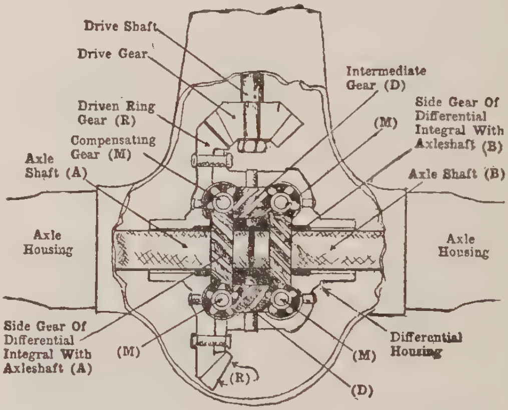

Fig. 51

OIL LEAKAGE FROM REAR AXLE; ADJUSTING FRANKLIN REAR AXLE

Preventing the grease or oil in the differential housing from making its way to the brake bands and thus causing inefficient braking was a big problem to manufacturers some years ago, but the difficulty has been overcome largely in all the present types. In all the axle housings on the market, some precaution is taken to prevent this leaking, usually, by means of a **felt washer,** termed an "oil retainer" or "grease retainer," and in nine cases out of ten when a leak occurs despite this, the condition is caused by **placing too much oil or grease** in the housing, or by **using too light** a grade of oil. Some axles use a heavy oil and others a light grease.

Methods of preventing oil leakage can be observed by referring to the various illustrations of rear axles. Note felt washers in rear axles on pages 883, 877, 875, 871, 869, 864, 858.

As an example of a method of preventing oil leakage, the Franklin rear-axle system will be used.

The Franklin series "9-B" has a semi-floating axle. Adjustments are possible on the wheel bearings, bevel gear and pinion, and the differential carrying bearings. The felt washers on the axle are also taken up from time to time (Fig. 52, next page).

To take up the pinion-shaft packing, loosen the lock for the washer retainer and screw in the retainer until the packing fits snugly around the shaft. To replace the packing it is necessary to disconnect the drive line and remove the universal-joint flange.

The axle-shaft felt washer is taken up by removing the wheel with the special wheel puller. The felt washer on the inside of the wheel hub is replaced. The retainer that holds the other felt washer into the end of the axle housing can be removed by taking out the three small screws. If this felt washer shows wear, it should be replaced.

If oil comes out of the axle at the drive-pinion shaft or at the wheels, examine the level of oil in the gear case. This should be within 2″ of the filler hole. Examine also the packing on the pinion shaft and the felt washers on the axle shafts. **600-W oil is used in rear-axle differential case of Franklin.**

Bearing and Pinion Adjustment

The bearings for the rear-axle drive shaft should be adjusted so that there is very little rock or play. The fact that the rock is perceptible is not necessarily an indication that the wheels are too loose. To adjust the bearings, screw their retainers up tight and then loosen them two notches each. See that each axle shaft extends the same distance from the housing. Take the measurements for this from the faces of the bearings to the ends of the axle housing. When the adjustment is completed, see that the bearing-retainer locking device is securely screwed into position.

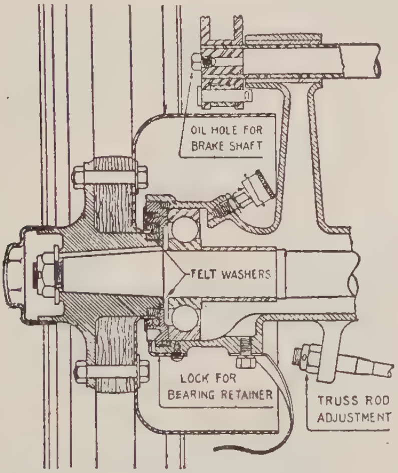

Fig. 52. Sectional view of the Franklin model "9B" rear wheel, showing the location of the felt washers.

The bevel gears on the Franklin are positively adjusted by shims. There are no screw adjustments except the one that takes up bearing wear on the pinion shaft (Fig. 53).

To mesh the pinion deeper into the bevel-drive gear, withdraw the pinion unit and remove one of the thin shims between the pinion housing and the rear-axle housing. The meshing of the gear and pinion may be inspected through the large plug hole in the left front side of the gear case. The edges of the gear teeth should be approximately flush.

To move the bevel gear sideways, take out the drive shafts and the bevel-gear unit, after which the unit can be shimmed in the necessary direction.

Pinion-Shaft End Play

If the bearings of the drive-pinion unit permit the pinion shaft to have end play, the axle is prone to become noisy, particularly when the brake is applied and when the car is coasting. To take up this end play, disconnect the rear universal joint and take off its flange. Then remove the housing, and after loosening the lock nut, make the adjustment with the nut. These bearings are very sensitive to adjustment and must not be made too tight. This adjustment is sometimes more easily made if the pinion unit is taken out and put in a vise.

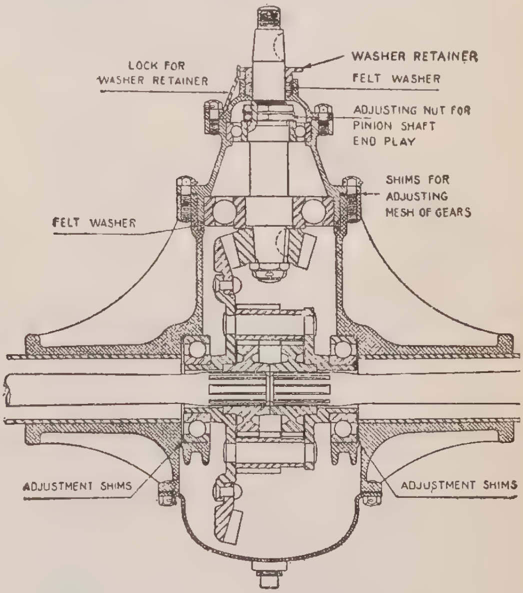

Fig. 53. Sectional view of the Franklin model "9B" rear axle, showing the points of adjustment.

Truss-Rod Adjustment

The truss rod under the gear case should be examined every 1,000 miles, and should be adjusted so that it sounds taut when struck. Keep it adjusted this way, but avoid pulling it up too tight, as the strain is likely to cause the gear case to leak oil.

The wheel-hub bolts should be tightened after the first 1,000 miles of running, and after that can be tightened every 5,000 miles. (*Motor World.*)

TIMKEN-DETROIT REAR WHEELS WITH OIL SEALS

Later types of semi-floating or "fixed hub" types of rear wheels than those shown on page 864, are Fig. 54 which has a single bearing, and Fig. 55 which has two bearings. The numbers are 5014, 5140, 5142, and 5143.

A feature of these types is the hydraulic compression cup leather (Q) which, when properly assembled, is absolutely oil-tight. The oil seal is also used on the Timken rear-axle drive pinion shaft (see page 910). See also the **shim adjustments of bearings.**

To clean and lubricate (Fig. 54): **Remove wheel** from axle shaft. Remove cap screws (**H**) which hold the bearing cage (**I**) in place. Now remove the cage, carrying with it the cup (**J**). **Pull out axle shaft** (**L**) on which is pressed the roller bearing. Clean, as on page 864. Cover bearing with cup grease. Pack end of housing with grease. Replace shaft (**L**) with bearing cone and rollers and cage (**I**) carrying bearing cup.

Adjustment of bearings: Add or remove shims (**K**). Screw up (**H**) until shims (**K**) are tight and shaft turns freely when revolved with a wrench placed on nut (**N**). When this condition is attained, add one of the thinnest shims to one of the bearing cages; this will give approximately .005" end-play. Replace wheel and tighten nut (**N**), and lock with cotter pin.

When making adjustment it is advisable to remove the oil seal by removing locking washer (**P**), cup leather (**Q**), and spring (**R**).

To clean (Fig. 55): **Remove wheel** from axle shaft. Now remove cap screws (**H**) which hold the outer wheel-bearing cage (**A**) and the inner wheel-bearing cage (**B**) in place. **Pull out axle shaft** (**L**), carrying with it the bearing cages, cones, and cups. This assembly is removed in one unit. Now place the axle shaft in a vise and remove the two short cap screws (**C**). The outer cage (**A**) and the inner cage (**B**) can now be taken apart.

Adjustment of bearings: Add or subtract shims as the case may be, being careful not to get the bearings too tight. Proper adjustment is .005" loose, or the thickness of the thinnest shim. Clean as on page 864.

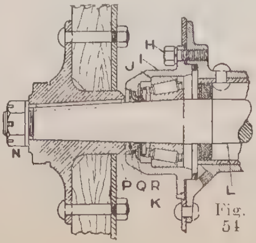

Fig. 54

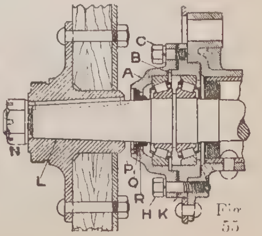

Fig. 55

INSTRUCTION No. 74

BRAKES: Types; Care and Adjustments

TYPES OF BRAKES

There are two kinds of brakes generally used on automobiles: (1) the external brake; (2) the internal brake.

The external brake is usually a contracting band brake consisting of a steel band, lined with an asbestos fabric that is placed around the circumference of the brake drum which is mounted on the rear wheel hubs, as shown in Fig. 1.

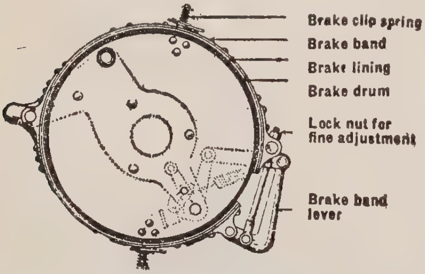

Fig. 1. The **external** contracting band brake. Note the brake-band lever which is connected with the foot pedal and draws or contracts the band around the brake drum.

The operation of the external band brake is usually by means of the brake-band lever connected with the foot-brake pedal. There are different methods employed for connecting this lever, and although the construction may vary, the principle or purpose —of contracting the band around the brake drum— is the same.

The internal brake is of two general types: (1) those using an expanding brake **shoe** (Fig. 2); (2) those using an expanding brake **band** (Fig. 3).

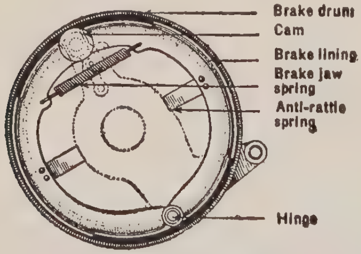

Fig. 2. An **internal** brake where metal **brake shoes** of hinged type are used. The shoe on this brake is lined with a fabric material, but sometimes we find this shoe without lining and made of metal, such as bronze. The brake shoes are caused to expand and tighten in the periphery of the brake drum by action of a **cam** connected with the hand-brake lever.

The internal brake using brake shoes (Fig. 2) can be of plain metal, such as bronze, or of metal lined with fabric, and are usually hinged.

Where metal-to-metal brakes are used, a constant and extravagant supply of oil is required to prevent excessive wear. The inconvenience and uncertainty of lubrication, together with the cost of renewing the expensive brake shoes, renders this type of brake unsatisfactory.

When the brake-shoe type is used, it is generally lined with an asbestos fabric, as shown in Fig. 2.

Operation of the internal shoe type of brake is usually by means of a **cam** which is connected with the hand-brake lever, thus expanding the shoes inside of the drum when pressure is applied.

The internal brake using an expanding brake band is shown in Fig. 3.

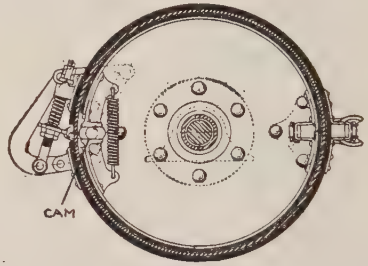

Fig. 3. An **internal** brake using an **expanding band** which is expanded inside of the brake drum by action of a **cam** connected with the hand-brake lever. Observe also that the **external** band brake on the outside of the brake drum is operated by a **lever** similar in principle to that shown in Fig. 1, but of slightly different construction.

The internal brake band is made of steel, lined with an asbestos-fabric brake lining.

Operation of this internal brake band (Fig. 3) is by means of a **cam action.** The cam is connected with the hand-brake lever, and when the lever is operated, the cam separates the two ends of the brake band, causing it to expand, thus tightening itself in the inner side of the brake drum.

Another method of operating the internal brake band is by means of a **toggle joint action** instead of a cam, as shown in Fig. 4. This method of operation is the method in general use.

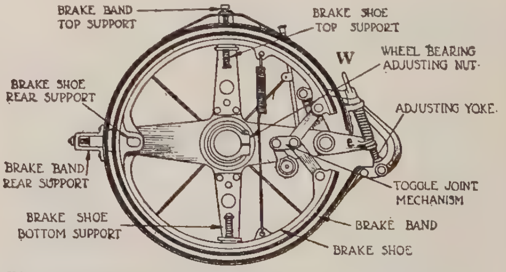

Fig. 4. Note that the **internal** brake band is operated by a **toggle joint** instead of by a cam action. Also observe that the **external** brake is of the band type, and that the lever for operating the external band is similar in principle to that shown in Figs. 2 and 3, but of slightly different construction (Dodge brake).

It will thus be observed, that **the external brake is of the contracting band** type and is operated by a **lever or fulcrum action.**

The internal brake is either a **shoe** or a **band** of the **expanding** type, and can be operated by a **cam action** or a **toggle-joint** action.

With this in mind, the classification of almost any type of brake can be determined instantly.

Brake Drums

Brake drums can be divided into two classifications: (1) the **single** brake drum; (2) the **double** brake drum.

On most makes of cars the brake drums are mounted on the inner part of the hubs of the rear wheels, and are **single brake drums.** There is usually an **internal** brake operating **inside** of the drum and the **external** brake operating on the **outside** of the brake drum.

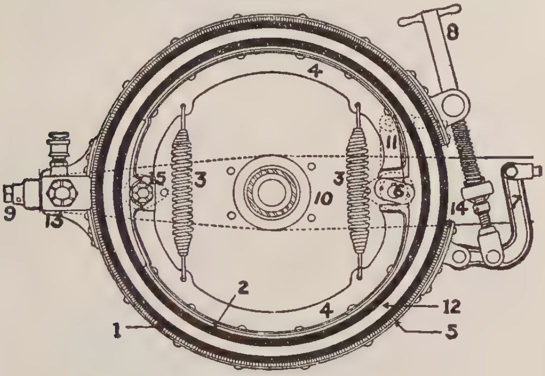

Fig. 5. The Locomobile double brake drum:

(1) Running brake drum
(2) Hand-brake drum
(3) Hand-brake shoe springs
(4) Hand-brake shoe
(5) Running brake band
(6) Hand-brake actuating cam
(7) Running brake bell lever
(8) Adjusting wrench for brake band
(9) Adjusting bolt fore and aft
(10) Distance rod
(11) Hand-brake lever
(12) Air space for cooling
(13) Running brake bracket (rear)
(14) Running brake bracket (front)
(15) Hand-brake shoe bracket

On the Locomobile, for example (Fig. 5), note that there are two brake drums, termed a "double brake drum."

The double brake drum, as stated, has two drums (1) and (2) (Fig. 5). The foot-brake lever connects with the fulcrum lever (7) attached to the contracting band (5) operating on the outside of the drum (1).

The hand-brake lever connects with lever (11) which actuates a cam (6), thus expanding the brake shoe (4) on the inner side of the drum (2).

Air space (12) between the drums keeps them comparatively cool and permits the use of one brake without the heating of the other drum.

The hand adjusting screw (8) is provided for adjustment of the foot brakes.

Mounting of brake drums: The brake drums are usually mounted on the hubs of the rear wheels.

Four-Wheel Brakes

This type has the advantage of equalizing the braking strain on the four wheels, eliminating skidding, and making possible quick stops at high speeds with a very smooth action. It also lengthens the life of tires, and the brakes are effective until the last bit of brake lining is gone. The four-wheel braking operation is usually operated on the **hydraulic, mechanical,** or on the **air** principle. The **Packard single-eight** and **Rickenbacker** use four-wheel brakes **mechanically** operated, using internal expanding shoes, cam actuated. Means are provided at base of foot brake pedal to step up the motion of the brake pedal by means of a differential type equalizer on the Rickenbacker and a planetary type on the Packard.

The Duesenberg car employs a hydraulic four-wheel brake for the foot brake, and a transmission brake for the hand brake. On this car, the brake drums on the four wheels are forgings 16″ in diameter.

In order to obtain a perfect braking surface, the drums are ground. Fins are machined on the outer edges to provide strength with lightness, and for radiating purposes. The four brakes are operated by hydraulic pressure. A master cylinder is connected to the brake pedal, and the liquid is forced through the lines running to the four wheels by a piston in the master cylinder.

By the term "hydraulic" is meant liquid pressure. One of the fundamental laws of physics is that pressure exerted by a liquid or gas, is equal and undiminished in all directions. Therefore, if we have a system of pipes all connected together and filled with a liquid, pressure exerted in any part of the system will be transmitted equally to all other points in the system. Founded on this principle, Duesenberg brakes are always equalized. Since air can be compressed and liquid cannot, we use liquid for the transmission of power or pressure.

A small cylinder in each of the four brakes has a piston which is forced upward by the liquid entering the cylinder. The piston at the brake operates a toggle arm, which in turn expands the two brake shoes in each brake. All four of these brakes are operated simultaneously by the service brake pedal. An interesting feature of the brakes is that, owing to the floating arrangement of the piston and toggle, the brakes are self-centering and consequently self-equalizing. When the brakes are applied, they provide equal pressure against the drum.

Water is used as the brake operating fluid in summer time, and an anti-freeze solution in winter.

The Christensen four-wheel air brake is used on fire apparatus and commercial trucks of large size, manufactured by the Christensen Engineering Co., Milwaukee, Wis.

LOCATION AND OPERATION OF BRAKES

Most of the cars are fitted with rear-wheel brakes, and therefore we shall confine our attention to this type.

The external brake is usually operated by a foot pedal, and is called the **foot brake.**

The internal brake is usually operated by a hand lever, and is called the **hand brake**—formerly known as the emergency brake. See pages 12 and 13.

Sometimes a brake pulley is mounted on the external part of the transmission shaft and connects with the hand lever. It is then called the **transmission or propeller-shaft brake,** but is usually operated by the **hand lever.** Therefore it would also be termed the hand brake.

The band brake is the most popular type of brake for both internal and external use.

Brake Connections

The foot-brake pedal and hand-brake lever are usually connected with the internal and external brakes in the rear-wheel brake drums by means of **rods,** and sometimes by **flexible wire cables.**

Brake Rods

Examples of how the connections are made with **brake rods** are shown in Figs. 6 and 7.

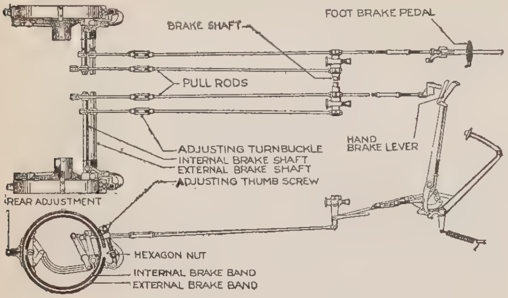

Fig. 6. Brake connections where rods connect the foot-brake pedal and hand-brake lever with external and internal bands. The foot pedal operates the external brakes, and the hand lever operates the internal brakes. Note that an **internal band brake with a toggle action** is shown.

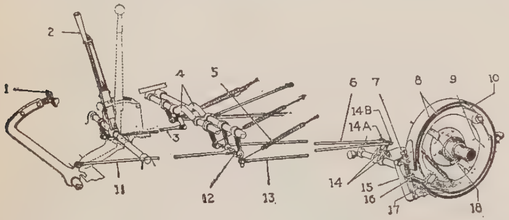

Fig. 7. Brake connections where rods connect the foot-brake pedal and hand-brake lever with an external band and an internal brake shoe. The foot pedal operates the external brakes and the hand lever operates the internal brakes. Note that the clevises (14) are used for "distance" or "pedal and lever adjustments," whereas the brake-band lever (15) is used for "brake-band clearance" adjustment. Note that the **internal brake shoe has a "cam" action.**

(1) Foot-brake pedal
(2) Hand-brake lever
(3) Hand-brake forward rod
(4) Brake shafts
(5) Pull-back springs
(6) Hand-brake rear rod
(7) Foot-brake adjustment
(8) Brake linings
(9) Hand-brake shoes
(10) Brake drum
(11) Foot-brake forward rod
(12) Foot-brake equalizer
(13) Foot-brake rear rod
(14) Foot and hand-brake adjusting clevises
(15) Foot-brake band lever
(16) Foot-brake centering nut
(17) Hand-brake operating cam
(18) Anti-rattler springs

The adjustment of the external contracting brake (Fig. 7), which is the foot brake, is similar to the adjustment explained on page 889 (Fig. 10).

The adjustment of the hand brake (Fig. 7) can be tried by pulling the wheels by hand to determine that equal braking effort is applied to both rear wheels when the **hand-brake lever** is partly set, and that both lock at the same time with the wheels jacked up.

Adjustment is made at clevis (**14A**). The two clevises (14) are mounted on a tube within a tube. The clevis (14A) attaches to the inner tube and operates the cam (17); clevis (14B) is attached to the outer tube and operates the external brake lever (15). When the brake lever is released there should be no dragging of the brake shoes on the drum.

Brake Cables

The Lexington series "S" car is an example where a **flexible-wire brake cable** is used instead of rods.

On this car both the hand and foot brakes are unusual in their construction.

The hand brake operates upon a drum located on the rear of the transmission.

The foot brakes are on 16″-diameter-brake drums attached to the rear wheels and in the form of contracting bands. The band brake is operated through a spring-tensioning device, so that it is possible to bring the car to a stop with very light pressure. The foot brakes are operated by a cable guided to each rear wheel by a heavy tube attached to the frame (see Fig. 8).

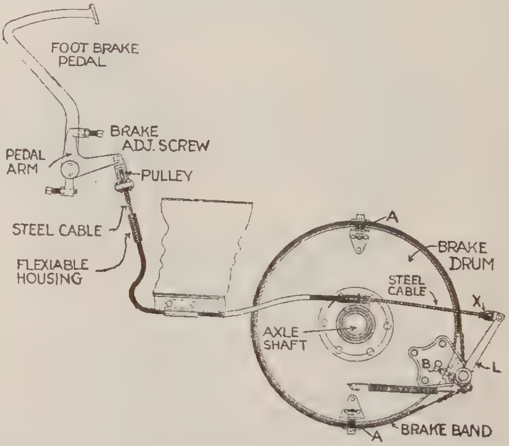

Fig. 8. **Principle of the brake operation on the Lexington "S":** A steel cable is connected to one lever passed around a grooved pulley attached to a pedal arm and back to a lever on the opposite drum, making the best form of equalizer. Over this cable is a flexible housing of closely wound steel wire, covered with a weather-proof material to keep out mud and water.

The rear ends of the housing are anchored to the axle; the forward ends are anchored to the frame near the pedal. Since the housing is practically noncompressible, it is evident that what cable is pulled out at the front end must come in at the rear end, thereby setting the brake.

The inner and outer members being flexible, any movement of the axle resulting from road conditions is not transferred to the pedal.

A simple screw and lock nut serves to take up any slack in the cable resulting from wear of the lining. If any great amount of wear in the lining causes too much pedal travel, by setting up the brake-lever stop screws at the rear drums as close as they will go without causing the bands to drag, and then taking up the slack in the cable at the pedal end, the brakes can be kept in first-class condition until the lining is worn out.

A little engine oil squirted into the housing at the front end every few weeks will keep the cable free.

CARE AND ADJUSTMENT OF BRAKES

As the safety of a car depends on its brakes, they must be kept in the best possible condition. They should bind tightly when pressure is applied to them, and be free and clear when the pedal or lever is released. A brake band or shoe that binds when the pressure is released produces friction, and makes the car hard-running.

A common brake trouble is slipping, generally the result of oil or grease working out of the rear axle. It is also caused by poor adjustment, or worn linings. Therefore the first and most important precaution is to stop any leak by putting in a washer. Poor adjustment may be cured by **readjustment.**

In the case of oil or grease working between the surface, **clean the brake lining** by washing out the oil with a little gasoline or kerosene, applied with an oil gun, and then stop the leakage of grease out of the rear axle. This is usually done by the replacement of a felt washer (or "grease retainer" washer. See "Studebaker axle," page 875) on the inside of the hub. The excess oil is generally due to too much oil in the differential casing, which works out into the brake drums.

Slipping caused by worn linings may be remedied to some extent by taking up the adjustment, but if it is too much worn for this, they must be replaced.

Replacing the worn lining is not difficult, as the brake lining is held to the steel band by copper rivets.

Because the application of the brake generates heat, leather linings would be burned if kept in contact too long. For this reason, the brakes are usually lined with fabric, called Raybestos, Multibestos, or Thermoid.

If, when applying the brakes, the car has a tendency to skid to one side, this indicates that one wheel is free and the other dragging. In such a case the brakes are not equalized in adjustment. Therefore the brake resistance should be equalized.

The operator can save considerably by applying his brakes gradually. For instance, if a stop is to be made, instead of dashing up to the stop and applying the brakes with full force suddenly, simply coast to the stop and apply the brakes gradually, or even not at all. This of course, requires practice.

If a brake squeaks, it is dirty and dry, and needs cleaning by removing and cleaning with a stiff brush and gasoline. The dirt clogs the pores in the surface of the lining and glazes it over, which causes the squeak. Brake squeaks are also caused by improper clearance or high points between the brake drum and the brake band.

Brake drag is usually due to insufficient strength of the releasing mechanism, such as the springs; or the connections may be adjusted too tight, or there may be insufficient clearance at the bands.

Lubrication of brakes: While asbestos lining requires practically no lubrication on account of its high resistance to heat, it is advisable to apply a few drops of thin oil to the brake shoes or bands occasionally, or about every 2,000 miles. This maintains a smooth surface on the brake drum.

See that the hinges, cams, toggles, and lever bearing are kept well supplied with oil. If an external contracting brake should **chatter,** apply three or four drops of oil to the friction surfaces. If this does not relieve the "chattering," look to the "clearance" of the lower part of the external brake band, or to looseness in the parts of the internal brake mechanism.

Inspection of Brakes Before Adjustment

Points to consider when starting to make adjustments of the brake mechanisms are: Do the brakes merely need adjustment, or do they need an overhauling? If a car has been run for a long time, it is advisable to make an inspection as follows.

1. **Inspect the bearings in the rear wheel hubs,** to see if they are in good condition. If the bearings are loose or worn, this will make a difference in the adjustment of the brakes, especially when adjustment is made with the car jacked up and when it is made with the car on the ground under its weight. The adjustment can be tested by grasping the wheel on each side of the car, when jacked up, and "feeling" for looseness.
2. **Inspect the rear wheels to see if they are out of line.** If they are, it is probably the result of having skidded against the curb and having slightly bent the axle shaft or having thrown the wheel out of line. This will affect the brake adjustment. Test by spinning the wheel when the car is jacked up.
3. **Inspect the parts** of the brake mechanism to see if they are loose; if so, tighten.
4. **Inspect the joints and parts to see whether they** are rusted or caked with dirt and grease; if so, clean.
5. **Inspect the brake linings to see if they are coated with oil or grease;** if so, clean with gasoline or kerosene, by removing the wheels with the drums. Find the cause of the grease or oil being on the brakes, and remedy it.
6. **Inspect the brake linings to see if they are worn.** If slightly worn, "clearance adjustment" will take care of the difficulty. If badly worn, a new lining will be needed. Also see if the lining has worn down to such an extent that the rivets have cut the brake drum; if so, the wheel must be removed and the brake drum smoothed down with emery cloth, or, in bad cases, the brake drum must be turned true, and even perhaps on a lathe. If the band is not entirely worn down, the brake band can be adjusted for clearance.

Testing the Brake Action

After the conditions enumerated above are attended to, and the parts are cleaned, replace the wheels and proceed to test the brake action as follows:

1. Jack up the rear axle, with the brakes in a complete "off" position. Note the **clearance of the internal bands** around the drum, which should be uniform and about 1/64″. On the external band, this will extend to within only about 3″ or 4″ of the end of the band, where the clearance will be greater.
2. To test the **internal brake band for clearance,** use a thin piece of metal, inserting this between the drum and the band from the inner side of the brake support.

For a more elaborate and sure test, both for holding power and, what is equally important, the equal action (termed "equalizing action") of the right and left brake bands, proceed as follows:

1. Block the front wheels securely to prevent the car moving forward or back.
2. Jack up the rear wheels until they are entirely clear from floor.
3. Put all brakes on both sides in complete "off" position.
4. Start the engine, run it slowly, and transmit the power to the rear wheels, as when driving in low gear.
5. Engage the brakes carefully and lightly, and note the action of the wheels, which will show clearly any inequality between the right and left adjustment. Both brakes should stop at the same time when the brakes are applied.

On some cars without equalizers the adjustment is made by lengthening or shortening the brake rods, by screwing off or on the yoke ends which connect to the brake cams.

Some cars are fitted with brakes in which the adjustment is made by varying the position of the brake-operating lever and slotted clevis on the brake cam shaft. Usually there is a hand adjustment on the contracting brake.

Sometimes all the overhauling the brakes need is a cleaning out of the drums with kerosene, applying a little also on the brake linings. If grease or oil works its way to the brakes, either too much is being carried in the differential, or the felt washers in the axle need replacing. Brake lining is expensive, and very often the old material will serve, if properly handled, with kerosene and a little oil to raise the fiber.

When going over the brake system, be sure to inspect the clevis pins, etc., for wear (see Fig. 7, page 886). These parts frequently are overlooked, and the result is an unpleasant rattle on the road. Oil should be applied to the joint.

Average Brake Adjustments

There are three adjustments to be considered when adjusting brakes: (1) brake-rod adjustment; (2) brake-pedal and lever adjustment; (3) brake-band clearance adjustment.

Brake-Rod Adjustment

The first adjustment of brakes should always be made in the brake rods rather than in the brake itself. Tighten up on these rods so as to get the proper travel in the brake pedal or hand lever. The adjustment of the brake pedal and hand lever is thus made through the rods, by seeing that the foot-brake pedal and hand-brake lever are in "off" position and the rods adjusted so that there is no binding. This can be tested by jacking up the wheels and observing if there is a drag. Adjustment can be made by a threaded adjustment at the front end of the rod, by screwing in one direction to lengthen and in the opposite direction to shorten the pull. The lever (see 15, Fig. 7) on the external brake should be in toward the band, in order to allow for full leverage.

Dragging of the brakes may be caused by too short an adjustment of the rods.

Before adjusting the brake bands, see that the **pull-back springs** are operating properly and lengthen the rods.

If the brakes will not hold, be certain that the brake lining has not become saturated with oil or grease; wash them off thoroughly with gasoline or kerosene if necessary.

When the proper brake action cannot be obtained by further adjustment of the brake rods, then adjust the brakes themselves.

Adjustments of External Brakes

Usually, ordinary external brake adjustment for clearance is all that is required, and this can be done without removing the wheel.

Clearance adjustment of the external brakes is very important. If the band touches the brakes at different points of its circumference, the brake will drag at that point, which of course consumes extra power and causes wear on the lining. The purpose of adjusting this **clearance** is to relieve the drag, or to take up on an excess of clearance due to wear of the lining.

The proper clearance on most brakes is about 1/64″ to 1/16″ all round. Usually this clearance can be taken up as follows:

1. By adjusting the **lever,** as at **(A)** (Fig. 10, page 889);
2. By adjusting the **rear clearance** of the band, as at **(D)** (Fig. 10, page 889).
3. By adjusting the **lower half of the band** for clearance, as at **(E)** and **(F)** (Fig. 10, page 889);
4. By adjusting the **upper half of the band** for clearance, as at **(G)** (Fig. 10, page 889).

This is ordinarily sufficient.

The top half of the brake is usually given slightly more clearance than the bottom, because the drum, revolving in a forward direction, has a tendency to draw the top half of the band to the drum.

A thickness gauge is handy to place between the brake lining and the drum when adjusting clearance.

The foot brake requires more adjustment, because it is used most. The hand brake is mostly used for locking the wheels when standing and at intervals in conjunction with the foot brake on steep hills; therefore it requires less attention.

After adjusting the brakes, notice if the wheels turn freely when the foot-brake pedal and hand-brake lever are in the "off" position.

If the wheels do not turn freely, or if they drag, the brakes are adjusted too tightly.

After adjusting the brakes, while the wheels are jacked up, then test and readjust.

Many repairmen, with the wheels on the ground, and after making adjustment, move the car backward and forward to see if the band drags. If this is done, be sure that both brakes are adjusted equally, as sometimes the weight of the car on the wheels will alter the adjustment.

Adjustments of Internal Brakes

The internal brakes are of the "toggle"-acting type or of the "cam"-actuated type, as previously explained.

As an example of adjusting clearance in the "toggle"-acting type of internal band brake, see Figs. 11 and 12, page 890. In order to make this adjustment, it is necessary to remove the rear wheels. Refer to page 889, and note the adjustments as there explained. See also, Figs. 17 and 18, pages 891 and 892.

As an example of adjusting clearance in the "cam"-acting type of internal brake, see Fig. 14, page 890, also Figs. 19 and 9, pages 892, 889.

Ordinarily, **the only adjustment required for the internal brake** is to adjust the pull rods or clevis.

If the brakes seem to be too tight after the car has just been washed, it is due to the fact that the brake lining, which is composed of a combination of closely woven wire and asbestos, has swelled slightly from the water. In a very short time this condition will disappear.

In adjusting the brake bands, be sure to take up the same amount on both right and left-hand brakes. If care is not exercised in making the adjustment, one brake may set before the other, thus destroying the braking effect and causing one wheel to lock and slide over the ground, wearing off the tread of the tire very rapidly. Also be careful not to set the bands up so tightly that they drag and will not release when the foot is removed from the pedal.

Stopping Car at Various Speeds

The average distances in which a car should be stopped by the brakes at various speeds on average and on good roads, are approximately as follows: 15 m.p.h., 20 ft.; 20 m.p.h., 38 ft.; 30 m.p.h., 85 ft.; 40 m.p.h., 160 ft.; 50 m.p.h., 240 ft.

THE STUDEBAKER "LIGHT SIX" BRAKE ADJUSTMENTS (AS AN EXAMPLE)

The foot brake, also termed the service brake, contracts on the brake drum. The **hand brake,** also termed the emergency brake, expands against inside of the brake drum. By studying Fig. 9, the functions of these brakes will be understood. Both brake bands are faced with brake linings.

The adjustment for clearance of the external brake band (**B**) is made at the nut (**C**) below the spring for clearance of the lower half of the brake band, and by nut (**D**) for the clearance of the upper half of the brake band.

The adjusting screws (**E**) and (**F**) are additional adjustments for procuring an even spacing or clearance all around the circumference of the drum. This clearance should be about 1/32″, or not over 1/16″.

The internal brake is operated by a cam (**H**) which expands a steel band lined with brake lining. The usual adjustment is made by shortening the brake rod at the turnbuckle.

The spring (**S**) serves two purposes: The adjustment nuts are locked by the spring and at the same time, it helps release the band when the pressure is taken off the brake lever.

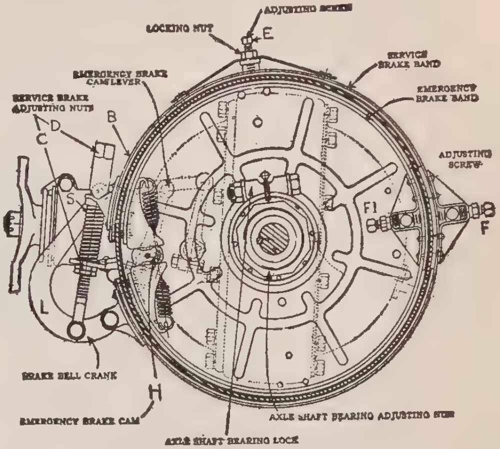

Fig. 9. The brake as used on the Studebaker "Light-Six" car. Note that a lever (**L**) termed a "**brake-bell crank,**" connects with the **external contracting band** (**B**). This lever (**L**) is connected with the foot-brake pedal through the clevises and brake rods.

THE TIMKEN BRAKE ADJUSTMENTS

The adjustments described in what follows are of the brakes as used on the Timken semi-floating or fixed hub type of axles, and on the full-floating axle as shown on pages 865, 866.

The **external** brake (Fig. 10) is the type used on both, but the **internal** brake is of two types, shown in Figs. 11 and 12. The one shown in Fig. 11 is the type used on the semi-floating, or fixed-hub axles, and the one shown in Fig. 12 is the "toggle"-operated expanding band type of internal brake used on the full-floating axles.

The **internal** brake shown in Fig. 14 is the "cam"-operated expanding band type of internal brake formerly used.

A later type of Timken brake is shown in Fig. 16.

External Brake Adjustments (Timken)

To adjust the external brakes, jack up both rear wheels, and put the brakes in the complete "off" position.

Adjust the stop screw (**B**) (Fig. 10) so as to allow the **lever** (**A**) to come down as far as possible and still have a clearance of about 1/16″ with the operating mechanism.

Now remove the cotter pin (**C**) and turn the adjusting screw (**D**) until the clearance between the brake lining and the drum at this point (rear) is not more than 1/32″. Be sure that the brake drum clears at all points; if necessary turn the adjusting screw out slightly. Replace the cotter pin.

Now adjust the **lower half of the band** by turning nuts (**E**) and (**F**) until about 1/32″ clearance is obtained at this point also.

After locking these nuts firmly, make a similar adjustment of the **upper half** by turning nut (**G**). Be sure that this nut is properly seated in the groove into which it fits, thus locking the adjustment.

When these adjustments are complete, there should be a maximum clearance between the brake lining and the drum of about 1/32″ at all points, but they should not be in contact at any place. Readjust until this condition is obtained.

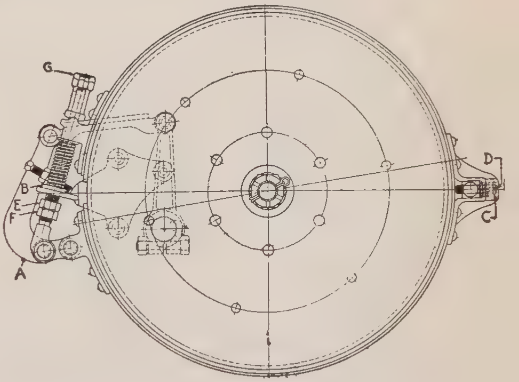

Fig. 10. External band brake (Timken).

Internal Brake Adjustments: Timken Toggle Type

In order to adjust the internal brake, it is necessary to remove the rear wheel, carrying with it the brake drum. Jack up both rear wheels, put the brakes in the complete "off" position, and remove the wheels.

To adjust the fixed-hub type of axle brake (see Fig. 11): First remove the cotter pin (**A**) and tighten up adjusting screw (**B**) until a maximum clearance of 1/32″ is obtained between the brake lining and the drum at this point. This clearance should be the least possible amount—only enough so that the drum will not rub at any point when revolved.

Having obtained the proper clearance, replace the cotter pin (**A**). Next remove the head pin (**D**) and disengage screw (**E**), freeing both ends of the brake band.

Adjust the four set screws (**F**) to give the least possible clearance between the brake lining and the drum—1/32″ should be the maximum.

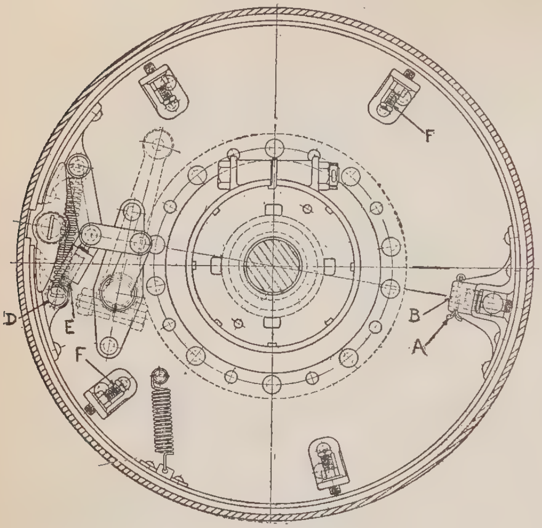

Fig. 11

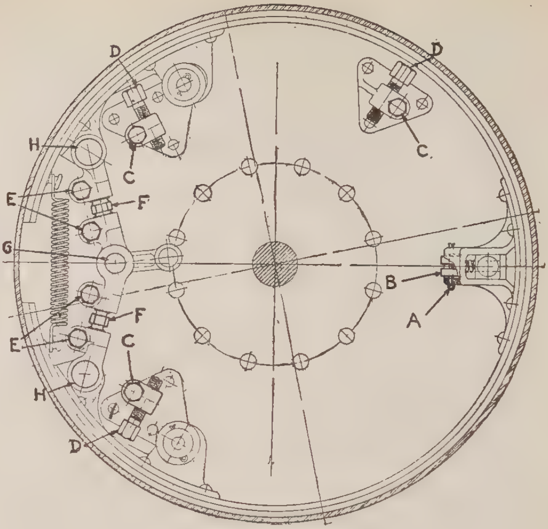

Fig. 12

Fig. 11. Internal toggle type of brake (Timken), as used on the fixed hub or semi-floating axle, as discussed on page 865.
Fig. 12. Internal toggle type of brake (Timken), as used on the full-floating type of axle, as discussed on page 865.

When this adjustment has been made, be certain that each set screw is firmly locked with the lock nut.

Now adjust the screw (E) to give not over 1/32″ clearance between the lining and the drum at the two ends of the band and replace the pin (D).

After making all these adjustments, there should be a maximum clearance all around the drum of 1/32″—if not, readjust until this result is obtained.

To adjust the internal brake on the full-floating type of axle, see Fig. 12.

Adjustment is made in a similar manner. Some of these axles are provided with a triangular plate in the brake drum which can be removed for adjusting the brake. In this case it is not necessary to take off the wheel.

Adjust the screw (B) to give the proper clearance at this point; obtain the correct clearance over the rest of the brake band by adjustment of screws (D) after loosening the clamp bolt (C).

After making these adjustments, be sure that the cotter pin (A) has been replaced and that the clamp bolt (C) has been tightened up firmly.

Now loosen the clamp bolts (E) and adjust screws (F) until the forward edge of head-pin (G) is in line with the rear edges of pins (HH). Tighten up bolts (E) and replace the wheel.

In replacing the wheel on the full-floating type of axle, be sure that you get a correct bearing adjustment as described on page 864 under "Wheel bearings."

Dummy Drum for Adjusting the Internal Brake

In garages or service stations when internal brake adjustments are frequently made, a dummy drum (Fig. 13) can be used to advantage. The same result can be obtained by a "cut-and-try" method, removing and replacing the wheel several times, but the use of a dummy will prove a great time saver.

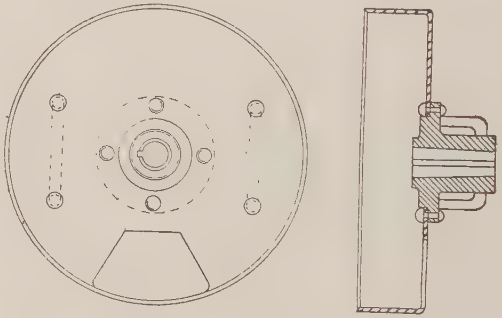

Fig. 13. Dummy drum which can be obtained of the Timken-Detroit Axle Co., Detroit, Mich.

Internal Brake Adjustments: Timken Cam Type

Adjustment of the Timken-cam type of internal brake: A cam type of internal brake has been used on several axles formerly produced (see Fig. 14).

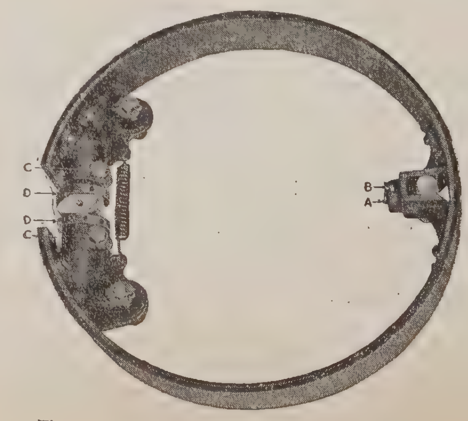

Fig. 14. Timken cam actuated internal brake.

To adjust this brake for slight wear of the brake-band lining, this can ordinarily be taken up satisfactorily without getting into the brake proper.

This is done by loosening nut (Q) (Fig. 15) and moving lever (J) forward one notch in ratchet (K), and then tightening nut (Q). Perhaps two notches forward may be required.

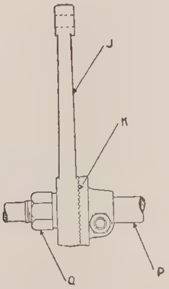

Fig 15

For more band-lining wear than can be taken up by this method, put jacks under the rear axles, being careful to have them press up against the housing proper (or, on some Timken axles, against the pads made for this purpose), but never against the truss rods. Raise both rear wheels off the ground.

Next, put all the brakes on both sides of the axle in a complete "off" position.

Now, if the adjustment is merely to take up for wear of the brake lining in service, it is necessary only to (1) remove the wheel which also removes the brake drum; (2) remove the cotter pin (B), give screw (A) two turns to the right (i.e., in a clockwise direction), and replace pin (B); (3) loosen screws (C,C) give cam plates (D,D) one half-turn outward (i.e., to the left or counter-clockwise), and tighten screws (C,C).

Put the wheel back on and try the brake in the "off" position for a bare yet sure clearance, so that it will not drag. Try it in the "on" position for holding power.

If greater clearance is required, remove the wheel and partially reverse the adjustments detailed just above.

If still more holding power is desired and there is some clearance yet to spare in the "off" position, remove the wheel and repeat the adjustments to a partial extent.

Timken Types "5510" and "5710" of Brake

Both the external and internal brakes on the 1922 series axles are the same as those made on the corresponding axles of the former series, except on the new series "5510" and "5710" for heavy cars.

On these axles the **internal** brake is of a new type, as shown in Fig. 16, and requires no adjustment beyond that which can be obtained in the brake-pull rods.

The adjustment of the external brake is similar to that explained on page 889.

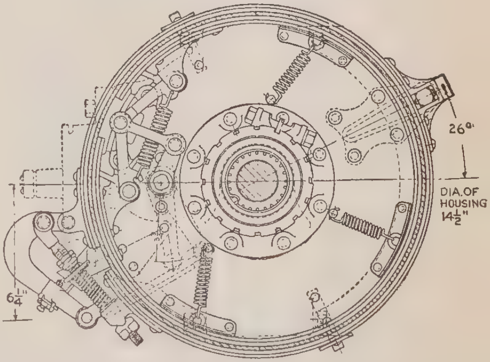

Fig. 16. Timken types "5510" and "5710" of brake—1922 series.

ADJUSTMENT OF BRAKES OF COLUMBIA REAR AXLE

External Brake Adjustment on Models "10000," "30000," "50000" and "51000" Columbia Rear-Axle Brakes

To adjust the external brakes on these models, jack up both rear wheels, and put the brakes in the complete "off" position with lever (A) back against stop (B).

Lever adjustment: Lever (A) must set back against stop (B)—lengthen pull rods if necessary to get this condition.

Rear clearance adjustment: Remove cotter pin (C) and lock (E), and turn adjusting screw (D) until the clearance between the brake lining and the drum at this point does not exceed 1/32″. Make sure that the drum clears at all points.

Lower half of band clearance adjustment: Replace lock (E) and cotter pin (C); next, adjust the lower half of the band by turning nuts (F) and (G) until the lining clears the drum evenly all around, not to exceed 1/32″; then lock nuts (F) and (G).

Adjust the upper half of the band by turning nut (H) until the lining clears the drum evenly all around, not to exceed 1/32″.

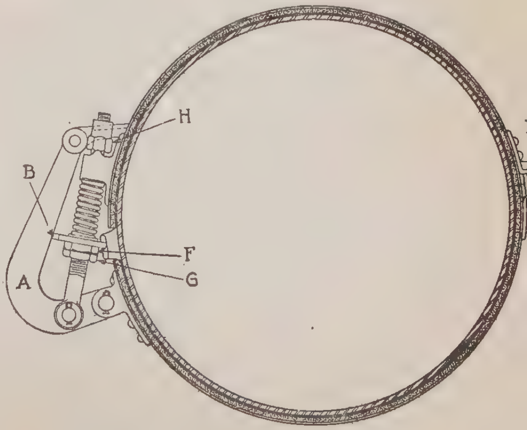

Fig. 17. External brake as used on the Columbia rear axles

Be sure that nut (H) is properly seated in the groove into which it fits, as this locks the adjustment.

When these adjustments are made, there should be a maximum clearance of 1/32″ between the brake lining and the drum at all points. The lining must not touch the drum at any place. Readjust until this condition is obtained, and test with a thickness gauge.

Internal Brake Adjustments on Models "50000," and "51000" Columbia Rear-Axle Brakes

To adjust the internal brakes on these models which are of the "toggle-acting type," and are provided with adjustment at four points proceed as follows:

As a time saver, and to get the best results in adjusting this type of brake, a **dummy drum should be used.** The openings in the drum permit a view of the parts to be adjusted, insuring a much closer and more accurate adjustment than could be obtained without its use.

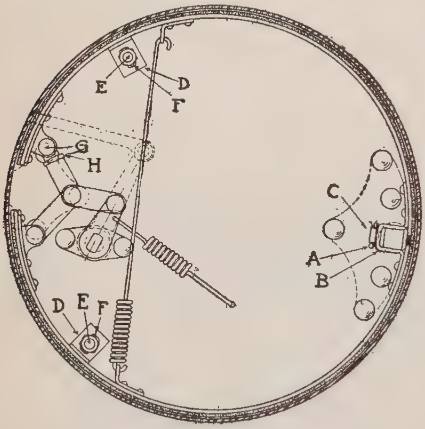

Fig. 18. Internal "toggle joint actuated" type of brake as used on the Columbia rear axles.

First, remove the rear wheels; then adjust the pull rods until the brake-shaft lever on the axle to which these rods connect is set back at same angle as external brake-tube levers when contracting lever (A) is back against stop (B) (see Fig. 17 and instructions for external brake adjustment above).

Next, remove cotter pin (A) and lock (B) (Fig. 18). Put on the dummy drum, bringing the opening in the drum directly over adjusting screw (C); turn adjusting screw (C) until the clearance between the brake lining and the drum at this point does not exceed 1/32″, or the least possible amount obtainable, so that the drum will not rub at any point when revolved. Having obtained the proper clearance, replace lock (B) and cotter pin (A).

Next, bring the openings in the drum directly over the internal brake supports (D). These supports have a small projection that fits into slots in the brake band. Be sure these are in place. Loosen the nuts on bolts (E) just enough to allow supports (D) to move freely. Adjust supports (D) so that the clearance between the brake lining and the drum does not exceed 1/32″, or the least possible amount that can be obtained, so that the drum will not rub the band at any point when the drum is revolved. In adjusting supports (D), use a bar as a lever for prying, working through the opening in the drum; with the bar resting on the drum-catch support, with the end of the bar at (F), move supports (D) up or down. This action moves the brake band until the proper clearance is obtained. Then hold the supports in place until the nuts on the outside of bolts (E) are drawn up tight, and remove the drum to see that it turns freely and that the clearance between the brake lining and the drum is the same all around. Clearance must not exceed 1/32″.

To get the proper clearance at the points, remove pin (G) and adjust screw (H) until a maximum clearance of 1/32″ is obtained; then replace pin (G).

After adjusting point (H), always check supports (D), making sure that this adjustment has not moved the band away from supports (D). If these supports do not set up tight to the band, readjust supports (D). After making all these adjustments there should be a maximum clearance all the way around the drum of 1/32″; if not, adjust until this result is obtained.

Important: Never adjust the pull rods without afterwards adjusting supports (D), as the adjusting of the pull rods pulls the band away from supports (D) causing rattles and also wear of the supports. To eliminate rattles, adjust supports (D) up tight to the band in release position.

In adjusting the brakes a thickness gauge should be used to measure the proper clearance between the brake lining and the drum. Dummy drums can be secured for models "10000," "30000," "50000," and "51000" from The Columbia Axle Co., Cleveland, Ohio. Thermoid brake lining 2½″ in width is used.

Internal Brake Adjustment on Models "10000" and "30000" Columbia Rear-Axle Brakes

The internal brakes on these models are the **"cam-operated type,"** and only one adjustment for "clearance" is provided. See Fig. 19.

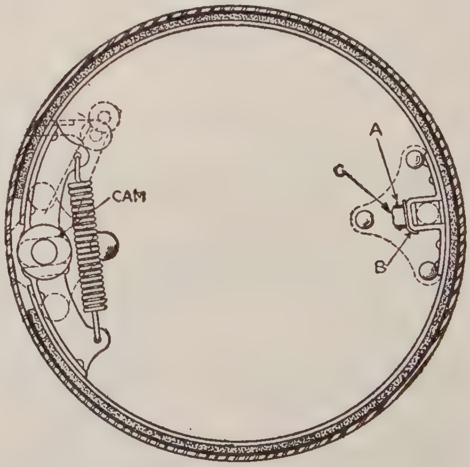

Fig. 19. Internal "cam-actuated" type brake, as used on Columbia rear axles.

To adjust, remove cotter pin (A) and lock (B), and turn the adjusting screw (C) until the clearance between the brake lining and the drum at this point does not exceed 1/32″.

Adjustment for wear, which is the only adjustment usually required, is made by shortening the pull rods from the cam lever forward to the chassis.

ADJUSTING DODGE BRAKES

The external brake is connected with the foot-brake pedal. Adjust the hexagon check-nuts on the lower part of the adjusting yoke (see Fig. 4, page 884) as well as the wing nut (**W**) at the top, in order that the band may be taken up as much at the bottom as at the top.

See that the "brake-supports" are adjusted so that the brake band takes hold evenly all the way around, and does not drag when released.

To adjust the internal brakes, take up on the front end of the pull rod.

Relining Brakes on Dodge

Material required for a Dodge brake relining job: 88″ lining 2¼″ x 3/16″ for the two external brakes; 71″ lining 2″ x 3/16″ for two internal brakes; 12 steel cotter pins 3/32″ x ¾″; 80 brass rivets 9/16″ long, ⅛″ diameter, ¼″ head.

Either 3/16″ or ¼″ brake lining can be used. On repair jobs ¼″ is often used.

Operation: (1) Jack up the rear wheels; (2) remove the wheel flanges; (3) remove the wheel-bearing adjusting nut; (4) remove the wheel and brake band; (5) wash the brake bands; (6) remove the old brake lining; (7) rivet the new lining bands; (8) replace the brake bands; (9) put the wheel on; (10) replace and adjust the wheel-bearing adjusting nut; (11) replace wheel flanges; (12) adjust brakes.

Note: It is now necessary to use a wheel puller to remove rear wheels on the later type of Dodge axle.

OVERHAULING BRAKES

There are three things which must be particularly noticed in taking care of brakes and putting them in condition:

1. There must be no grease on the shoes.
2. The fabric must be in the best of condition.
3. The brake linkage must apply the brakes when the pedal is depressed.

The grease which penetrates to the brake lining usually works its way from the differential, and can be stopped by renewing the washer in the wheel hub.

To remove grease, first remove the wheel, then inspect the brake lining and see if it comes under the condition mentioned in No. 1 or No. 2 in the list above.

If a coating of grease is over the surface of the fabric, there will be two methods of procedure. The first method for removing grease is by the application of gasoline. This removes the grease from the outer surface very well, but not from below the surface of the fabric. A blow-pipe torch can be used in this instance, which can be gently applied as shown in Fig. 20, this page, care being taken not to char the fabric.

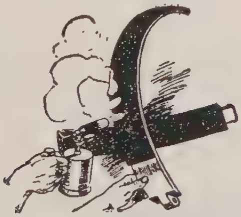

Fig. 20. Removing grease from under fabric brake lining on a two-piece internal expanding brake shoe.

After the heat has been directed against the surface of the brake for a short length of time, it will be noted that the grease will literally fry out of the fabric, leaving it upon the surface in the form of a black carbonaceous deposit. In this state it is readily removed by a cloth steeped in gasoline. The surface of the brake will now be in good condition if the lining has not been worn out.

If the brake lining is badly worn down, so far that the fabric lining is too thin to be of service, a new brake lining must be applied.

If the brake lining has worn down to the rivet heads, it should be renewed, unless the rivets can be sunk lower by a round-nosed punch, the other end of the rivet being placed over a small hole in a piece of metal on an anvil or vise. Then the rivets can be set up tighter.

Relining External Contracting Brake Bands

To reline the external brake: First, jack up the rear wheels. Disconnect the levers, etc., from the brake bands and remove the wheels and bands, being careful to keep all parts separate, so that they can be replaced with ease.

Second, wash all parts in gasoline or kerosene to remove the grease and dirt.

Third, remove the old brake lining, by placing the band in a vise and cut the rivets with a chisel (Fig. 21); then open up the bench vise about ½″, setting the bands so that the old rivets come over the opening one at a time. Drive them out with a nail set (Fig. 22). As the heads will most likely be worn off, it is easier to drive them from the lining side through to the band side. The old lining can then be easily removed from the band.

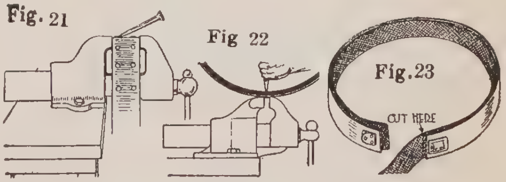

Fig. 21 Fig. 22 Fig. 23

Fig. 21. Method of cutting rivets on worn band.

Fig. 22. Punch the cut rivets out.

Fig. 23. Method of determining length of lining for an external contracting band type of brake.

Fourth, measuring brake lining:[1] It is best to secure the lining from the automobile dealer or manufacturer ready to apply, but if this is not possible, then proceed as follows: Place it **inside** the band (Fig. 23), holding it firmly against the band and cut the lining from ¼″ to ⅜″ **longer** than the band, depending upon the diameter of the band.

Fifth, rivet one end flush with band (Fig. 24-1) after having countersunk a hole in the lining for the rivet.

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[1] Most accessory dealers possess data books of brake-lining measurements from early to late model cars. See also Index, under "Brake-Lining Sizes." The Raybestos Co., Bridgeport, Conn., supplies **brake service material** and supplies.

Sixth, place lining firmly in band all around, which should leave a projection of about 3/8" at other end (2, Fig. 24). **Seventh,** make a loop in middle (Fig. 24), so end (2) of lining will come flush with end of metal band, then countersink lining and rivet this end.

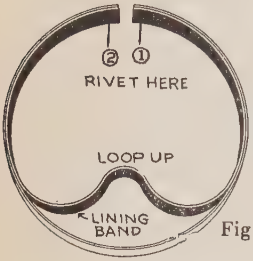

Fig. 24

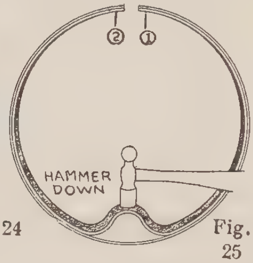

Fig. 25

Figs. 24, 25. Lining external contracting brake band.

Eighth, force lining straight against band with hammer (Fig. 25). **Ninth,** place band over a block of wood or vise and use holes in band as a template. **Drill holes** for the rivets. It is important that the holes be in the correct **position.** **Tenth,** countersink holes so that the rivet heads will be below surface of lining. Use a countersinking tool (Fig. 26).

A 3/8" metal drill can be used. Do not countersink too deep, but just enough to permit rivet head to be below lining surface. (The solid or tubular copper rivet is used in this example; see Fig. 31.)

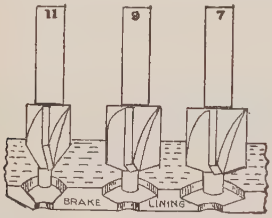

Fig. 26. **A brake lining counter-sink** for flat-head solid or tubular rivets 9/16", ½", and 13/32". This device will countersink holes in any style of brake or clutch lining. The shank is 5/16" in diameter, and works on a hand or power drill. (Stevens Co., 375 Broadway, New York.)

Eleventh, place copper rivets through lining so head of rivet will rest in countersunk hole in lining. See "Riveting Brake-Band Lining." **Twelfth,** round up with the brake drum and reassemble.

Relining Internal Expanding Brake Bands

Follow "First, Second, and Third" procedures under "Relining External Brake Bands." **Fourth,** place lining around band (Fig. 27) and cut lining length of band. **Fifth,** place lining on metal band (ends flush). Hold in place with a "C" screw clamp at each end; then mark holes from inside of band. **Sixth,** remove lining; drill and countersink holes. **Seventh,** place lining on band (Fig. 27) and start riveting at one end and follow around to the other end. **Eighth,** round band up with drum and reassemble.

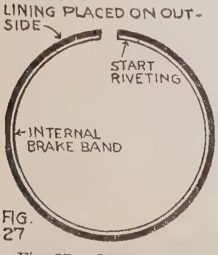

FIG. 27

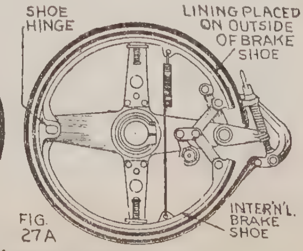

FIG. 27A

Fig. 27. Lining internal expanding brake band.
Fig. 27A. Lining internal expanding brake shoes.

Relining Internal Expanding Brake; Two-Piece Shoe Type

Procedure (see internal expanding brake shoes in Fig. 27A): Use brake lining longer than necessary for complete job. Rivet one end flush with one end of brake shoe. Insert free end of lining in vise. Rest other end of brake shoe against vise and press down, thus stretching brake lining tight over shoe band. Drill holes, countersink and rivet around the shoe, and cut off surplus brake lining. **If the brake is of the metal-to-metal** type, it is a matter of adjustment, no lining being used.

Riveting Brake Band Lining

Do not clinch the rivets against the brake drum. Drill and countersink the rivet head into the lining.

To place the rivets, see Fig. 27B. This shows a way of using a bolt held in a vise with the head of bolt resting on the arm of vise to give a solid foundation.

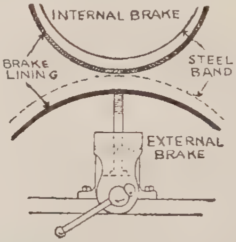

Fig. 27B. One method of riveting. Note that the illustration shows the internal brake curved up and the external brake curved down. The rivet head goes next to the fabric, and the riveting is always done on the band side.

Insert a rivet through the lining and band, as shown, the head of the rivet resting on the bolt. Draw rivet snug with a rivet set, or a short piece of small gas pipe. Two or three blows with a hammer will be enough to draw the rivet head and the lining tight and in place. Too much pounding will tend to draw the rivet deeper in the lining and perhaps weaken it to the point of breaking through.

To rivet: Holding the band in the same position, the projecting end of the rivet is peened down with the ball peen of hammer till a good head is formed and the rivet draws tight.

Brake Lining[1]

Most of the brakes now in use are fitted externally and internally with steel bands faced with a fabric lining. **There are several good brands of brake lining** on the market, for instance, Raybestos, Multibestos, Thermoid, etc.

Fig. 27C. Fabric brake lining. Fig. 28 Fig. 29 Fig. 30

The sizes are usually measured in thickness and width, and are sold at so much per foot.

The thicknesses run 3/32", 3/16", 1/4", and 5/16". The widths run from 1", 1¼", 1½", 1¾", on up to 6" wide. The Ford uses 1⅛"x5/32".

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[1] See Index under "Brake-Lining Sizes," as used on various cars.

Brake Lining Rivets

The rivets are made of **solid copper** (Fig. 28), without burrs, or are made of **tubular brass** (Fig. 29) (hollow rivet), which are used on the Dodge and Maxwell cars, or are a **clinch or split rivet** (Fig. 30), as used on the Ford.

Solid Rivets and Split Rivets—How Used

When solid or tubular rivets are used, the head of the rivet is placed next to the brake lining fabric and is countersunk into it, and the rivet is bradded on the steel lining of the brake, as shown in Fig. 31.

Timken Detroit Axle Co. advises **copper rivets,** as they will not score the drum when the lining becomes worn.

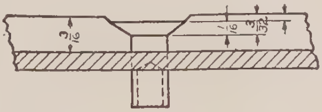

Fig. 31. Showing how the flat-head solid or tubular rivet is used with the head countersunk into the lining.

When split rivets are used, the head of the rivet is placed next to the steel band and the projecting ends of the rivets are turned into the brake lining or fabric as in Fig. 31A.

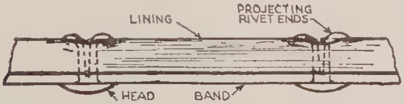

Fig. 31A. Showing how the split rivet is used with the head next to the steel band.

Many mechanics do not punch holes in the lining, but drive the split rivets through the lining. Place the lining and the band over a wooden block clamped in a vise, and **drive** the rivets through a hole in band and through the lining into the wood. Then put the rivet head on the bolt clamped in a vise, and turn over the projecting ends of the rivet into the lining, as shown in Fig. 31A.

The Raybestos Co., in its publication, "Silver Edge," advises **not to use split rivets,** the proper method being that of drilling, countersinking, and riveting, with the flat head of the rivet about 1/32″ below the surface of the lining (Fig. 31), **using a flat-head tubular or solid rivet** that will not split the lining and will hold until the lining is worn to half its original thickness.

There is only one efficient way to reline a brake and that is to **remove the band** so that you may be sure of what you are doing. The questionable practice of attempting to reline the brakes with split rivets without removing them from the drum is a rather poor gamble, because about every third rivet does not split. Both prongs turn the same way, enlarge the hole through the lining, and have no binding effect.

The **general condemnation of split rivets** arises from the fact that, as usually applied to a band that has been removed from the drum, the prongs are turned lengthwise of the lining, so that they parallel the warp threads. When the prongs are jammed into the lining they cut the cross-threads, or filling, which hold the warp threads together.

Experience has proved that split rivets, except for Ford cars, can never be substituted for tubular or solid rivets properly applied.

Brake lining tools and special machines for locating, drilling, countersinking, and riveting (also for punching the old rivets out) can be secured of the Raybestos Co., Bridgeport, Conn. **There are firms who specialize on brake adjusting, relining, and steering-gear work** exclusively.

THE ELECTRIC AND VACUUM BRAKE

Although the brakes under this heading are not in general use, they will be explained as a matter of information.

The Electric Brake

Construction: The Hartford braking motor (Fig. 32) is shown with reduction gearing. The armature shaft carries a worm gear which drives at a reduction of 100 to 1.

This worm gear in turn operates a drum through an internal gear at a reduction of 4 to 1, giving a total reduction of 400 to 1.

A steel brake pulling cable, which is wound on the drum, transmits the pull of the motor to the brake mechanism.

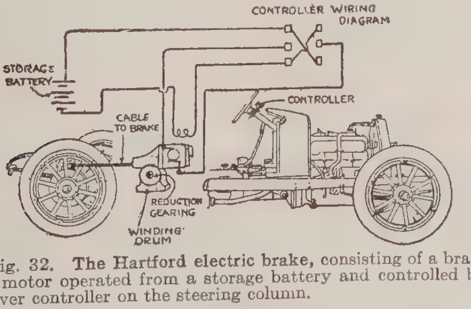

Fig. 32. **The Hartford electric brake,** consisting of a braking motor operated from a storage battery and controlled by a lever controller on the steering column.

The controller is moved by degrees, which applies the brake gradually; or suddenly, if moved to the extreme limit.

The point of decreased speed before coming to a full stop is illustrated by the fact that a car, moving at the rate of 50 miles an hour, or 73 1/3 feet a second, can within 35 feet, or in one half-second's time, be slowed down to 15 miles an hour or 22 feet a second, and can be brought to a dead stop within the next 10 feet.

The current required is 40 amperes for two-fifths of a second, at a pressure of 6 volts.

The Vacuum Brake

This brake is known as the Prest-O-Vacuum brake, and is shown connected with the rear brakes in Fig. 33.

Principle: By utilizing the suction in the intake manifold to exhaust the air from a cylinder (B) carrying a piston, the piston is forced to move, and in its motion applies the brakes through the usual braking system. The extent to which the brakes are applied depends, of course, upon the suction of the cylinder, and this is controlled by the driver through a throttle valve operated either by a pedal or a hand lever.

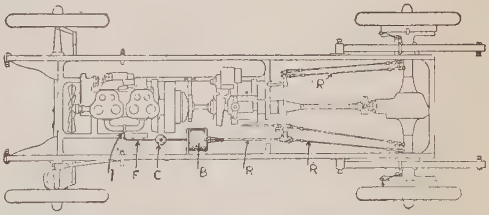

Fig. 33. The vacuum brake.

The general layout of the system when installed on a car is shown in Fig. 33. It will be noted that the forward end of the suction tube is attached to the intake manifold at its junction (I) with the carburetor pipe, this being the point of most constant suction. From here it leads to the throttle valve (C), located convenient to the driver's foot.

The construction and principle involved is similar to the air-brake cylinder used on railway trains, having a pressed-steel shell, a cast-steel head, and carrying a pressed-steel piston with leather packing. This piston has a diameter of 7″, an area of 38½ sq. in., and a stroke of 4″, the entire braking cylinder assembly weighing about 10 lbs.

The suction in the manifold (I) varies from 8 to 12 lbs. per sq. in. When the throttle valve (C) is opened wide, at least 10 lbs. per sq. in. suction is applied to the piston in the braking cylinder. Hence the area of the piston being 38½ sq. in., a suction, or, to be more exact, a pressure, of 10 times 38½ or 385 lbs., is applied to the piston.

The piston, therefore, is moved under a direct pull of 385 lbs., and this in turn is compounded through the toggle-joint connections to give a pull of 4,000 lbs. on the brake rods. This is an extreme example of what the system can do, as a pull of 4,000 lbs. is seldom required, unless on large trucks. It is evident that the pull applied to the brakes may be graded from 0 to 4,000 lbs. at the option of the driver, the pull depending only upon the opening of the throttle valve.

BRAKE LINING SIZES ON 1921 CARS[1]

Name and Model	Length	External Width	Thick-ness	Length	Internal Width	Thick-ness
Ace, LL						
Allen, Series 43	38 3/8	1 3/4	5/32	34	1 3/4	5/32
American, C 6	43	2	3/16	42	2	3/16
Amer. Beauty, 6-55	26	3	5/16	26	3	5/16
Anderson, 30	43 1/2	2	5/32	41 7/8	2	5/32
Apperson, 821-S	48 1/2	2 1/4	3/16	44 3/4	2	3/16
Apperson, Anniversary						
Auburn, 639 H-K	43 1/2	2	3/16	41 7/8	2	5/32
Argonne, 1920	48	2 1/4	3/16	20	2 1/4	3/16
Biddle, B 1						
Bour-Davis, 20						
Bour-Davis, 21 S	43	2	3/16	43	2	3/16
Brewster, 1920				18 10 1/2	2 1 3/4	1/4 3/16
Briscoe, 4-34	29 21 1/2	2 2	9/64 9/64	....	....	....
Buick, K 6-45	43 1/16	1 7/8	5/32	40 15/16	1 5/8	5/32
Buick, K 6-49						
Bell						
Cadillac, 59	53 1/2	2 1/2	3/16	49	2 1/2	3/16
Case, V	48	2 1/2	5/32	46 5/8	2 1/4	5/32
Chalmers, 6-30	43 1/2	1 3/4	3/16	41 3/4	1 1/2	3/16
Champion, C 4						
Chandler, 27	45 1/8	2	3/16	38 1/2	1 3/4	3/16
Chevrolet, 490						
Chevrolet, F B						
Cleveland, 40	21 3/8 38	1 1/2 2	5/32 5/32	Transmission Rear Axle		
Cole, 870	48	2 1/2	5/32	46 5/8	2 1/4	5/32
Columbia, D-C & CS	44	1 3/4	3/16	41 3/4	1 1/2	3/16
Comet, C-53						
Commonwealth, 42	37 7/16	1 3/4	5/32	35 1/4	1 3/4	5/32
Crow-Elkhart, L 53-55						
Crow-Elkhart, H 53-55						
Cunningham, V-4	54	2 1/2	3/16	54	2 1/2	3/16
Douglas, G	46	2	3/16	44	2	3/16
Daniels, D 19	48 3/4	2 1/2	3/16	44 3/4	2 1/2	3/16
Davis, 51-55	44 5/16	2	3/16	40 7/8	2	5/32
Dispatch, G						
Dixie Flyer, H-S-70	19 1/4	2 1/4	3/16	14 3/4	1 3/4	3/16
Dodge Brothers						
Dorris, 6-80	47 1/2	2 1/2	3/16	47 1/2	2 1/2	3/16
Dort, 15	35 3/8	1 5/8	9/64	35 3/4	1 5/8	9/64
Dupont, A	47 1/2	2 1/2	3/16	47	2 1/2	3/16
Economy, 646						
Elcar, 4	35 1/4	2	3/16	38	2	3/16
Elcar, 6	35 1/4	2	3/16	38	2	3/16
Elgin, K	43 7/8	2	5/32	39	1 3/4	5/32
Essex, A	20 3/16	1 3/4	3/16	42 1/2	1 1/2	3/16
Ferris						
Ford, T	23 5/16	1 1/8	5/32	....	....	....
Franklin, S 9-B	28	2 5/8	5/32	23 7/8	3	3/16
Gardner						
Geronimo, 6-E 45	37	1 3/4	3/16	36	1 3/4	3/16
Grant Six, HX	38 3/8	1 3/4	5/32	34	1 3/4	5/32
Hanson, 54						
Harroun, AA-2						
Haynes, 47	....	....	....	31	1 3/4	5/32
H. C. S.						
Hollier, 206-B						
Holmes	28 13/16	3	1/4	41 1/2	2 1/2	1/4
Hudson, O	22 1/4	2 1/2	3/16	20 3/8	2 1/2	3/16
Huffman Six, R	44	2	3/16	42	2	3/16
Hupmobile, R	33 1/8	2	5/32	33 7/8	1 3/4	1/8
Jordan, M	20 3/16	1 3/4	3/16	42 1/2	1 1/2	3/16
Jackson, 638	35 1/4	2	5/32	15 3/4	2	5/32
Jones, 28	49 5/8	2 1/4	5/32	44 1/4	2 1/4	5/32
King, H	48	2 1/2	5/32	46 5/8	2 1/4	5/32
Kissel, 45	44 1/4	2	3/16	....	....	....
Klinekar, 6-55-J	53	2	3/16	31	1 3/4	3/16
LaFayette	58	2 1/2	3/16	51 11/16	2 1/2	3/16
Leach, B-W						
Lexington, S 20	45	2	5/32	24 1/4	2	5/32
Liberty, 10-C	20 3/16 23 13/16	1 3/4 2 1/2	3/16 3/16			
Locomobile, 43	14 15/32	2 1/2	3/16	48 5/8	3	3/16
Lorraine						
Maibohm, B	37 1/2	1 3/4	5/32	35 1/4	1 3/4	5/32
Martin-Wasp						
Marmon, touring, 34 B	47	2	3/16	54	1 1/2	3/16
Maxwell, 1920						
McFarlan, 127						
Mercer, Series 5						
Meteor, K & R						
Metz, M 6	42	1 3/4	3/16	20	1 3/4	3/16
Mitchell, 7-40	40 3/4	2	3/16	40 3/4	1 1/4	3/16
Monitor, S-3						
Monroe, S-9 & S-10	35	2	1/8	31 7/16	1 3/4	1/8
Moon, 6-48	41	1 3/4	3/16	41	1 1/2	3/16
Moon, 6-68						
Moore, 30 G	37	1 3/4	3/16	35 1/2	1 3/4	3/16
Nash, 682						
Nash, 681-6						
Nash, 684						
National Sextet, BB	48	2 1/2	5/32	46 5/8	2 1/4	5/32
Nelson, D	33	1 1/4	5/32	--------	--------	--------
Norwalk, A 30 K						
Noma, 1 B						
Oakland, 34-C	35 1/8	1 7/8	5/32	35	1 5/8	5/32
Ogren, 6-60						
Oldsmobile, 45-B						
Oldsmobile, 37-A						
Olympian, 45	37 7/16	1 3/4	5/32	35 1/2	1 3/4	5/32
Overland, 4						
Owen Magnetic, 60						
Packard, 335	53 5/64	2 1/2	1/4	21 5/32	2	3/16
Paige, 6-42	37 1/8	2	3/16	35 1/4	2	5/32
Paige, 6-55	44	2	3/16	42	2	3/16
Paterson, 647				12 3/4 16 3/16	2 1/2 2 3/4	3/16 3/16
Peerless, 56	19 1/4	2 1/4	3/16	38 3/4	2 1/4	3/16
Piedmont, 6-30						
Piedmont, 6-40	16	2	3/16	14	3	3/16
Pierce-Arrow, 31	18 3/16	3 1/4	3/16	16 7/8	3	3/16
Pierce-Arrow, 51	20 7/8	3 1/4	3/16	19 1/8	3	3/16
Pilot, 6-45						
Porter, 45						
Premier, 6-D	49 5/8	2 1/4	5/32	19 9/16	2 1/4	5/32
R. & V. Knight, R						
R. & V. Knight, J	21 5/8	2 1/2	3/16	20 7/8	2 1/2	3/16
Reo, T-6	43	2	3/16	39	2	3/16
Revere, C	42	2 1/4	1/4	42	1 1/2	3/16
Roamer, C-6-54						
Roamer, D-4-75						
Saxon, 125						
Sayers Six, S P	42 9/16	2	5/32	17 1/4	2	5/32
Scripps-Booth, B-39	35 1/8	1 7/8	5/32	35 3/8	1 5/8	5/32
Seneca, L	39	1 3/4	3/16	36	1 3/4	3/16
Severin Six						
Singer, 20						
Skelton, 35						
Spacke, S 20						
Standard 8, I	16 3/4	2 1/2	3/16	16 3/4	1 1/4	3/16
Stanley Steamer						
Stearns, SKL4						
Stephens, 80	42 9/16	2	5/32	17 1/4	2	5/32
Studebaker, EJ-40						
Studebaker, EH-50	46 3/4	2	5/32	43 1/4	1 3/4	5/32
Studebaker, EG-60						
Stutz, H						
Templar, A-445						
Texan						
Tulsa, E-1	43	2	3/16	42 1/2	2	3/16
Velie, 48	19 13/16	1 3/4	3/16	42 1/2	1 1/2	3/16
Velie, 34						
Vogue, 655						
Vogue, 666						
Westcott, C-48	22 1/4	2 1/2	3/16	20	2 1/2	3/16
Westcott, C-38	20 1/4	1 3/4	3/16	42 1/2	1 1/2	3/16
Willys-Knight, 20	44	2 1/4	3/16	13	2 1/4	3/16
Winther, 61						
Winton, 25	53 1/2	2 1/2	3/16	49	2 1/2	3/16

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[1] From *Motor Age*

[*Continued on page* 897

BRAKE LINING SIZES ON 1920 CARS[1]

Continued from page 896]

	EXTERNAL			INTERNAL		
Car and Model—	Length	Width	Thickness	Length	Width	Thickness
Allen, 43	38 3/8	1 3/4	5/32	34	1 3/4	5/32
American	45	2	3/16	44	2	3/16
Anderson	44	2	3/16	40	1 3/4	5/32
Apperson	49 7/16	2 1/4	3/16	46	2	3/16
Auburn	43 1/4	2	5/32	40 1/2	1 3/4	5/32
Bour-Davis, 20	43	2	3/16	43	2	3/16
‡‡Biddle, H-3	42 1/2	2	5/32	17 1/2	2	5/32
Briscoe, 4-24	2/5/8	1 1/2	5/32	27 5/8	1 1/2	5/32
Cadillac	54	2 1/2	3/16	51	2 1/2	3/16
Case, U	45	2	5/32	40	1 3/4	5/32
Chalmers, 6-30	43 1/2	1 3/4	3/16	41 3/4	1 1/2	3/16
Champion, KO	37	1 3/4	5/32	36	1 3/4	5/32
Chandler	45 1/8	2	3/16	43	1 3/4	3/16
Chevrolet, FB	38	2	3/16	37	2	3/16
Chevrolet, 490	28	1 3/16	3/16	27	1 3/16	3/16
*Cleveland	38	2	5/32	......	......	....
	21 3/8	1 1/2	5/32	......	......	....
Cole	48	2 1/4	5/32	46 5/8	2 1/4	5/32
Columbia	44	1 3/4	3/16	41 3/4	1 1/2	3/16
Comet	45	2	3/16	42	2	3/16
Commonwealth	36	1 3/4	3/16	35	1 3/4	3/16
Crawford	41	2	3/16	38	2	3/16
Crow-Elkhart	38	1 3/4	5/32	36	1 3/4	5/32
Cunningham	55	2 1/2	3/16	55	2 1/2	3/16
Daniels, B	48 3/4	2 1/2	3/16	44 3/4	2 1/2	3/16
Dixie, HS-50	36	1 3/4	3/16	36 1/2	1 3/4	3/16
‡Dodge Brothers	19 1/4	2 1/4	3/16	14 3/4	1 3/4	3/16
Dort, 11	35 3/8	1 5/8	3/16	35 3/4	1 5/8	3/16
Elcar	38	2	3/16	35 1/4	2	5/32
Elgin, H	34 3/8	2	5/32	35 5/8	1 3/4	5/32
Elgin, K	43 7/8	2	5/32	39	1 3/4	5/32
**Essex	20 3/16	1 3/4	3/16	42 1/2	1 1/2	3/16
†††Ford	23 5/16	1 1/8	5/32	.....	.....	....
*Franklin, 9-B	28	2 5/8	3/16	......	......	....
	25	3	3/16	......	......	....
Geronimo	36	1 3/4	3/16	36	1 3/4	3/16
Glide, 6-40	41	2	5/32	40 1/2	2	5/32
Grant	37 5/16	1 3/4	5/32	35 1/4	1 3/4	5/32
Hackett	35 1/2	1 3/4	5/32	36 1/2	1 3/4	1/8
Harroun, AA-1	33 5/8	1 3/4	5/32	35 7/8	1 3/4	5/32
†Haynes	....	......	....	15	1 3/4	5/32
	....	......	...	15	1 3/4	5/32
Hollier, 206	37 1/16	2	3/16	34 13/16	1 1/2	3/16
***Holmes	41	2	1/4	....	......	....
	22	2 1/4	1/4	....	......	....
‡Hudson	22 3/16	2 1/2	3/16	20 3/8	2 1/2	3/16
Hupmobile	33 1/8	2	5/32	33 7/8	1 3/4	1/8
Jones	45	2	3/16	40	2	3/16
Jordan, F	48 3/4	2 1/2	3/16	44 15/32	2 1/2	3/16
King, G	45	2	5/32	43 1/16	1 3/4	5/32
KisselKar	44 1/4	2	3/16	....	......	....
‡Klinekar	29 1/2	2	1/8	27 1/2	1 3/4	1/8
†Le Marne	....	......	....	42	2	3/16
	....	......	....	42	2	3/16
Lenox, O	40	2 1/4	1/4	42	2 1/4	1/4
Lexington, R-19	24	2	5/32	38	2	5/32
Liberty	37 3/16	1 15/16	3/16	23 13/16	2 1/2	3/16
††Locomobile, M-48	48 5/8	3	3/16	14 1/2	2 1/2	3/16
Maibohm	35 1/2	1 3/4	5/32	36	1 3/4	5/32
Marmon	54	2	3/16	47 1/8	1 1/2	3/16
Marshall, K	37	1 3/4	3/16	35	1 3/4	3/16
*Maxwell	38 3/8	1 1/2	3/16	....	......	....
	19 1/2	1 3/4	3/16	....	......	....
McFarlan	54	2 1/2	3/16	49	2 1/2	3/16
†Mercer	....	......	....	17 3/8	2 1/2	3/16
	....	......	....	12	2 1/2	3/16
**Metz	21	1 3/4	3/16	44	1 3/4	3/16
Mitchell, E40 & E42	39 1/2	2	3/16	40	1 1/2	3/16
Moline, L	42 1/2	2	3/16	40	2	3/16
Monitor	36	2	1/8	34	2	1/8
Moon, Victory	41	1 3/4	3/16	41	1 1/2	3/16
Moon, 6-66	42 1/2	2	3/16	37	2	3/16
Moore	38	1 3/4	3/16	35 1/2	1 3/4	3/16
*Nash, 681	40 13/32	2	3/16	....	......	....
	18 11/16	2 1/2	3/16	....	......	....
National, AL & AM	45	2	5/32	43 1/16	1 3/4	5/32
†Nelson, D	....	......	....	33	1 1/4	5/32
	....	......	....	33	1 1/4	5/32
Oakland, 34-B	34 3/4	1 7/8	5/32	35	1 5/8	5/32
Oldsmobile, 37-A	38 1/8	1 7/8	5/32	35	1 5/8	5/32
††Overland, 90-B	38	1 3/4	3/16	12 1/2	1 3/4	3/16
††Overland, 4	31 3/32	2 1/4	3/16	10 1/2	1 1/4	5/32
††Overland, 20	44 1/4	2 1/4	3/16	13	2 1/4	3/16
Packard	53 5/64	2 1/2	1/4	47 1/2	2	3/16
Pan-American	44	2	1/4	40	2	1/4
Paige, 6-40	38	2	3/16	35 1/4	2	5/32
Paige, 6-55	44	2	3/16	42	2	3/16
††Paterson	43	2	3/16	17 3/4	2	3/16
**Peerless, 56	19	2 1/4	3/16	38 3/8	2 1/4	3/16
†Phianna, R	....	......	....	42	1 1/4	3/16
	....	......	....	42	1 1/4	3/16
Pierce-Arrow, 38	18 3/16	3 1/4	3/16	16 13/16	3	3/16
Pierce-Arrow, 48	20 7/8	3 1/4	3/16	19	3	3/16
Pilot, 6-45	45 3/4	2	3/16	43 1/2	1 3/4	3/16
Premier, 6-C	43 3/4	2	3/16	38 3/4	2	3/16
Reo, T6 & U6	43	2	3/16	38 13/16	2	3/16
†Revere, A-B-C	....	1 3/4-1	3/16	....	......	....
Roamer	60	1 3/4	5/32	60	1 3/4	5/32
Sayers, B	38	2	5/32	32	1 3/4	5/32
Scripps-Booth	37 3/4	1 7/8	5/32	35	1 5/8	5/32
Seneca, H-2	37 1/4	1 3/4	5/32	35 1/4	1 3/4	5/32
Singer, 19	96	2 1/2	3/16	96	2 1/2	3/16
Stanley, 7-35	39	2	1/4	37 1/2	2	3/16
††Stearns	47	2 1/2	3/16	20	1 1/2	1/4
††Stephens	42 3/16	2	5/32	17 1/4	2	5/32
‡Studebaker, S-H	19 5/8	2	5/32	17 29/32	1 3/4	5/32
‡Studebaker, EH & EG	20 13/16	2	5/32	18 7/8	1 3/4	5/32
‡Stutz, G	16 1/2	1 3/4	5/32	16 1/2	1 3/4	5/32
†Templar, 445	....	......	....	18	1	3/16
	....	......	....	18	2	3/16
Tulsa, D-1-2-3	88	2	3/16	81	2	3/16
**Velie, 48	19 13/16	1 3/4	3/16	42 1/2	1 1/2	3/16
Westcott, A-48	44	2	3/16	41	2	3/16
Westcott	42 1/2	1 1/2	3/16	40 1/2	1 3/4	3/16
††Willys-Knight, 88-8	44 1/4	2 1/4	3/16	13	2 1/4	3/16
††Willys-Knight, 88-4	44 1/2	2 1/4	3/16	13	2 1/4	3/16
Winton, 24	48 3/4	2 1/2	3/16	44 3/4	2 1/2	3/16
Winton, 25	52 3/4	2 1/2	3/16	49 7/8	2 1/2	3/16
††Willys Six, 89-6	41	2 1/4	3/16	10 3/16	2 1/4	3/16

*Transmission brake.

**External brake in two pieces.

***Rear wheel brake in two pieces.

†Both brakes internal.

††Internal brake in two pieces.

†††Foot transmission brake, low speed and reverse bands.

‡Both brakes in two pieces.

‡‡Internal brake in four pieces.

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[1] From *Motor Age*

INSTRUCTION No. 75

STEERING GEARS: Types; Care of; Adjusting; Lubricating and Overhauling FRONT AXLE: Alignment. FRONT WHEELS: Alignment; Adjusting Front-Wheel Bearings

TYPES OF STEERING GEARS[1]

The two methods of connecting a steering gear with the front axle of a car are the "fore-and-aft" method and the "cross-method," as explained on page 10.

The various types of steering gears are classified under six headings as follows, and as shown on pages 10 and 11.

1. Pinion and sector
2. Worm and sector
3. Worm and worm wheel
4. Planetary
5. Screw and nut
6. Screw and half-nut

Some of the leading makes of steering gears are illustrated on this and on the following pages, together with the method of adjusting.

Jacox Steering Gear

Type: Screw and half-nut type (Figs. 1 and 2); consists of a steering tube, to the lower end of which is attached a double-threaded screw (S). Turning the steering wheel moves the screw (S), which moves the two half-nuts (N). One of these nuts has a left-hand thread and the other a right-hand thread; therefore one half-nut (N) moves upward and the other down.

The two half-nuts (N) bear against two rollers (H) attached to a yoke (L) on a shaft (A), which projects outside of the housing and to which is attached a pitman arm (J) which is attached to the drag link, which in turn is connected to the steering-knuckle arm on the front axle.

Adjustment: If excessive backlash or lost motion develops, it can be taken up by loosening the clamp screw (B), and screwing down on the adjusting screw (D) which is screwed down directly on the thrust bearing (E), which forces down the double-threaded screw (S) and the sliding half-nuts (N) against the yoke rollers (H). After adjusting, lock the clamp bolt (B).

Lubrication: The gear is filled with heavy graphite grease when it leaves the factory. However, this should be thinned occasionally by inserting a little engine oil through the oil plug at the top of the gear housing. The telescoping tubing can be oiled occasionally at oil holes (OH) (Fig. 2).

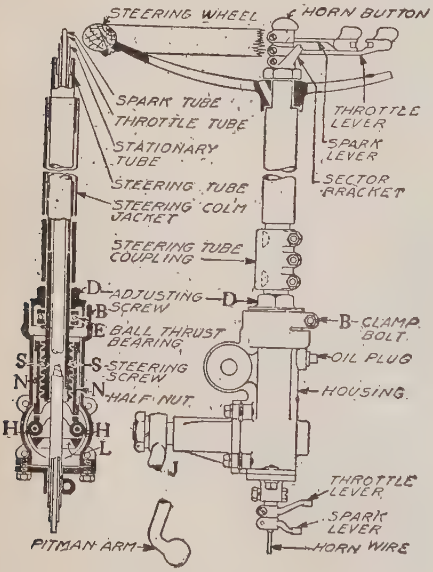

Fig. 1

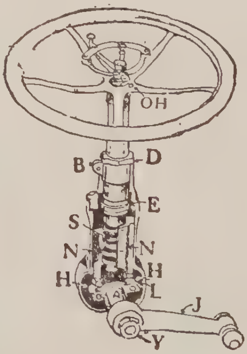

Fig. 2. Hard steering is not always due to adjustment. It may be due to lack of lubrication. The other members of the steering device, such as the drag-link connections, may also be dry. Likewise looseness may be due to the connections. Always keep nut (Y) drawn tight.

Assembling: If the steering gear is taken apart, and the method of steering is **"fore-and-aft,"** the left-hand nut (N) (Fig. 2) should be on top for left-hand steering, and the right nut should be on top for right-hand steering.

If the method of steering is the **"cross-steering"** method, the right-hand nut should be on left side for left-hand steering, but on the right side for right-hand steering.

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[1] Address of steering gear manufacturers: "Jacox," Jackson, Church & Wilcox, Saginaw, Mich.; "Lavine," Lavine Gear Co., Racine, Wis.; "Warner," Warner Gear Co., Muncie, Ind.; "Ross," Ross Gear & Tool Co., La Fayette, Ind.; "Barnes," Barnes Gear Co., Oswego, N.Y.; "Gemmer," Gemmer Mfg. Co., Detroit, Mich.

Warner Steering Gear

Type: Worm (W) and worm-wheel (H) (Fig. 3).

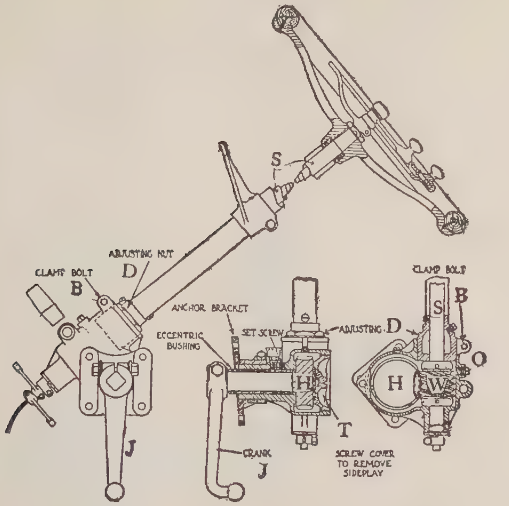


Fig. 3

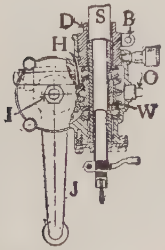
Adjustment: There are two adjustments. The adjusting nut (D) on top of the steering device can be adjusted by loosening clamp bolt (B) to take any up-and-down motion found in the wheel. The worm (W) and worm wheel (H) can be brought into closer contact by adjusting the eccentric bushing (T).

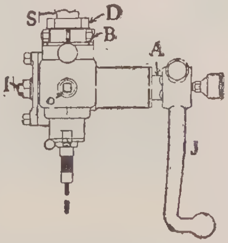
Lubrication: Pack with grease through plug (O). Inject oil occasionally.

Gemmer Steering Gear

Type: Worm (W) and worm wheel (H) (Figs. 4, 5, 6).

Adjustment: The end play in the worm-wheel shaft (A) is taken up by loosening lock nut (L) (Fig. 5) and taking up on adjusting nut (I).





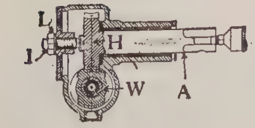


Fig. 4 (upper)
Fig. 5 (lower)

Fig. 6

The second adjustment is made by loosening clamp bolt (B) (Figs. 4 and 6) and tightening adjustment collar (D).

Ordinarily these two adjustments will remove any wear. However, if the wear is excessive and these adjustments will not remove the trouble, the arm (J) should be removed and the steering wheel turned around so that cross-shaft (A) will have turned one quarter-turn. In this position place arm (J) back, and it will be found that a new surface will be given to the gears.

Lubrication: Pack with grease. Oil can be injected occasionally to keep the grease from hardening.

The Lavine Steering Gear

Type: Screw and half-nuts.

Action: Nuts (N) are divided, and operate on right and left-hand threads cut in a worm or double-threaded screw (S). When steering wheel is turned, one nut moves up, the other down, causing (O) to operate arm (J).

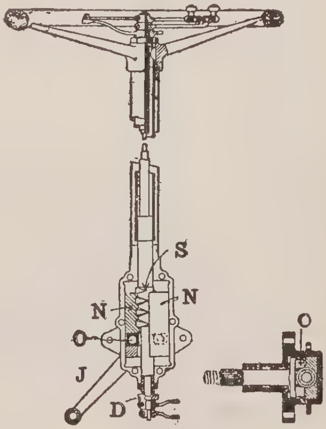


Fig. 7

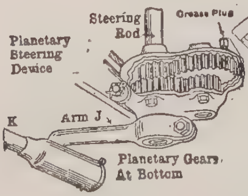
Adjustment is by nut (D) at the bottom.

Lubrication: Grease.

The "Planetary" and "Pinion and Sector" Types of Steering Gears

The planetary type of steering gear (Fig. 8) differs from other types in that there are reduction gears at the bottom of the steering device. This type is used on the Chevrolet "490" and the Overland "4." The "cross-type" steering method is used.

The planetary type is also used on the Ford, but the gears are at the top of the steering column instead of at the bottom, as shown on page 11, Fig. 9; see also Index under "Ford steering gear."



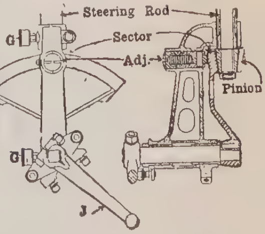


Fig. 8 Fig. 9

Fig. 8. Planetary type of steering gear with the gears at the bottom of the steering device.

Fig. 9. The pinion and sector type of steering gear as used on the Reo.

Adjustment of the planetary type of steering gear: There is no adjustment except to see that all nuts are tight.

Lubrication: Pack with grease.

The "pinion and sector" type of steering gear is shown in Fig. 9, and is that of the steering device used on the Reo model "F" truck, but it serves to explain the principle, as used on other Reo cars.

Adjustment of pinions and sector endwise may be controlled by the adjusting screw. This pinion may be moved up or down by unclamping the locking bolt (not shown) near the bottom of the steering device, allowing the whole steering column to move up or down to give the right engagement. Do not disturb the adjusting screw when making this adjustment.

Lubrication: Inject grease.

Steering Gears Used on Trucks

The steering gears as used on trucks differ but little from those used on passenger cars.

A popular type of truck steering gear is shown in Figs. 10 and 11.

Observe in Fig. 10 the **fore-and-aft method of steering** is shown. This means that the rod (drag rod) which connects from the arm J (Fig. 10) to the steering-knuckle arm has a direct forward-and-backward or aft motion, which turns the steering knuckle as shown in Fig. 19, page 902.

Observe in Figs. 11 and 12, the **cross method of steering** is shown. This means that the drag rod **D** (Fig. 12) is placed ahead of the tie rod (B) and a motion crosswise of the car is imparted to the steering knuckle arms by movement of arm J (Fig. 11).

The **type of steering device** shown in Fig. 10 is the screw-and-nut principle, and the action is explained under the illustration.

The **type of steering device** shown in Fig. 11 is the differential screw principle, and the action is explained under the illustration.

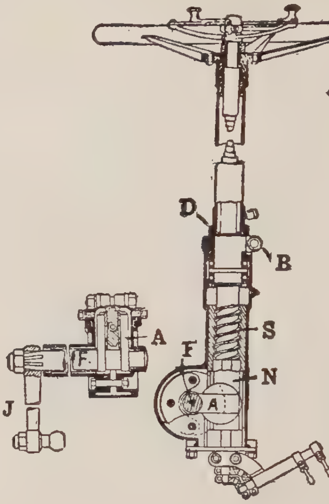


Fig. 10

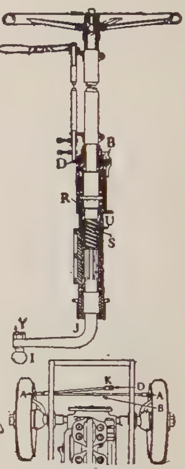


Fig. 11 (upper)
Fig. 12 (lower)

Fig. 10. **Ross "fore-and-aft" steering device for trucks. Type:** screw and nut. **Action:** movement of the steering wheel turns screw (S). This causes nut (N) to travel up or down, which moves (A) (F) and (J). **Adjustment:** loosen clamp bolt (B) and tighten down (D).

Fig. 11. **Ross "cross-type" steering device for trucks.** Note that ball (I) on arm (J) fits into the end of the drag rod (D) at (K) (Fig. 12). **Type:** differential screw. **Action:** arm (J) is caused to turn by a differential action of one screw of fine pitch operating into another screw of coarse pitch. **Adjustment:** loosen (B) and tighten (D). **Lubrication:** oil injected at top.

Fig. 12. Note that the connections are all in front of the axle, and it is thus termed the "cross-steering" method.

EXAMPLES OF ADJUSTING STEERING GEARS

As an example, the "worm-and-worm wheel," or "worm-and-gear" (as it is often termed), type of steering device, as used on the Studebaker "Light Six" is shown below (Fig. 13).

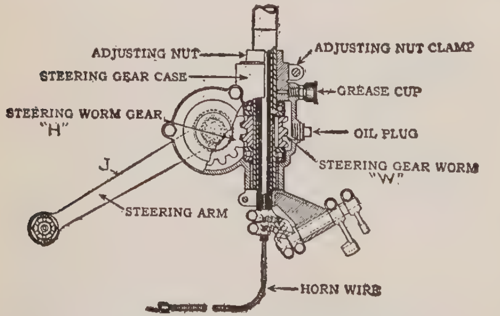


Fig. 13. The **Studebaker "Light Six"** steering gear. **Adjustment:** Jack up the front axle so that the steering device will turn freely. Make adjustment with the steering wheel turned to the extreme right, as if about to turn a sharp corner. There is less wear at this position than in the straight-ahead position, and a tight adjustment in the straight-ahead position would probably be a binding adjustment in the angle position.

In this extreme position work the steering wheel up and down. If the steering column moves up or down, loosen the adjusting-nut clamping bolt, and slowly turn down the adjusting nut until all end play is eliminated; then tighten the clamp bolt.

If there is still backlash, it is an indication that the teeth on the worm (W) and worm wheel (H) are worn. **To adjust:** Remove the steering arm (J). Turn the steering wheel until the steering worm gear (H) has rotated one-quarter around, and replace arm (J) and tighten it. This will permit the engaging of entirely new sets of teeth on the worm wheel and the worm gear.

Lubrication: Usually when a steering gear begins to steer hard, it is due to lack of lubrication. The grease cup is used to lubricate the worm-shaft bearing, and heavy oil is injected at the oil plug.

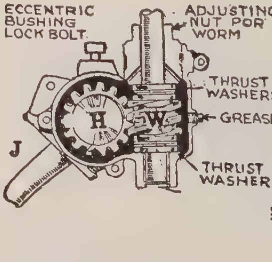


Fig. 14

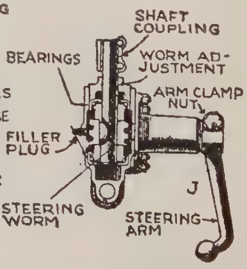


Fig. 15

Fig. 14. **Dodge: Type:** "Worm-and-worm wheel." Both made of hardened steel. **Adjustment:** To remove end play in worm shaft, loosen the coupling or shaft connection (not shown) on the steering column, also the clamping bolt at the top of the steering case. Then screw down the adjusting nut until the play is removed, but not too tight. Tighten the parts which were loosened.

To take up end play between worm (W) and worm wheel (H), remove the eccentric-bushing locking bolt. Then turn the octagonal end of the eccentric bushing, which projects through the frame, until (H) is brought in close contact with (W). Be sure to replace the eccentric-bushing locking bolt, so that it sets between the teeth on the inner end of the eccentric bushing. After long usage the steering lever arm (J) can be disconnected and (H) can be rotated 90° or one quarter-turn, and new teeth are then brought into play. Any end play found in the worm-wheel shaft can be taken up by an adjustment on the side of the steering device (not shown).

Lubrication: Pack cup grease in the steering-gear case at the grease plug, with a grease gun. Turn a grease cup above (H) (not shown) every 100 miles.

Fig. 15. Maxwell "25": Type: "Worm-and-worm" wheel; has two adjustments.

If an excessive amount of end play or lost motion exists, remove the two upper bolts in the steering-gear shaft coupling, and pull the steering wheel and shaft upwards. Then unscrew the steering-arm clamp nut and remove the steering arm with the worm-wheel shaft. The steering-gear worm adjusting-plug clamp screw should then be loosened, and while turning the steering gear with a hand on the coupling about a quarter-turn to the right and left, tighten the plug until the play is taken up.

If there is still lost motion in the steering wheel, remove the steering arm and turn the wheel until the steering-arm clamp has rotated a quarter-turn and replace the steering arm, thus giving the gear and worm a new bearing surface. **Lubrication:** Soft cup grease through the filler plug.

Removing, Disassembling, Adjusting, and Lubricating a Steering Gear (Mitchell "F" as an Example)

The steering gear is of the worm-and-gear type, a complete gear being provided to allow for wear between the worm and the gear. It is irreversible in operation, while ease of steering is obtained by the provision of ball bearings to absorb the thrust.

Removing the steering gear from the car: The throttle and spark connections should be removed from the bottom of the steering column, and the wheel and tube are then removed The side arms should be taken off by removing the clamp screw and pulling the arm off the end of the shaft.

Loosen the screw which supports the steering gear in the bracket riveted to the frame, and remove the entire gear by sliding it in toward the engine free of the bracket, when it can be lifted out of the car.

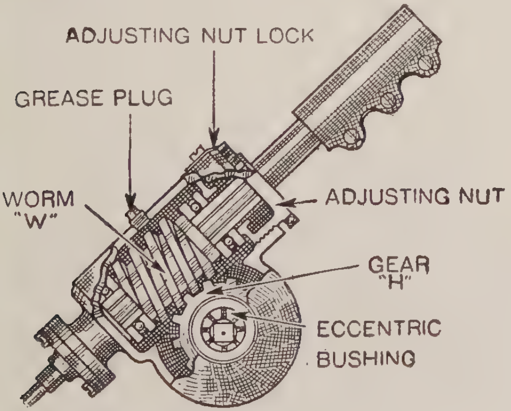


Fig. 16. Mitchell steering gear.

To disassemble the steering gear, remove the steering adjusting nut lock and unscrew the adjusting nut. Remove the cover on the inner side of the steering-gear housing, when the gear with its shaft can be drawn out of the housing. The worm with its ball bearings can then be removed from the housing and the steering gear is completely disassembled.

In adjusting the steering gear it is important first to locate the looseness or play. Do this by having someone move the wheel back and forth, watching meantime to see if the column itself moves up and down, indicating end play in the worm. This can be overcome by tightening the adjusting nut at the top of the housing. If close observation shows end play on the gear shaft, this can be overcome by tightening the gear adjusting screw on the cover.

If there appears to be **play between the gear and the worm,** the steering gear should be removed from the car and the eccentric bushing in which the gear shaft is supported should be moved around until the gear is in proper mesh with the worm. When the bushing has been moved around to the point where all adjustment has been taken up, a new part of the gear can be brought into mesh with the worm by revolving the steering tube until the gear has made one quarter-revolution. A new slot will have to be filed in the square end of the shaft to accommodate the side-arm clamp screw. In making this adjustment, the eccentric bushing should be moved back to give all the adjustment possible with the gear properly meshed with the worm.

If play is found to exist where the side arm goes on the shaft, it can easily be taken out by tightening up the clamp screw. Play sometimes develops **in the drag-link** connections either at the steering gear or at the front axle, and this can be taken out by tightening up the adjusting plugs in the ends of the drag-link connections.

Lubricating the steering gear: About once every season, or every 5,000 miles, the plug on the steering-gear housing should be removed and the housing packed with cup grease. The grease cup on the steering-gear housing should be filled with cup grease and given two or three turns every week or every 500 miles. The **spark-and-throttle-lever rods** in the bottom of the housing should be lubricated with a few drops of oil every 300 miles. The **drag-link connections** at the front axle and at the steering gear should be packed with grease once a season, or every 5,000 miles.

The Marmon Steering Gear

Type: Worm-and-worm wheel (Fig. 17).

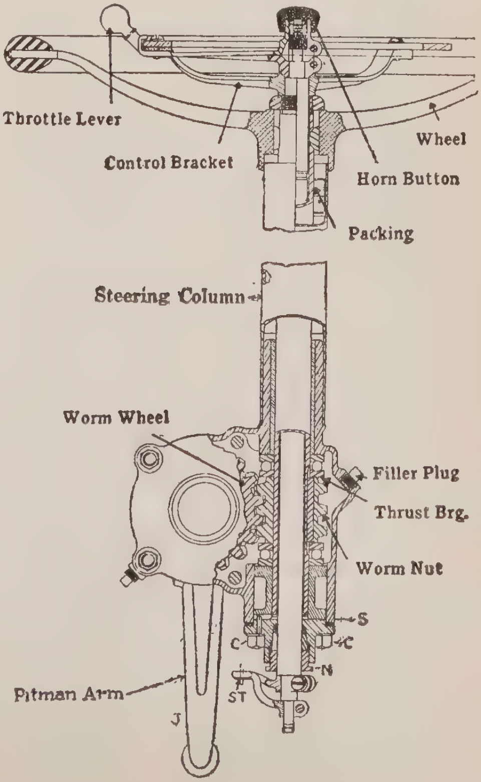


Fig. 17. Marmon steering gear.

The steering column contains five concentric tubes, with respective connections for the four controls at the wheel. Through the center runs the horn wire, surrounded in order by tubes for the throttle, spark, friction ring (stationary), steering wheel, and outer shell. On the lower end of the steering shaft is a worm, provided with thrust bearings, which turns the worm gear operating the steering-crank shaft. If end play develops in the steering shaft, it may be adjusted.

The steering gear may be removed from the frame and disassembled for cleaning and lubricating, but if no change in its operation is detected, refilling of the oil chamber every 1,000 to 3,000 miles is the only necessary attention.

Adjustment: When enough wear has taken place to necessitate taking up some of the lost motion, this may be done by removing one or two of the shims (S) under the plate at the bottom of steering gear.

To do this, disconnect the spark and throttle control arms (S) and (T) at the bottom of the gear and slide them off. Then remove the nut (N) which is around the column and which fits into the bottom plate. Next, remove the four cap screws (C) holding this plate, and it may be taken off without difficulty.

STEERING GEAR TROUBLES, TESTS, AND REMEDIES

The play in the steering gear itself can be taken up by the various adjustments provided.

The up-and-down play of the wheel is taken up by loosening the clamp screw on top of the frame bracket and turning the adjusting nut down. This action forces the shoulder on the column closer to the thrust bearing, as shown in Fig. 18.

Most gears have an eccentric bushing on the side to take up the **play between the worm and wheel,** or sector, as the case may be. There are holes or slots in the eccentric bushing for turning it after the clamping device has been loosened up. If this does not take up the play, there is still **another remedy for the worm and wheel type.**

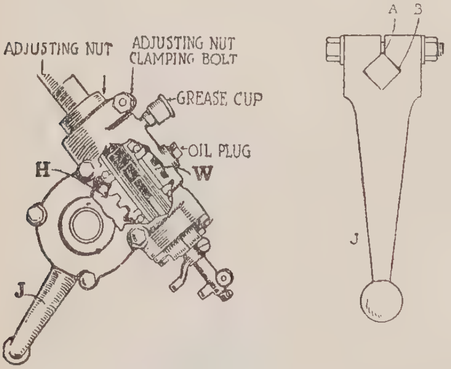


Fig. 18. Method of bringing a new surface of the worm and wheel into engagement to take up the play after all other adjustments fail.

Remove the steering gear by disconnecting all the spark and throttle controls, dash brackets, etc. Then take off the steering arm, and turn the wheel so that the square shaft to which the arm was attached will make a quarter-turn. In other words, the corner (A) will be replaced by (B). Then the arm is clamped back.

This operation brings a new surface of the worm and wheel into engagement, and takes up the play. The eccentric bushing should be turned back, so that it can be used to take up the play in the usual manner, after the steering arm has been changed.

Repack the steering gear with grease, and clean out the oil cups, refilling with clean lubricant. When making adjustments on the steering gear always have the wheels locked over, either to the right or left, as far as they will go.

Loose Steering Connections and Their Relation to the Front Axle

Lost motion in the steering mechanism or connections: The extreme amount of play in a steering wheel should **not exceed a 2″ movement** of the steering wheel.

On the preceding pages it was explained how "up-and-down motion" and "play in the steering gears" could be taken up. If these adjustments fail to relieve the play, then the trouble must be **in the connections from the steering device to the steering connections of the front axle.** The illustration (Fig. 19) shows the connections of the steering device with the front axle and the points where play could exist.

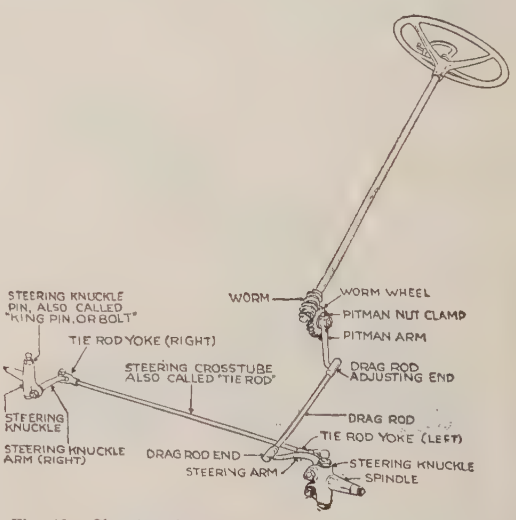


Fig. 19. Showing the principal connections from the steering device to the front axle.

It will be observed that if the play is not in the worm-and-worm wheel, it could be in any of the points from the pitman arm nut clamp to the steering knuckle pin, or it may be due to loose bearings in the front wheels.

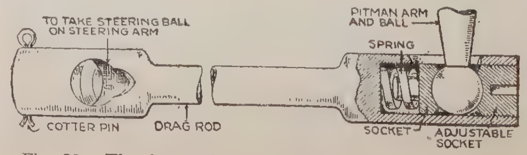


Fig. 20. The drag rod, also called "drag link," "steering-gear thrust rod," etc.

The drag rod or link (Fig. 20) connects the steering ball with the steering arm of the steering knuckle. It should be taken off and the inside cleaned out.

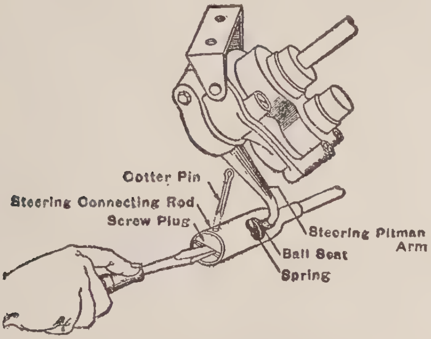


Fig. 21. Method of adjusting pitman arm ball.

Adjustment for this is made by screwing the slotted nut either in or out, and then replacing the cotter pin. Repack the joints with fresh grease, and, if possible, put on a leather boot.

If there is considerable play in the steering knuckles, the bushings should be renewed, and in some cases the steering-knuckle pin itself must be replaced. Always cover the surface well with oil when replacing, as when new parts are fitted there is little space between the walls, and it takes the oil some time to get there.

The steering ball is the ball on the end of the steering arm on the steering knuckle to which the drag-rod connection fits. There is a great thrust imposed upon this ball at all times when the car is in motion, and the nut securing it to the connections should be drawn up occasionally and locked.

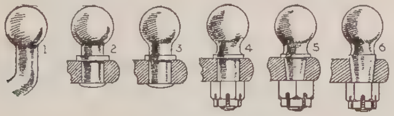


Fig. 22. An evolution of improvements made by the Timken Co. in the steering ball is shown above. The original method is shown in (1), which was integral with the arm. The ball (4) was later produced, and this could be replaced, but it was found that wear would occur in time; therefore a tapered ball with a shoulder was produced as in (5). But this did not provide for "take up," as the take up would draw the shoulder and not the taper; therefore the improved ball without the shoulder (6), and with a tapered shank, permits drawing the ball tight in its seat. Thus there is no limit to the amount of adjustment possible.

Hard or Difficult Steering

Hard or difficult steering may arise from a number of causes as follows:

1. Too tight an adjustment of the steering gears.
2. Lack of lubrication in the steering device, drag link, yoke ends, or steering-knuckle pin.
3. Lack of lubrication or tightness in the connections at the yoke ends of the axle, as well as at the tie rod and steering-knuckle pin bearings.
4. Wheels out of alignment.
5. Tires not properly inflated.
6. Wobbly wheels.

To Test for Steering Troubles

1. Jack up the front wheels.
2. Disconnect the drag link and try the gear thus disconnected.
3. Examine the drag-link and tie-rod connections, and the steering-knuckle spindles.
4. If this inspection does not locate the trouble, loosen the toe-board bracket and see if the steering column is in alignment.
5. See if the steering gear is fastened securely to the frame.

If, on inspection, nothing is found to indicate excessive tightness of the parts, and the steering operates freely when the car is jacked up, yet operates hard when the car is running on the road (with the tires properly inflated), it is evident that the front wheels are out of alignment.

Note. When the car is standing, it is very difficult to turn the steering wheel; do not therefore judge the tightness of the steering gear or its connections except when the front of the car is jacked up and the front wheels are clear, or when the car is in motion.

Never take a steering gear apart except as a last resort.

The lubrication of the steering gear is explained under the different examples given in the pages preceding. In addition, all parts of the steering connections should be kept lubricated, as the grease cups on the tops of the steering-knuckle pins and the steering cross-rod pins should be given two or three turns every week, or each 500 miles.

The steering column on most steering devices is a tube 1¾″ in external diameter.

The steering wheel is usually 18″ in diameter, except on the very light cars.

ALIGNMENT OF THE AXLES AND WHEELS

The word "alignment" or "alinement" means to "line up," that is, to line up the two wheels, or the axles, or the steering knuckles, or the frame, or the springs, or, in fact, any part of the car which should be in alignment with the other like part.

For example, suppose the one side of the front axle has shifted farther ahead than the other side; this throws the front wheels out of alignment on the side that is shifted, and the result is harder steering as well as wear on the side of the tire, as the wheel which is out of line is at all times being drawn sidewise.

Likewise a bent or twisted front axle will cause excessive vibration, especially in the steering, because there are certain angles at which a front axle should be set, and each side should be in alignment. If either is out of alignment, the result is that the part out of alignment is not working in harmony with the other part.

Wheels and axles that are out of alignment produce:

1. Vibration.
2. Excessive wear on tires.
3. Wobbly wheels, in some instances.

Parts which should be lined up are:

1. Front axle.
2. Front axle with rear axle.
3. Springs with axles.
4. Front wheels.
5. Front wheels "toed-in" and "cambered."
6. Front axle and steering knuckle "castered."

Each of these parts, if not properly aligned, will produce one or all of the following:

1. Vibration.
2. Wear on tires.
3. Hard steering.
4. Wobbly wheels.

Alignment of Front Axle

The front axle, if bent or twisted, will cause the wheels to be out of alignment.

In order to check a front axle for a twist or bend at the steering knuckle or at the axle end yoke, one method is to line up the center of each steering-knuckle spindle hole with the other, as shown in Figs. 23 and 24 from **(A)** to **(B)**. This line should be central with the top of the axle and the spindle holes.

If one point is higher than the other, or if the spring seats are out of line, or if the axle is bent or twisted, it should be bent cold if possible; otherwise heat it at the point where it is out of line and straighten it with a press, but do not heat the axle more than a dark red.

If the steering-knuckle yokes are bent, they can be twisted back into place by means of a rod through the yoke holes, thus twisting the yoke back to normal.

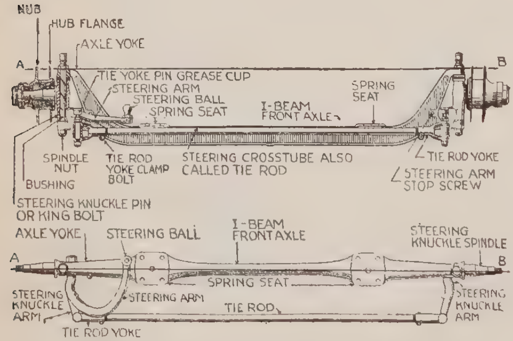


Fig. 23 (upper)
Fig. 24 (lower)

Figs. 23 and 24. Testing for alignment of the steering-knuckle spindles with the front axle.

If play develops between the steering knuckle and the front axle yoke and tightening of the nut does not relieve the play, then it is a case of renewing the bushing, or reaming out the old one and putting in an oversize steering-knuckle pin.

Alignment of the Front Axle with the Rear Axle

Measure the distance on one side of the front axle at the spring seat, at the center of the front axle, to the center of the rear axle, as at **(E)** (Fig. 25).

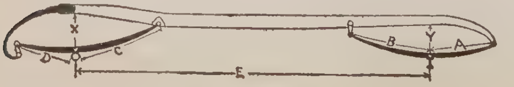


Fig. 25

Then measure the same on the other side. These distances should be equal. If they are not, one of the front wheels, or one of the rear wheels is out of line, thus affecting the steering as well as producing tire wear.

The spring clips can be loosened and the axle slightly moved, if axle proves to have been shifted. If the axle is bent, it should be straightened.

Lining up Springs with the Axle

Measure the distances (Fig. 25) from the horneye of the spring to the center of the axle as shown at **(A)**, **(B)**, **(C)**, and **(D)**, also **(X)** and **(Y)**. The distances should be the same on each side of the car. Measure with a stiff straightedge of some sort, not a tape line.

Alignment of Wheels

This subject is of more importance than one would imagine. For instance, if the wheels are not properly "lined up," there will be wear on the tire, and steering will not be easy. If a car has been subjected to severe jolting or has struck a curb, the wheels may have been thrown out of alignment or the back or front axle may have been moved sideways.

In lining up the front wheels there are four factors to be considered:

1. Trueing up the front wheels.
2. Toeing in the front wheels.
3. Camber of the front wheels.
4. Caster of the steering knuckle.

Trueing up the Front Wheels

In considering the first factor, "trueing up the front wheels," many points are to be taken into account. For instance, **wheels which are not properly trued up are:**

1. Unbalanced;
2. Wobbly.

The fact that the wheels are unbalanced causes the wheels to become wobbly.

The front wheels of the car should be carefully balanced, so that, when the wheel is jacked up and spun, the wheel will come to rest with the valve stem at the bottom.

Factors which cause an unbalanced wheel are:

1. Rim out of true, vertically and laterally, due to unevenness in drawing up the tire bolts or rim lugs, or due to the rim having shifted on the felloe of the wheel, or having been placed out of line on the felloe originally.
2. Heavy blow-out patches in the tire.
3. The wheel itself being out of line.

Should the wheels be badly out of balance, owing to the uneven section of the cover or other part of the tire, a steering "wobble" may be set up at high speed in the steering wheel. This, of course, should be corrected by careful balancing.

FACTORS WHICH PRODUCE WOBBLY WHEELS, HARD STEERING, VIBRATION, AND TIRE WEAR

The principal factors which tend to produce wobbly wheels, hard steering, vibration, and tire wear are enumerated as follows:

1. Wheel bearings worn or loose.
2. Worn steering-knuckle pins or bushings.
3. Steering-knuckle pin nut loose.
4. Steering-gear connections loose, such as the drag rod, steering ball, tie rod, and other connections.
5. Wheels out of alignment.
6. Wheels out of balance.
7. Loose spokes at the hub or felloe.
8. Tire rim out of line on the wheel.
9. A sprung wheel, usually due to skidding force.
10. A bent steering knuckle or yoke end.
11. Front springs out of line, and also the steering ball and steering arm connections on the steering knuckle, which should be in line with the pitman arm on the steering device.

A method of testing the front-wheel bearings to see if they are loose is shown in Fig. 26. In testing for lost motion in front-wheel bearings, a wedge-shaped block or the like should be jammed between the spindle and the axle end, as shown at (**A**), otherwise lost motion in the spindle or knuckle might be taken for looseness in the wheel bearing. After taking this precaution, try to move the wheel as indicated by the dotted lines, and any lost motion in the bearings can be readily felt.

If a wheel is suspected of being out of true, it may be tested as shown in Fig. 27. With one hand resting on a block to steady it, and holding a rule, or the like, close to the wheel rim, the wheel is revolved very slowly; if it is out of true, the space between the end of rule and the wheel rim will vary.

If the trouble is simply due to the rim having shifted on the felloe, it may be rectified as indicated in Fig. 27 (center illustration).

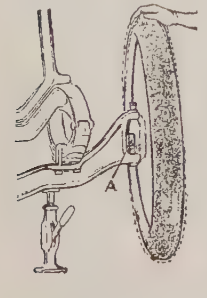


Fig. 26

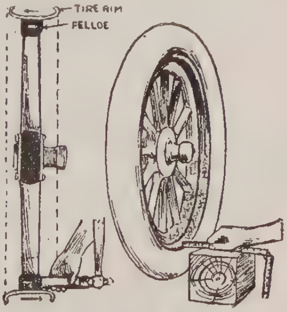


Fig. 27

Fig. 26. Testing for loose front-wheel bearings.

Fig. 27. Testing for a wheel out of true, which causes it to become unbalanced and thus to produce wobbling.

Sprung axle or spindles will either throw the wheels too far out at the bottom, as shown in Fig. 28, or the steering knuckle will be bent either in or out, which will produce wobbling. The point to determine is whether the wheel itself is out of true, by testing as shown in Fig. 27, or if the steering knuckle or axle is out of true by testing as shown in Figs. 23 and 24 (page 904).

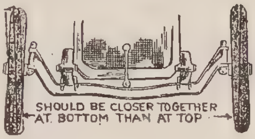


Fig. 28

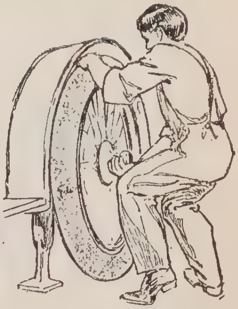


Fig. 29

Fig. 28. Wobbly wheels can be due to a sprung axle yoke or a sprung steering knuckle. Usually, the tendency to wobble is caused by side pressure on the wheels, called "skidding force," due to **skidding** against a car track or curb.

Fig. 29. Testing the rear-wheel bearings for play. Wobbly rear wheels are caused by their being **loose,** or rear axle ends **bent** due to **skidding** against curb or from car tracks.

Testing rear-wheel bearings: Lost motion in a rear-wheel bearing is best tested for by taking hold of the tire with one hand to steady the body, then working the wheel up and down with the other hand, assisted by the knee and lower portion of one leg (Fig. 29). When the right hand is placed on the hub, the right leg is often more conveniently used than the left, as shown in the illustration.

Keep spring clips tight: It is well to notice the spring clips occasionally, especially when the car is new. In fact, it is a good idea to tighten the bolts holding the spring clips occasionally. A loose spring clip will often cause a **disalignment.**

Why tires wear unevenly: Very often, when a front tire has a worn place around the tread, it is due to disalignment. The reason why a right rear tire wears faster than others is the fact that the crown of the road is oval, and also that as most of the driving is done on the right side, the weight is thrown more on that side.

Tighten the hub caps: Occasionally hub caps are lost through carelessness in replacing them after lubricant has been applied. While they should be set up snugly, undue force should not be used, as the threads of the brass member may become stripped. An excellent plan is to screw the caps up tightly, and then to tap the wrench a light blow with the hammer. Sometimes too much lubricant is used, and when tightening the cap, the grease gives one the impression that the cap is snug.

On wire wheels it is very necessary that the hub cap be drawn very tight, otherwise a noise and probable damage will result. See also page 601.

Adjustable stop screws on front axles: Adjustable screw stops (**C**) (Fig. 31, page 906) are provided in the body of the I-beam front axle against which, bosses forged integral with the steering-knuckle arms strike, to limit the cramping angle of the wheels; the amount of this cramping angle is determined by the interference of the tire with the chassis. The stops should be adjusted so that the tire does not come nearer than 1″ to any part of the frame.

CAMBER, TOE-IN AND CASTER; MEANING OF

These terms are often used in the instruction books of the various automobile manufacturers, but their meaning is vague. The following explanations will make them clear.

"Camber" of the Front Wheels

The front steering-knuckle spindles of a front axle are "cambered" about 2°, that is, the front wheels are closer together at the bottom or ground than they are at the highest point directly above.

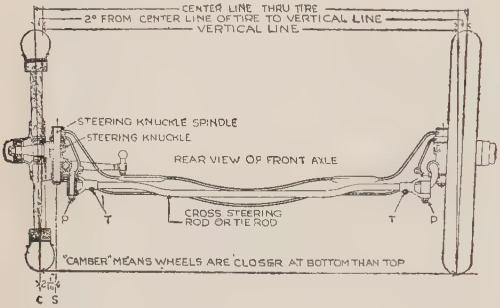

CENTER LINE THRU TIRE
2° FROM CENTER LINE OF TIRE TO VERTICAL LINE
VERTICAL LINE
STEERING KNUCKLE SPINDLE
STEERING KNUCKLE
REAR VIEW OF FRONT AXLE
P
T
CROSS STEERING ROD OR TIE ROD
T
P
"CAMBER" MEANS WHEELS ARE CLOSER AT BOTTOM THAN TOP
2 1/16
C S

Fig. 30. **"Camber"** of front wheels of the Columbia front axle. "Camber" means that the wheels are closer together at the bottom, due to the steering-knuckle spindle being placed at an angle instead of being perfectly vertical; thus the wheel itself is inclined 2°.

By observing the illustration (Fig. 30), which is a view taken when looking toward the front when seated in the car, it will be noted that a center line drawn through the center of the wheel is 2° from the vertical line.

This camber is given to the steering knuckles and spindle when they are machined, by tilting the steering knuckle. If the camber has been lost, due to a heavy shock on the wheels or axle, it can be recovered by bending the front axle between the spring seat and the steering-knuckle yoke. It is best to bend cold if possible. If the axle is heated, do not heat quite red.

The idea of cambering is to make the center line of the spindle bolt coincide, as near as it is practical, with the center of contact of the tire with the ground (C) to (S).

The purpose is to bring the point of contact of the tires with the road more nearly under the spindle pins, or king bolts, thus permitting the car to be steered more easily. Wheels have a tendency to spread apart at the bottom and to come together at top, when speeding.

On the **Ford,** the front wheels are cambered about 3°, or about 1 9/16″, that is, the distance between the front wheels at the top is greater than at the bottom. If a plumb line was dropped through the spindle, it should strike the ground at (S) (Fig. 30), or about 2 1/16″ from the pivot point of the wheel (C). This of course varies on different cars.

"Toe-in" of the Front Wheels

To offset the wearing action on the tires by the "camber," and to produce more even wear on them, the wheels are slightly "toed-in" at the front. An additional reason for this is, that when the car is running at high speeds, the wheels have a tendency to "toe-out." If toed-in too much, or not enough, the treads of the tires will grind.

The term "gather of the front wheels" is also sometimes used instead of "toe-in."

The cross-steering rod is so adjusted, that the distance between the front of the wheels (**A**) is from ¼″ to ⅜″ less than at the rear of the wheels (**B**) (Fig. 31), when measured in front of the tires about half-way up or in line with the horizontal center of the hubs. Usually the measurement is taken from inside of the felloe of one wheel to the other.

Do not compare "toe-in" with "camber," as "camber" means that the wheels are set in at the bottom.

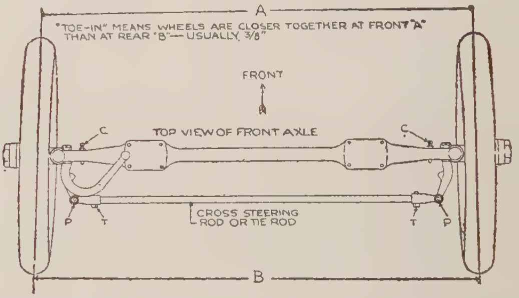

A
"TOE-IN" MEANS WHEELS ARE CLOSER TOGETHER AT FRONT "A" THAN AT REAR "B"— USUALLY 3/8"
FRONT
C
TOP VIEW OF FRONT AXLE
C
CROSS STEERING ROD OR TIE ROD
P
T
T
P
B

Fig. 31. **"Toe-in"** of the front wheels, meaning that the front wheels are closer together at (**A**) than at (**B**). The purpose of the adjustable stop screws (C) is explained on page 905.

The "toe-in" can be adjusted by adjusting the length of the tie rod from one steering-knuckle arm to the other, by removing the tie-rod yoke pin (**P**) (Fig. 31), loosening one or both clamp bolts (**T**), and screwing in or out until the wheels are given the proper adjustment. This adjustment should be made with the wheels on the ground. If inspection shows that the axle or spindles are bent, it will be necessary to have those parts straightened or replaced before correct alignment can be secured.

The average "toe-in" is ⅜″. On the Studebaker, Dodge, and many other cars this is the extent of the "toe-in." On the Ford, it is about ¼″.

As the steering knuckles become loosened from wear, the toe-in will become affected.

To check the toe-in: One method is shown in Fig. 33. Jack up the front axle. Make a center line on each tire as the wheels revolve. Then measure the distance from one line to the other. A straight stick with uprights can be used as shown in Fig. 33. The measurement should be made at points about where the tops of the upright are shown in the illustration, and this distance should be about ¼″ to ⅜″ less in front than at the rear, as at (A) (Figs. 31 and 32). Another method (and one that is more accurate) is shown in Fig. 34.

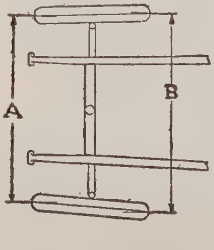


Fig. 32

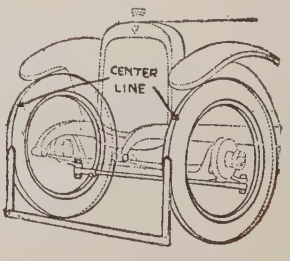


Fig. 33

Fig. 32. Another explanation (in addition to that given in Fig. 31) of "toe-in" of the front wheels.

Fig. 33. One method of checking "toe-in."

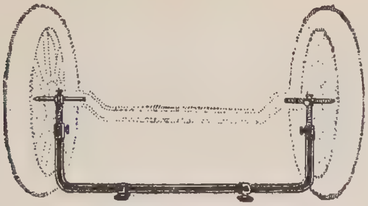


Fig. 34. This illustration shows an automobile **running-gear aligner,** which has a graduated scale and will make exact measurements on the felloe of the wheel, front and rear (instead of from center to center of the tire), at the exact horizontal center of the wheel. (Mfd. by the Mechanical Utilities Corpn., 1348 N. Clark St., Chicago, Ill.)

"Caster" of the Front-Axle Yoke and Steering Knuckles

This subject will require some explanation. We quote from the Timken manual on the subject as follows:

"**Caster steering effect:** You have noticed the casters on a bureau or bed. The little wheel touches the floor at a point to the rear of the caster's vertical axis.

"Because of this the wheel **trails,** and does not tend to change the direction of motion of the bed. Steering the bed in any direction is done with scarcely any effort.

"The principle of caster steering was introduced into Timken Detroit front axles some years ago, but by a construction somewhat different and more effective than that of a bed caster.

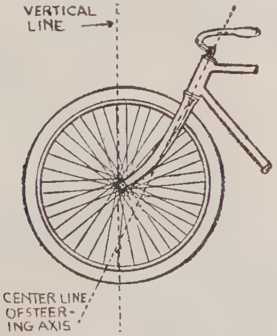


Fig. 35. The steering axis meets the ground in advance of the point of contact of the wheel. This is termed **"caster action."** This is why the handle bar will come back to position when released, and why one can pedal a bicycle with "hands off."

If one strikes a rut or hole with a "caster action," the jar is not nearly as great as if there were no "caster action," or if the frame were vertical.

The caster principle is one that has long been used in the front wheel of a bicycle. The axle is mounted so that it tilts slightly forward at the bottom. As in a bicycle, straight lines passing through the steering heads, or the pins of the steering knuckles, meet the ground a little in advance of the points of contact with the front wheels, so that each wheel really **trails** behind its steering axis.

"That is why the bicyclist can steer without using his hands.

"This particular method of effecting caster steering brings another and a very great advantage to the driver of a car.

"It would require considerable technical discussion to explain what can easily be seen by examining a bicycle. Turning the wheels to the right or left actually raises the body of the car slightly; thus the weight of the vehicle tends to bring the wheels back to the straight fore-and-aft position.

"This gives added security, for, if the steering gear should break or escape your control, the very weight of the car will tend to keep it on its course.

"The safety of Timken-Detroit construction received a remarkable demonstration by a prominent American racing car on the Speedway at Indianapolis.

"The cross-rod connecting the two steering knuckles in the front axle was removed. Thus steering could be effected through the control of only one wheel; the other front wheel was absolutely independent of control.

"With the two steering knuckles thus disconnected, the car was run several times around the Speedway at forty miles an hour."

This "caster" effect is given to the steering knuckle at the factory, and it varies, with different manufacturers, **from 2° to 14°, depending** on the type of car.

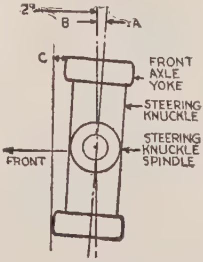


Fig. 36

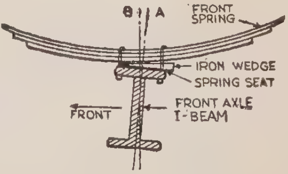


Fig. 37

Fig. 36. The illustration is supposed to represent the end view of a front axle looking at the end of the steering knuckle. Line (**A**) is a center line through the center of the knuckle and axle end, which represents the **"caster"** or angle at which the steering knuckle is inclined from the vertical line (**B**), which is about 2°. The distance at line (**C**) is about 3/16" or ¼".

Fig. 37. An exaggerated illustration showing how to **wedge** between the front spring and the spring seat **to give a "cant" or "caster"** effect to the steering-knuckle spindle on the front axle.

By observing Fig. 36, it will be noticed that the steering knuckle is inclined slightly, at the top, away from the direction of travel. The center of the steering knuckle (**A**) is about 2° off the vertical (**B**).

Thus the front wheels are purposely placed 2° out of perpendicular (or "castered"), in order to bring the point of contact between tire and road more directly under the steering spindle, thus insuring easier steering and less vibration when striking ruts, holes, etc., in the road.

A serious disalignment, perpendicularly, is occasioned only after a very severe shock, and in such a case it is advisable to repair or replace, as soon as possible the front axle or steering knuckle which has been injured to such an extent as to spring it badly.

If the axle is not sprung and is in line, as in Figs. 23 and 24 (page 904), but is tilted forward at the top, instead of backward, it can be temporarily given the caster effect by wedging the front springs between the spring and spring seat, as shown in Fig. 37, which will give a slight cant to the front axle. The wedge can be placed at the front or rear of the spring to give the desired effect.

REMOVING, CLEANING, AND ADJUSTING FRONT WHEEL BEARINGS; ALSO STEERING KNUCKLE PINS

All front-wheel bearings are of the roller or the ball type. The adjustments are given on next page, and full instructions are also given just how to take-up on steering-knuckle pin if loose or worn.

Removing, Cleaning and Adjusting Front Wheel Roller Bearings

As an example, the Timken will be used (Fig. 38). Front wheel bearings in ordinary service should be removed, cleaned, greased, and readjusted at least twice a year. If the service is unusually severe, the condition of the lubricant and the bearing adjustment should be inspected every two or three months.

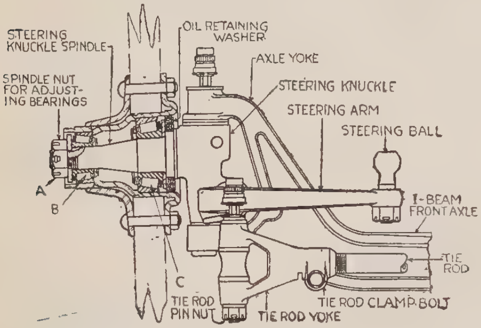


Fig. 38. The Timken-Detroit front axle steering knuckle of the Elliott type.

To remove the bearings, take off the hub cap and jack the wheel up clear of the ground. Wipe the grease from the end of the spindle and take off the **castellated nut (A)** (Fig. 38) after pulling out the cotter pin which locks it.

Now, kneeling directly in front of the wheel, grasp the rim with both hands and pull directly toward you, being careful not to let the outer bearing slip from the hub and fall to the floor, as this may bend or damage the cage so that the bearing will not render perfect service when replaced.

The outer bearing (B) having been removed, lift the wheel off the spindle, exposing the inner bearing.

With a stiff brush and gasoline or kerosene, clean all old grease from the bearings, spindle, and inside of the hub. It is not necessary to remove the inner bearing (C) from the spindle to clean it, although it can be removed if desired.

Occasionally both bearings should be removed, placed in a solution of washing soda and water, and brought to a boil. This cleans off any grease from behind the rollers which may not have been removed by the brush and gasoline.

The bearings having been thoroughly cleaned and dried, replace the larger, or inner, bearing on the spindle, covering it well with good clean grease free from acid, grit, or any solid matter. Care should be taken to have no grit or dirt on the paddle. Pack the inside of the hub between the two bearing cups, and cover the outer bearing with grease.

Adjusting front-wheel bearings: Now replace the wheel and, holding it firmly in position, slide the smaller or outer bearing on the spindle, pressing it firmly into the hub.

Slide on the keyed lock washer and screw the adjusting nut tightly up against it, so that the wheel binds, at the same time revolving the wheel to insure all working surfaces on the bearings coming in contact.

Now **back off** the adjusting nut just enough to allow the wheel to rotate freely, but without noticeable end play. Lock the nut at this point with the cotter pin.

Be sure your bearing adjustment is right before locking it—**the wheel should be loose enough to oscillate,** that is, when spun, it should come to a stop and then start to turn back in the opposite direction, but not loose enough to have any amount of shake.

When your adjustment is correct, cover the end of the spindle with grease and replace the hub cap, screwing it up tightly.

Adjustment of steering-knuckle bearing: Timken heavy-type passenger-car front axles, and some front axles for cars of medium weight, are fitted with a Timken roller bearing in the steering knuckle head (Fig. 38).

To adjust this bearing tighten up on the nut on the bottom of the knuckle pin after removing the cotter pin. This forces the bushing on the lower boss of the yoke up against the steering knuckle, which in turn forces the bearing up into the cup for a proper seat.

Do not fail to lubricate this bearing thoroughly with a good quality of cup grease through the cup on the top of the knuckle pin.

Removing, Cleaning, and Adjusting Front-Wheel Ball Bearings (Chevrolet "490" as an Example)

The front wheel bearings used on Chevrolet cars are of the cup-and-cone type, and are very easily adjusted. See Fig. 39.

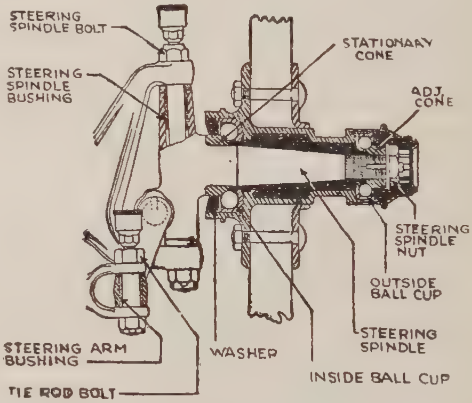


Fig. 39

To keep the bearings clean and well lubricated is an absolute necessity if you are to secure maximum efficiency. Once a month the front wheels should be removed and the bearings thoroughly washed in gasoline or kerosene.

To remove the wheel, unscrew the hub cap, spindle nut, and adjusting cone. (See note below.) The wheel can then be slid off the spindle. The adjusting cones screw on the spindle and can be removed with a wrench, gripping the milled faces. The **hub caps** have right-hand threads, unless wire wheels are used.

The front wheels should fit the steering spindle snugly without end play.

To adjust the bearings, spin the wheel and at the same time screw the adjusting cone up until it is tight enough to stop the rotation of the wheel; then unscrew the adjusting cone just enough to allow the wheel to spin.

Note: The **lock nut and adjusting cone** on the right-hand wheel (as viewed when one is seated in the car) has left-hand threads. To unscrew, turn to the right. The lock nut on the left-hand wheel has right-hand threads. To remove, turn to the left. When the lock nuts are removed, the wheel can be pulled off very easily, as the cone merely slides on the spindle.

Before replacing the wheel, examine the felt washer. If it is damaged, replace it after prying out the retaining washer. Press the cone in as far as possible and slide on the retaining washer. Then turn the cone until the lug on the washer fits into the recess on the back of the cone to prevent its turning. Tighten up the lock nut until the wheel has no perceptible side play on the spindle, but still revolves very freely; then replace the cotter pin and spread it and then screw the hub cap in place.

To lubricate the bearings, remove the hub cap and pack it full of cup grease, and replace. If the bearing is dry, repeat this operation two or three times.

If grease runs out, between the hub of the front wheel and the steering knuckle, the cause is either too much grease or a defective felt washer.

Adjustment of Front-Wheel Bearings and Front-Axle Steering Knuckle (Mitchell Model "F" as an Example)

There are two adjustments in connection with the front axle, namely, the wheel bearings, and the steering-knuckle ball bearing.

Should play develop between the steering knuckle and the axle, it may be taken up by loosening the nut at the bottom of the pivot pin and tightening the pin by screwing it down. It should be tightened just enough to remove the play and not enough to bind the bearing. With the adjustment made, the nut should be replaced on the bottom of the pin and locked with a cotter pin.

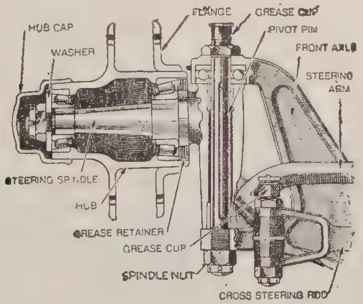


Fig. 40

In reassembling the wheels on the steering knuckles, or in taking up play, the bearings should be carefully cleaned, the hub packed with grease, and the wheel mounted on the spindle with the bearings in place. The washer should then be mounted on the end of the steering knuckle and the nut drawn up. The wheels should be rotated by hand while the nut is being drawn up, and the nut tightened until the wheel binds. Turn the nut back until the cotter-pin hole in the spindle registers with the next slot in the nut. Rap the wheel outward to free the bearings, and see if the wheel spins freely, when the nut should be locked in place with a cotter pin.

The correct adjustment is had when the wheel revolves freely with just a perceptible shake in the bearings.

Grease should be packed inside the hub cap, and the hub cap mounted.

Testing for Play in the Wheel Bearings

Play in the rear or front wheels can be detected by jacking up the car, grasping the rim, and working the wheel laterally (Fig. 26, page 905).

If the wheel shows looseness, the adjustment nut should be tightened. This nut is located within the hub cap, and whatever its shape may be, it is made so that a slight turn makes a considerable change in adjustment. Do not have the wheels too tight, but turn the nut until the wobble disappears.

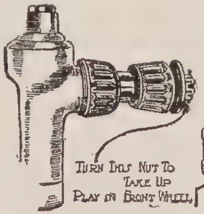


Fig. 41

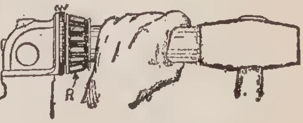


Fig. 42

Fig. 41. Taking up play in a front wheel having roller bearings.

Fig. 42. **A good method of getting the bearing into position** is to slip a short length of pipe over the spindle, against the inner shell of the bearing, and to drive the bearing to its proper place by hammering on the pipe.

In case of ball-bearing wheels, it would be well to take out all the balls and examine them for wear. If any signs of wear are found, remove and replace the worn balls at once. The ball races should be carefully cleaned with gasoline and freed from the slightest suspicion of grit. The same attention as regards cleaning should be given the bearings.

If a "click" is heard when turning the front wheels with ball bearings, look for a broken or cracked ball, and remove it at once, otherwise it will ruin the entire bearing.

Do not fail to see that the felt washer or grease-retainer washer is in place, so that grease will not work out between inner part of the hub and the bearing, when replacing.

To Adjust Steering Knuckle

Steering yoke and knuckle: Wear between the steering yoke and knuckle can be taken up by a thin shim put under the bottom of the steering knuckle if it is worn to such an extent that the adjustment does not take up the wear.

Steering-knuckle pin and bushings: Steering knuckle pins and bushings are usually assembled with a clearance of .005″. This clearance permits a perceptible looseness of the pins in the bushings, but with a closer fit than this, steering becomes stiff.

An Example of Rebushing a Front-Axle King-Pin Bearing

For this example we shall use the front-axle assembly of the Traffic truck. Note the **lower and upper bronze bushing** in the axle yoke which is the bearing surface for the king-pin or steering-knuckle pin.

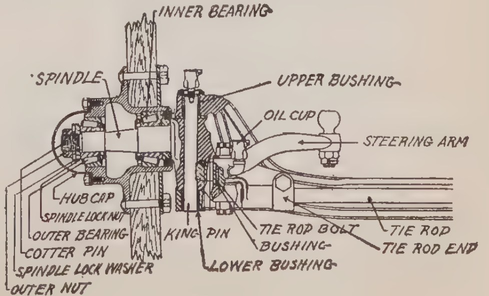


Fig. 43

After most trucks have been in service for a considerable period of time, certain parts of the front axle will become worn to such an extent as to cause "lost mostion" or looseness in steering. This wear depends almost entirely upon the lubrication the various parts receive.

In designing the Traffic truck these points were taken into consideration, and therefore bronze bushings are provided in all such parts as are most subjected to wear. Such bushings will be found at the upper and lower ends of the axle yoke in which the king-pin revolves, and in the tie-rod ends.

There is nothing difficult about replacing the bushings, as the work may be done with the aid of such tools as the average truck owner has in his possession.

To replace the axle bushings it will be necessary first to remove the king-pins and steering spindles. This may be done by raising the front axle until the weight of the truck is removed from the front wheels, removing the steering arms and driving out the steering-spindle king-pins. The bushings may now be driven out with a flat end punch slightly smaller than their outer diameter. The tie-rod end-bushings may be driven out in a similar manner.

The new bushing is now driven in, taking care that it goes in perfectly straight so as not to affect the "line-up" with the other parts. As the bushing will shrink when being pressed in, it is usually necessary to bore out its inner wall slightly so as to make it the exact diameter of the king-pin or bolt it is to receive. This may be done with a special reaming tool, care being taken that it does not wobble or chatter when being turned through the bushing, as this will destroy the bearing surface.

The new part should not bind in the bushing, as this will prevent lubrication, causing the bushing to "freeze" or seize the king-pin or bolt.

TYPES OF FRONT-AXLE STEERING KNUCKLES

Types of Front Axles

The principle of steering an automobile, as explained on page 10, is termed the **Ackerman** principle.

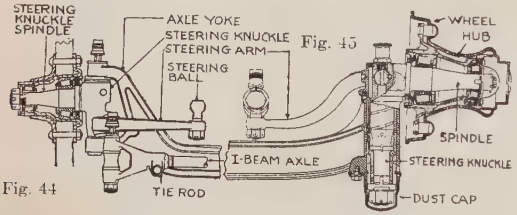


Fig. 44

Fig. 45

The type of **front-axle steering knuckle** in general use is the **Elliott** (Fig. 44).

Another type, the **Lemoine,** used on the Marmon, is shown in Fig. 45.

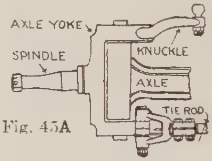


Fig. 45A

In the **reversed Elliott type** (Fig. 45A), the yoke is mounted on the steering knuckle spindle, while the steering knuckle is mounted on the axle. (Used to a limited extent on some large vehicles, such as busses, which permit a very low center of gravity.)

ADJUSTMENTS OF TIMKEN REAR AXLE DRIVE PINION AND BEARINGS

The rear-axle **drive pinion and bearing adjustments** (Figs 46, 47, 48) are on later types of Timken axles than those shown on pages 865, 867.

There are three conditions which make adjustment of drive pinion, differential gears, and bearings necessary: (1) noise; (2) excessive backlash in gears; (3) loose pinion or differential bearings.

Noise is the most common condition—see instructions on pages 865, 867. Be sure the drive-pinion shaft bearings and differential bearings are properly adjusted.

Adjustment of Timken drive-pinion shaft bearing (Fig. 46): Remove cap screws (O) and (X) which hold the bearing cage (L). After removing cage, add or remove shims (M) until properly adjusted, which is about .003" loose, or the thickness of thinnest shim.

Adjustment of drive pinion gear (Fig. 46) **to eliminate noise and backlash,** is made by loosening cap screws (O) and turning (B).

Adjustment of differential bearings is made by tightening up on adjusting rings (J) and (K) as explained on page 865.

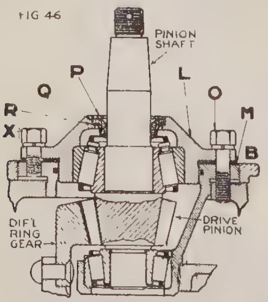
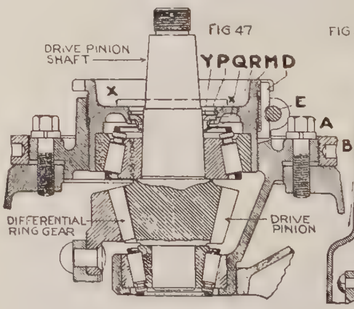


Fig. 46. Timken Model 5014, rear-axle drive pinion adjustment. Note oil seal (Q). Adjustment of **bearings,** by removing shims (M); adjustment of **mesh of drive pinion** and ring gear, by turning (B).

Adjustment of Timken drive pinion for backlash and elimination of noise (Fig. 47): Loosen cap screws (A) and turn adjusting ring (B) about 2" to the left. Tighten (A) and run axle to determine whether noise has increased or lessened. If lessened, continue adjustment by turning (B) to left until quietest point is found. If noise is increased, then adjust (B) to right to obtain quietest running position. Tighten (A).

Adjustment of drive pinion shaft bearing (Fig. 47): Remove lock bolt (E) and lock (D), and turn adjusting cap (M).

Adjustment of differential bearings is made by tightening up on adjusting rings (J) and (K), as explained on page 865.



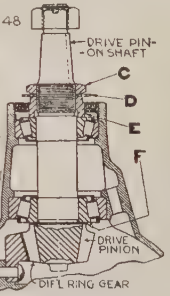


Fig. 47. Timken Models 5114, 5140, rear-axle drive pinion. Note oil seal (Q). **Bearing** adjustment, by turning (M); mesh of **drive pinion** and ring gear, by turning (B).

Fig. 48. Timken Model 0500, rear-axle drive pinion. **Bearing** adjustment, by turning (E); mesh of drive pinion and ring gear, by removing or adding shims (F).

Oil seal: In Figs. 46 and 47 there is a hydraulic cup leather (Q) oil seal used on drive-pinion shaft. The seals need no attention, as a special tension spring (Y) keeps the leather cup tight. After long use it may be necessary to replace (Q). If so, remove lock wire (P) and outer tension spring (Y). This releases the tension on the cup leather (Q) which can be removed. To remove axle-shaft oil seal, it is first necessary to pull out axle shaft from housing. This oil seal is also used on fixed hub types of axle shafts, as on page 883.

Adjustment of Timken drive pinion shaft bearings (Fig. 48): First straighten lock washer (D). Loosen lock nut (C). Tighten adjustment nut (E) until shaft turns freely without noticeable end-play. Tighten (C) and peen over (D).

Adjustment of drive pinion for backlash to eliminate noise (Fig. 48): Move drive pinion in toward ring gear by adding shims (F). To move drive pinion in opposite direction, remove shims (F) as required.

Adjustment of differential bearings is made by tightening up on adjusting ring (J) and (K), similar to explanation on page 865.

INSTRUCTION No. 76

COMMERCIAL CARS: Trucks; Types and Construction; Transmissions; Truck Engines; Governors; Truck Chains; Dump Bodies and Hoists; Trailers; Truck Axles; Worm-Gear Ratio; Taxicabs

Commercial cars include those cars principally used for commercial purposes, such as trucks and taxicabs.

It is interesting to note that the automobile truck and delivery-wagon manufacturers have increased at a very rapid rate, even greater in proportion than the manufacturers of the passenger car.

There were 10,449,785 passenger cars and trucks registered in 1921: a gain of 1,517,327 over 1920, or 16.9 per cent. Thus the importance of the automotive industry and its potential needs is plain.

TRUCKS: GENERAL EXPLANATIONS

Probably the subject of trucks will interest many of our readers, as it is fast taking the place of horse-drawn vehicles. There is not much to be treated under this head, however, as the truck, as a whole, involves precisely the same principle as the pleasure car—with the exception of minor details of construction which will be taken up in their respective order.

Therefore for one to master the truck construction and operation, he has but to refer to the subjects of **engines, carburetion, ignition, lubrication, operating a car, etc.,** discussed elsewhere in these pages.

Truck Motive Power

Motive power used for trucks is derived from:

1. Gasoline engines (used most).
2. Gasoline engines and electric motors.
3. Electric motors.
4. Steam.

Truck Engines

The general principles of the gasoline engines, as generally employed on trucks, are identically the same as those used on pleasure cars; the ignition, carburetion, clutch, and all parts, with minor exceptions, such as governor and starter, and the drive principle, are identically the same. Therefore, if the reader will master these subjects, he will then understand the construction of a truck.

Four-cylinder engines are used mostly on trucks. Some manufacturers use the two-cylinder-opposed type of engine, but not the six, eight, or twelve. See page 936 for a typical truck engine.

The four-cylinder engine is more efficient for truck and tractor use than a six or twelve-cylinder engine. The four has less parts, is simpler to care for, and as its speed is less than that of a pleasure car, the four-cylinder engine is the adopted type for trucks and tractors. See also pages 937, 38, 39.

The main difference between a passenger-car engine and a truck engine is explained below.

Passenger-car engines must be constructed as lightly as possible consistent with strength, so that the total weight of the car can be kept at a minimum. It is rarely ever called upon for its maximum power at any speed, and only a small percentage of developed power is required under normal driving conditions. The result is that the resistance offered the power impulses is small in proportion to the developed power of the motor. Therefore in design, the weight and strength of the reciprocating parts are in proportion to the resistance offered the power impulses in average service. Consequently the engine is lightly constructed throughout, accelerates quickly, and attains a high speed.

Truck engines are called upon for a larger percentage of their developed power at practically all times. Therefore the moving parts are more generous in size, and are designed to withstand greater strains. The engine must operate for long periods of time under a great many unfavorable conditions, such as heat and dust. This calls for more adequate cooling facilities and generous water radiating surface.

Ignition must be positive and simple, and as the speed is limited, and because of the governor action on the carburetion mixture to the cylinders, the magneto is the adopted type of ignition for most trucks.

Starting is usually by hand crank in connection with the "impulse" starter. See also pages 281, 286.

Governor: A great number of trucks use governors. **Gasoline feed** is usually gravity principle.

Truck Drive Methods

The driving methods are:

1. Double-chain drive.
2. Propeller-shaft drive (used most).
3. Two-wheel drive.
4. Four-wheel drive.

The double-chain drive has the advantage of a solid or "dead" rear axle, but has the disadvantage of a chain, which causes considerable wear and jerky action.

The worm-driven rear axle with a propeller-shaft drive method is considered the best. A "live" axle is used, but constructed in such a manner that it is as substantial as a "dead" axle.

The maximum speed of the average truck is 9 m.p.h. for heavy duty, and 25 m.p.h. for light duty trucks.

Types of Trucks

Trucks are classified as to their carrying capacity, and are usually rated as ½-ton, ¾-ton, 1-ton, 1½-ton, 2-ton, 2½-ton, 3½-ton, and 5-ton capacity. Those in greatest use are of 1 and 2-ton capacity.

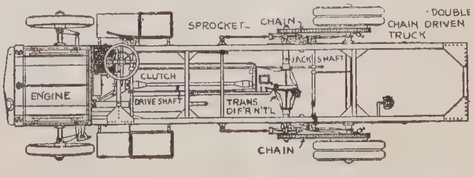


Fig. 1. Top or plan view of a truck chassis using a **double-chain drive.** Note that the rear axle is a "dead" type of axle, and the differential is mounted on the jack-shaft (see pages 6 and 15). The engine is a four-cylinder engine. In fact, most truck engines are four-cylinder (see pages 937, 38, 39).

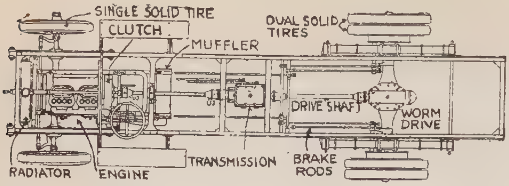


Fig. 2. Top or plan view of a truck chassis using a **propeller-shaft and worm-gear drive.** Note that the rear axle is a "live" type of rear axle. The differential is mounted on the axle shafts.

We shall classify commercial cars in three divisions: motor delivery, trucks, and taxicabs.

When the ½, ¾, 1 and 1½-ton trucks are fitted with pneumatic tires, they are called "motor delivery" or "speed wagons," etc.

How to select a car for commercial use is treated elsewhere. See page 640.

The motor delivery is usually an automobile of the passenger-car class, with a special delivery body, as illustrated in Fig. 3. Inasmuch as this type of car was treated in previous instructions, it will not be further dealt with here.

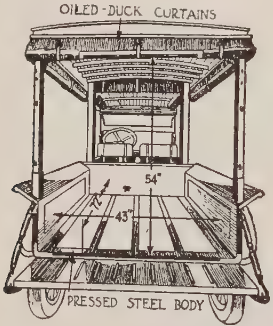


Fig. 3. Dodge light delivery.

The specifications of a light motor delivery are similar to those of the standard passenger car, except that various parts have been strengthened.

The gasoline tank is beneath the driver's seat, and the steering wheel has been set at a higher angle to give a greater loading space.

Maximum load	1,000 to 1,500 lbs.
Tires	33" x 4"
Loading space	72" x 43"
Wheelbase	114"
Clutch	dry plate
Gear ratio	4 to 1
Body	steel, 54"high

The truck is constructed along the same lines, except that the chassis, engine, axle, and all parts are heavier, and the chain or worm drive is usually employed.

Truck Gear Shifts and Gear Ratio

The gear shift is usually the S. A. E. standard three-speed (page 29) for **light-duty** trucks, such as 1-ton capacity and under, and the S. A. E. standard four-speed truck gear shift (Fig. 4) for **heavy-duty** trucks of 2-ton capacity and over.

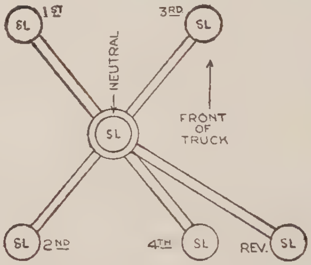


Fig. 4. Standard 4-speed S.A.E. truck-gear shift position.

Gear ratio: Three speeds forward are usually provided on **light-duty** or high-speed trucks under 2-ton capacity. Many of the manufacturers are adding a 4-speed transmission, however.

Heavy-duty trucks of 2-ton capacity and over, are usually equipped with a 4-speed transmission, the ratio of the fourth speed being 1, or **direct drive** from the engine to the rear axle. On some trucks, the fourth speed is higher than the direct drive.

Details of Three Models

Capacity, lbs.	2,000	4,000	7,000
Price	$1,575	$2,200	$3,000
Wheelbase, in.	128	148	168
Tires, front	34x3	36x4	36x5
Tires, rear	34x4	36x6	40x5
Bore	3½	4⅛	4½
Stroke	5	5¼	5½
Horse power	19.61	27.20	32.40
Speed, r.p.m.	1,700	1,300	1,200
Speed, m.p.h.	22	17	9 to 14
Gear, ratio in high gear	7¾-1	8½-1	10¼-1
Final drive	Worm	Worm	Worm

Operating a Truck

It would be merely a repetition to go into details here regarding the operation of a truck, because it involves identically the same principles as explained in connection with the operation of a pleasure car.

Trailers: See Index.

FORD ONE-TON TRUCK

The engine, with its ignition and carburetion, cooling and lubrication systems, is the same as the model "T" (see Ford instruction).

The clutch is the standard Ford multiple disk in oil, delivering the drive to a two-speed planetary gearset in unit with the engine. From here the final drive is by means of a propeller shaft and **overhead worm,** instead of a bevel pinion gear.

From the worm the drive transmission passes through the bevel-gear differential and semi-floating rear axle to the rear wheels.

The Ford truck is rated at 1-ton capacity and has 30" x 3½" pneumatic tires in front and 32" x 4½" in the rear. It can be specially equipped with solid tires on the rear wheels.

The wheel base is 123" instead of 100". **Weight of the truck chassis,** with solid tires in rear, 1,395 lbs.; with demountable rims for pneumatic tires, 1,340 lbs.

The springs are of the same principle as those used in the Ford passenger car, excepting that they are made heavier in the rear to withstand a great load. This is a transverse type, having an arch in the center.

The wheels are of the wood artillery type. **Brakes, steering gear, control system,** etc., are the same as on the model "T."

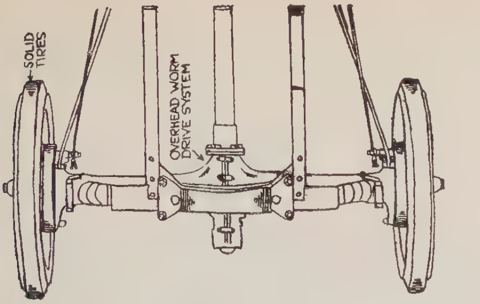


Fig. 5. The Ford worm gear rear axle and heavier springs are the features in which the Ford truck differs chiefly from the Ford passenger car. Pneumatic tires are standard equipment. Solid tires can be obtained specially.

The principal changes are in the rear worm drive, and heavier rear spring and tire equipment.

Tail and side lights are oil or electric. The frame is larger and heavier.

To obtain details of construction, adjustments, etc., other than of the rear axle, see the Ford instruction.

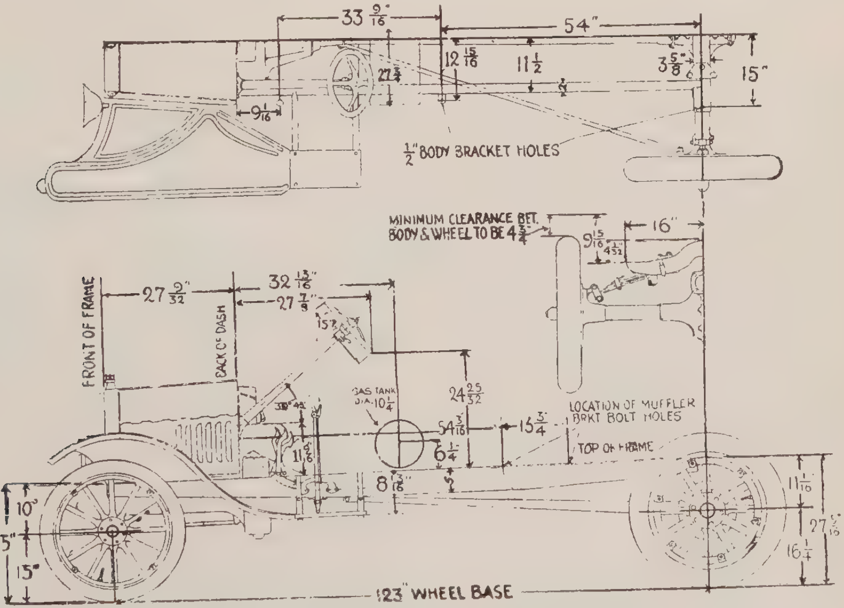


Fig. 6. Dimensions of the Ford truck chassis, from which one can estimate the dimensions for suitable bodies for various purposes.

The Ford truck chassis includes a hood for the motor, front fenders, stepping boards, headlights, tail light, horn, and a set of tools. The starting and lighting system is optional.

The Ford truck may be purchased either with standard or special gearing. The standard gearing gives the truck a maximum of power. The special gearing increases the speed of the truck from five to seven miles an hour, converting it into a fast delivery car.

The rear axle reduction of the worm and gear of the standard gearing is 7¼ to 1 on high gear. The worm gear has 29 teeth, and the worm has 4 threads cut on it; consequently the ratio is 29÷4=7.25. On low gear the total gear reduction is 19.9 to 1, and on reverse 29 to 1. See page 956; "How to compute worm-gear ratio" and also page 8 for the meaning of "Gear ratio."

The rear axle reduction of the worm and gear of the special gearing is 5 1/6 to 1 on high; 14 to 1 on low; and 21 to 1 on reverse speed.

This rear axle is of the "plain live type" construction, because the inner bearings are on the axle shaft and the axle shaft supports the differential.

Ford Truck Specifications Condensed

Engine: Four-cylinder; cylinders cast in block; bore, 3¾"; stroke, 4"; horsepower, 20.

Frame: Heavy pressed steel.

Transmission: Special Ford planetary type; multiple steel disk clutch operating in oil.

Gear ratio: Choice of standard gearing (7¼ to 1) or special gearing (5 1/6 to 1).

Final drive: Worm-gear type.

Starter: Ford starting and lighting system—optional.

Wheel base: 124 inches.

Wheel equipment: Demountable rims, pneumatic tires front 30" x 3½", rear 32" x 4½". (Solid tires for rear wheels optional.)

Capacity: One ton. Price $380. (Elect. starter, etc., $70 extra.)

Speed: With standard gearing, a speed of not more than 15 m.p.h. is recommended, and with the special gearing, a speed of not more than 22 m.p.h. is recommended.

Disassembling Rear Axle and Differential (Ford Truck)

First, remove the entire rear system from the car, which is done as follows:

1. Jack up the frame of the truck to raise the rear. If a hoist is available, it will serve the purpose very well.
2. Disconnect the universal (see Ford instruction).
3. Disconnect the front end of the radius rods.
4. Disconnect the brake rods.

   If the rear spring shackles are now disassembled, thereby freeing the rear system from the frame, the entire rear system may be rolled from the truck.

5. Raise the rear system and support the axle housing near each end. A pair of carpenter's horses will be handy for supports.

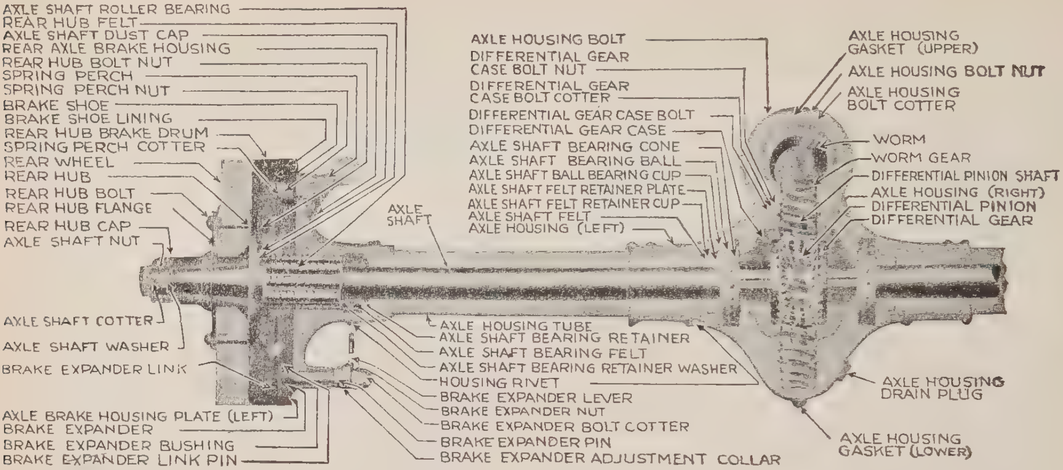


Fig. 7. Ford truck rear axle—longitudinal view.

6. Unscrew the drive-shaft tube-flange screws.
7. Remove the rear-axle housing cap.
8. Take out the bolts which join the two halves of the axle housing.
9. Remove the rear wheels, after which the two halves of the axle housing may be pulled apart, thereby exposing the differential to view.

The differential gear case may now be disassembled.

To remove the worm, proceed as follows:

1. Take out the drive shaft to worm coupling pins.
2. Remove the front-worm roller bearing with its retainer and felt. These can be slipped over the coupling.
3. Now drive the coupling from the drive shaft after which the worm should be forced from the coupling.
4. Unscrew the worm-thrust bearing-retainer nut, after which the retaining washer, thrust bearing, and rear-worm roller bearing can be taken off.

The differential gears fit on splines cut on the axle shaft. They are held in place by means of two half-rings which fit into a groove cut in axle shaft.

To remove, force them toward the wheel end of shaft, and drive out the two half-rings. Then force the gear off the differential end of the shaft.

Reassembling

In reassembling the system, take care to replace parts correctly and to use new paper liners.

Lubrication of the rear axle is accomplished by the use of a good semi-fluid oil, and it is only necessary to see that an adequate supply is in the axle housing. A new truck should have its axle lubricant changed after 500 miles, again after 1,000 miles, and thereafter whenever the condition of the lubricant demands it. Two grease cups insure the lubrication of the axle-shaft roller bearings. These cups should be filled with cup grease and should be given one complete turn every 100 miles.

After reassembling a rear axle, the truck should be jacked up; the differential should be filled with oil, and then run for 10 minutes to allow the lubricant to reach all parts.

Adjustments: As on the Ford passenger car, there are no adjustments on the rear axle. When the parts are worn they are replaced, the parts costing less than the repair.

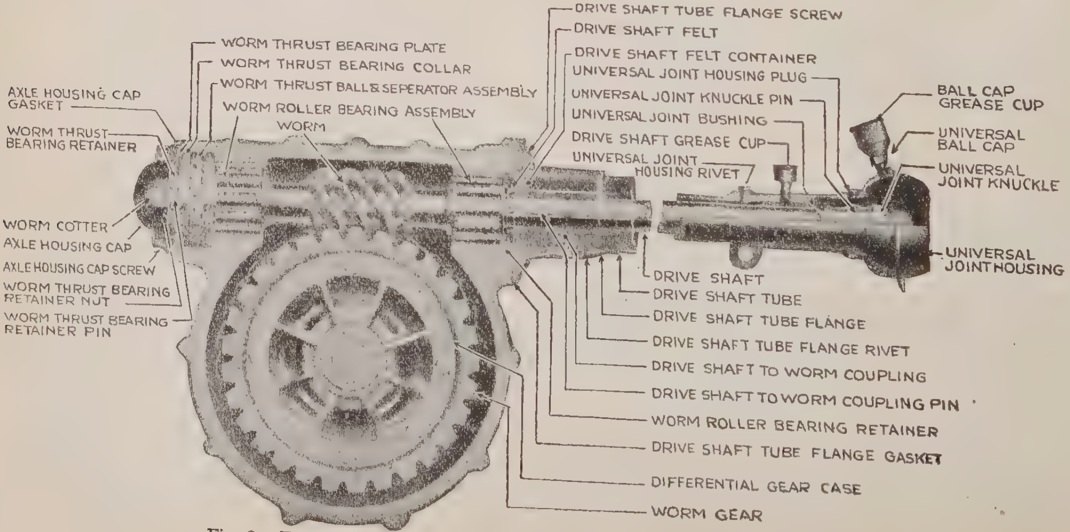

AXLE HOUSING CAP GASKET
WORM THRUST BEARING RETAINER
WORM COTTER
AXLE HOUSING CAP
AXLE HOUSING CAP SCREW
WORM THRUST BEARING RETAINER NUT
WORM THRUST BEARING RETAINER PIN
WORM THRUST BEARING PLATE
WORM THRUST BEARING COLLAR
WORM THRUST BALL & SEPERATOR ASSEMBLY
WORM ROLLER BEARING ASSEMBLY
WORM
DRIVE SHAFT TUBE FLANGE SCREW
DRIVE SHAFT FELT
DRIVE SHAFT FELT CONTAINER
UNIVERSAL JOINT HOUSING PLUG
UNIVERSAL JOINT KNUCKLE PIN
UNIVERSAL JOINT BUSHING
DRIVE SHAFT GREASE CUP
UNIVERSAL JOINT HOUSING RIVET
BALL CAP GREASE CUP
UNIVERSAL BALL CAP
UNIVERSAL JOINT KNUCKLE
UNIVERSAL JOINT HOUSING
DRIVE SHAFT
DRIVE SHAFT TUBE
DRIVE SHAFT TUBE FLANGE
DRIVE SHAFT TUBE FLANGE RIVET
DRIVE SHAFT TO WORM COUPLING
DRIVE SHAFT TO WORM COUPLING PIN
WORM ROLLER BEARING RETAINER
DRIVE SHAFT TUBE FLANGE GASKET
DIFFERENTIAL GEAR CASE
WORM GEAR

Fig. 8. Ford truck rear axle—cross-section showing worm and worm gear.

G.M.C. MODEL "K41" TWO-TON TRUCK

Specifications

This model is built in two lengths: type "A," 146″ wheel base; type "B," 158″ wheel base.

Load capacity: 4,000 pounds, with additional maximum allowance of 1,500 pounds for body equipment.

Engine: G.M.C. design and manufacture; four-cylinder "L" head, water cooled; bore 4″; stroke 5½″.

Horse power: By S.A.E. formula, 25.6; actual horse power at governed speed, 37.

Cylinder and crank case: Cast in unit; cylinders, removable sleeve type.

Lubrication: Positive pressure system from gear pump, forcing oil with constant pressure to all bearings of engine; chassis lubrication by pressure-gun system.

Governor: Fly-ball type of special manufacture.

Carburetor and fuel supply: G.M.C. two-jet type of carburetor with special heated intake manifold; fuel by gravity from sheet-steel tank of 20½ gallons capacity.

Cooling: Combination pump-driven and thermo-siphon; pump capacity approximately 20 gallons per minute.

Radiator: Continuous fin, tubular, built-up type; capacity 7½ gallons.

Ignition: High-tension magneto with impulse-starter coupling.

Clutch: Multiple-disk dry-plate type of special manufacture.

Transmission: G.M.C. selective two-range transmission, each range having four forward speeds and one reverse; in unit with the engine; provisions for tire pump and power takeoff.

Rear axle: Worm drive, full floating, with gear ratio of 7.25 to 1; drive through radius rods from rear axle to frame.

Frame: Pressed open-hearth steel, heat treated.

Brakes: Service and emergency, both internal expanding; interchangeable brake rods, meaning that when the foot-brake linings become worn, the pedal may be connected to the hand-brake linings, which are usually in good condition, because the hand brake is not used as much as the foot brake. The hand-brake lever is then connected with the old foot-brake linings which are sufficient to hold the truck, as the hand brake is only used to lock the truck when stopped.

Wheels: Metal, hollow-spoke type.

Tires: Solid, 36″x4″ front; 36″x7″ rear. Pneumatic, non-skid cords, 36″x6″ front and 40″x8″ rear, supplied at extra cost.

Maximum body length: A, 11½ ft.; B, 13½ ft.

Road Clearance: Rear axle, 9½″, solid tires; 12″ pneumatic tires.

Turning radius: Type "A," 28½ ft.; type "B," 31 ft.

Weight of chassis: Type "A," 5,245 pounds; type "B," 5,285 pounds.

Controls: Left-hand steering and center control; spark and throttle levers located on segment with connections outside of steering column; foot throttle operated by driver's right foot; ignition and light switches, oil gauge, ammeter, and choker throttle located in instrument case on dash.

Equipment: Electric headlamps mounted on radiator side members, electric tail lamp, generator and storage battery, horn, tool kit, and jack.

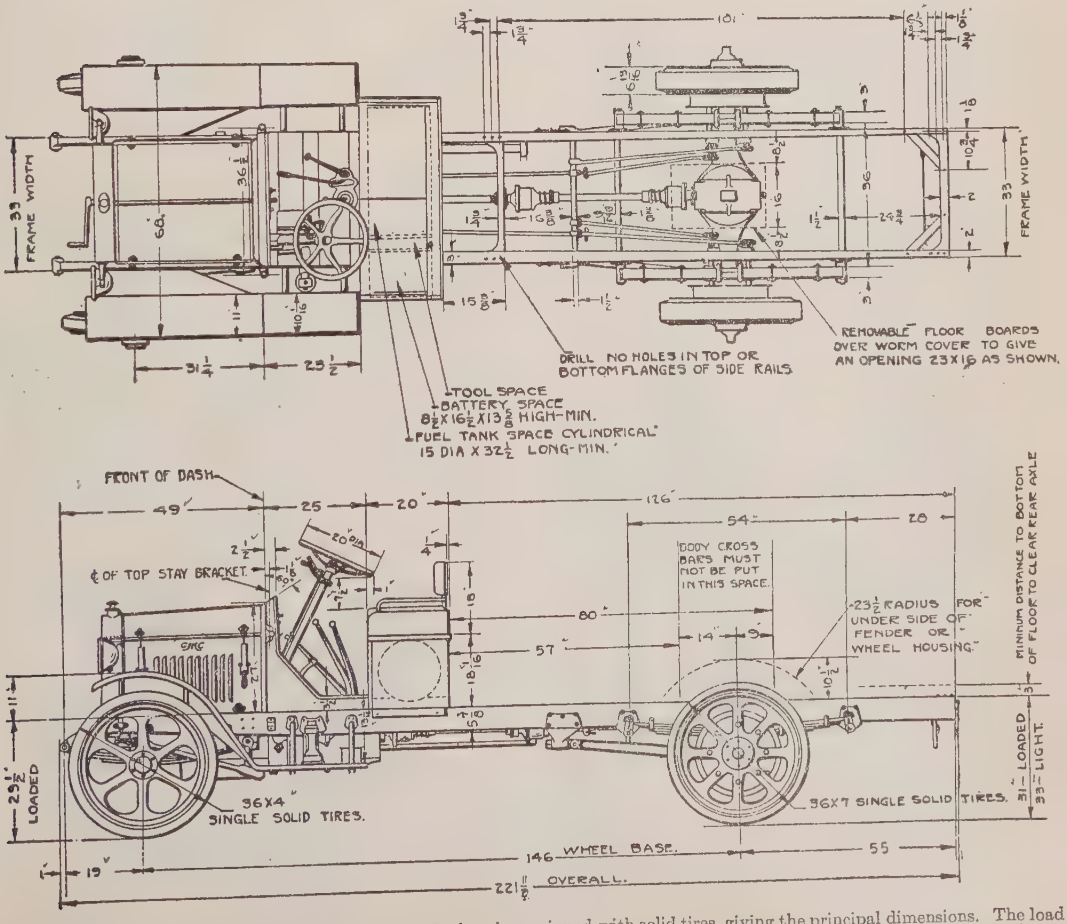

33 FRAME WIDTH
101
68
36½
31¼
25½
15⅝
24¾
33 FRAME WIDTH
DRILL NO HOLES IN TOP OR BOTTOM FLANGES OF SIDE RAILS
REMOVABLE FLOOR BOARDS OVER WORM COVER TO GIVE AN OPENING 23X16 AS SHOWN.
TOOL SPACE
BATTERY SPACE 8½X16½X13⅝ HIGH-MIN.
FUEL TANK SPACE CYLINDRICAL 15 DIA X 32½ LONG-MIN.
FRONT OF DASH
49
25
20
126
54
28
20 DIA
℄ OF TOP STAY BRACKET
GMC
BODY CROSS BARS MUST NOT BE PUT IN THIS SPACE.
80
57
14
9
23½ RADIUS FOR UNDER SIDE OF FENDER OR WHEEL HOUSING
MINIMUM DISTANCE TO BOTTOM OF FLOOR TO CLEAR REAR AXLE
29½ LOADED
36X4 SINGLE SOLID TIRES.
36X7 SINGLE SOLID TIRES.
31 LOADED
33 LIGHT
19
146 WHEEL BASE.
55
221½ OVERALL.

Fig. 9. **Top and side view of G.M.C. 2-ton truck chassis,** equipped with solid tires, giving the principal dimensions. The load capacity is 4,000 lbs. In addition to the body for which 1,500 lbs. is allowed. When the load of 4,000 lbs. is removed, the frame will rise 3″.

The main features in which the G.M.C truck differs from other trucks is in the **two-range transmission** and the **engine cylinders fitted with sleeves.**

Engine

Engine: 4-cylinder "L-"type; detachable head. Removable cast-iron cylinder sleeves (or barrels) pressed into the cylinder block are used. These sleeves can be removed when worn and new ones substituted. Thus if a cylinder is scored, or if the cylinder wall is damaged, it is not necessary to re-bore; pull out the sleeve and substitute a new one.

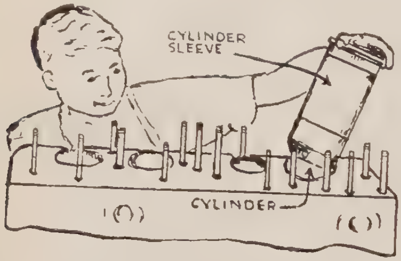


Fig. 10. Illustrating a "cylinder-sleeve" removed from the cylinder block. The piston moves in this sleeve.

To remove the sleeves, the cylinder head is removed and the oil pan is removed so as to remove the piston and connecting rod. The sleeve is withdrawn and replaced by a special assembly tool (Figs. 11 and 12), explained as follows:

To Remove Cylinder Sleeve

To remove the sleeve, first take off the cylinder head and oil pan, and withdraw the piston and connecting-rod assembly from the cylinder to be replaced.

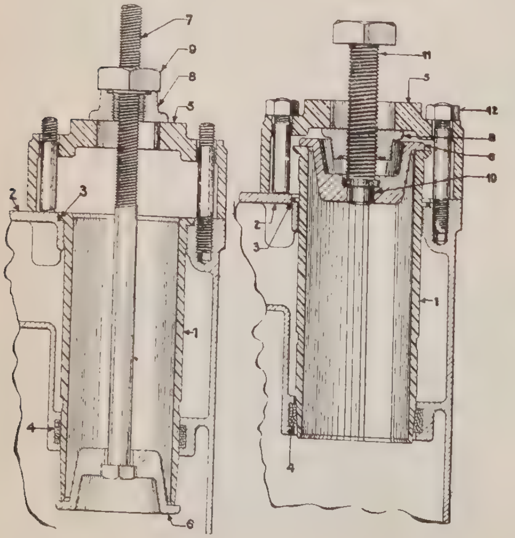


Fig. 11 Fig. 12

Fig. 11. Removing the cylinder sleeve.

Fig. 12. Replacing the cylinder sleeve.

Refer to Fig. 11 for an assembly of the tool in place for withdrawing the damaged sleeve. First, insert the long bolt (7) in the bottom plate (6) and place this in the sleeve (1) as shown by illustration. Put the upper part (5) over the cylinder so that its edges clear the top of the sleeve, as shown, and slip the spacer nut (8) over the bolt and, by turning the nut (9), pull the bottom plate (6) up to the position shown. Part (5) is used on all three sizes of G.M.C. engines, and has been so designed that there is a position on each cylinder where it will clear the studs so that it is not necessary to remove the cylinder-head studs.

Make sure that the bottom plate (6) is well centered on the bottom end of the sleeve, and then tighten the nut (9) until there is a good strain on it. Then strike the top of the bolt (7) a good sharp blow with a hammer, which should break the sleeve loose from its seat, and then, by turning the nut (9), pull the sleeve up until the top end of it comes in contact with part (5). Then remove the tool plate, etc., and by prying under the bottom edge of the flange on the top of the sleeve at two opposite points it will be possible to pull it the rest of the way out.

To Replace Cylinder Sleeve

Before replacing the sleeve, clean out the old gasket (3) in the corner of the recess at the top of the cylinder block for the flange of the sleeve, and put in a new gasket (Fig. 12). Also, remove the cork gasket (4) from the groove in the cylinder and clean the groove out thoroughly and put in a new cork ring, taking care not to break it when putting it in. If the cork is soaked in warm water, it will be easier to handle it.

To insert a new sleeve first paint lightly the entire outside of it with a mixture of red lead and machine oil. Then push it down into place as far as it will go by hand, and tap it down with a lead hammer or wooden block until the replacing tool can be put on as shown in Figs. 12 and 13.

Plate (6) should be inserted in the sleeve as shown, and in its center should be dropped plug (10). Slip the bolt (11) through part (5) as shown, and screw on the nut (8) so that the bolt is just flush with the bottom of the nut. Then place part (5) over the top of the sleeve in such a position that two opposite cylinder-head studs will project through the holes in part (5) so that the cylinder-head nuts can be put on to hold part (5) down on the cylinder head. Tighten up the cylinder-head stud nuts (12) and then screw down bolt (11) (Figs. 12, 13) and push the

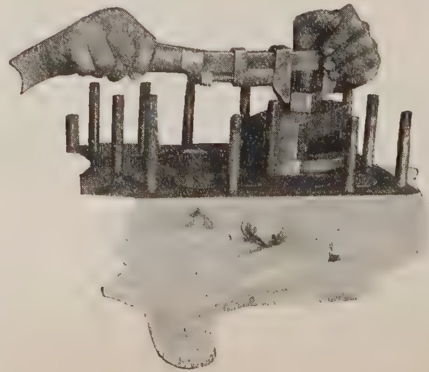


Fig. 13

sleeve down in place. The process of pushing down can be assisted by tapping the top of bolt (11) with a lead hammer from time to time as it is screwed down. Make sure that the top of the sleeve flange goes down until flush with the top of the cylinder head, so that the cylinder-head gasket can be properly seated.

G.M.C. Manifold and Jackets

Exhaust gas from the manifold is employed to heat the in-going fuel and air. Fig. 14 shows a section through the center of the intake and exhaust manifolds, governor-throttle body, and carburetor.

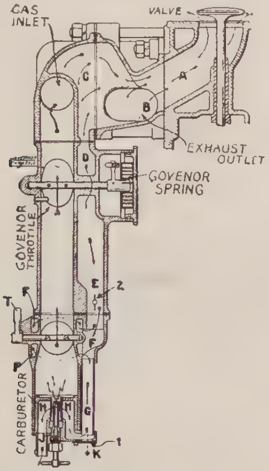


Fig. 14. G. M. C. combined inlet and exhaust manifold.

Principle: Exhaust gas leaving the cylinders at (**A**) enters the exhaust manifold where the major portion of it goes out through (**B**) to the muffler. Some portion of it, however, takes the course indicated by the arrows and strikes the wall of the intake manifold at (**C**). Some of the gas goes down back of the governor-throttle body as indicated at (**D**), and passes on through (**E**) to the heat jacket (**F, F, F**) surrounding the upper part of the carburetor.

From this point, it goes down through the tube (**G**) and circulates through the space around the low-speed jet at (**H**) and passes out into the atmosphere at (**J**).

Adjustment: In very warm weather it may be found that this system provides too much heat, and that an excessive amount of heat reduces the power considerably.

In order to control the amount of heat used, two adjustments are provided. The first of these is the shutter (1). When open, it allows the exhaust gas to escape at (**K**) instead of circulating through (**H**) and going out at (**J**). This prevents preheating of the fuel and of the in-going air at the low-speed jet.

Should there still be too much heat with the shutter (1) open, the damper (2) may be partially or entirely closed. As will be seen from the drawing, this damper may be used to close off the passage from the throttle-body jacket (**E**) into the carburetor jacket (**F**).

This damper is provided with a lock nut on the outside to hold it in any position desired. The (**T**) handle on the damper is parallel to the butterfly valve on the inside, so that the position of the handle on the outside indicates the position of the valve inside.

Electric System

The Remy generator with third-brush regulation and thermostat control with cut-out on the top of the generator is used. See page 362 for explanation of this type of generator.

Ignition: The ignition is by means of an Eisemann high-tension magneto entirely independent of the electric system. An **impulse starter** is used. The timing order is 1, 3, 4, 2. The breaker gap on the magneto is .012.

To check the ignition timing: Turn the engine over by hand until No. 1 piston is at the top of its compression stroke. In this position, the setting mark (see page 269; "Eisemann magneto type G4") on the rotating distributor disk should be just under the set-screw pointer at the top of the magneto frame. If it is not in this position, the timing is incorrect and the coupling should be re-set.

To re-set the coupling, leave the engine on top of dead center of No. 1, as described above, and loosen the two clamping screws on the forward end of the impulse coupling. When these screws have been loosened, turn the magneto **backward** until the setting mark (**R**) (Fig. 2, page 269) is under the setting point. Then retighten the clamping screws on the magneto coupling. When tightening the adjusting screw, make sure that the loose intermediate insulating disk of the coupling is not pinched endwise. It should have 1/50″ end play.

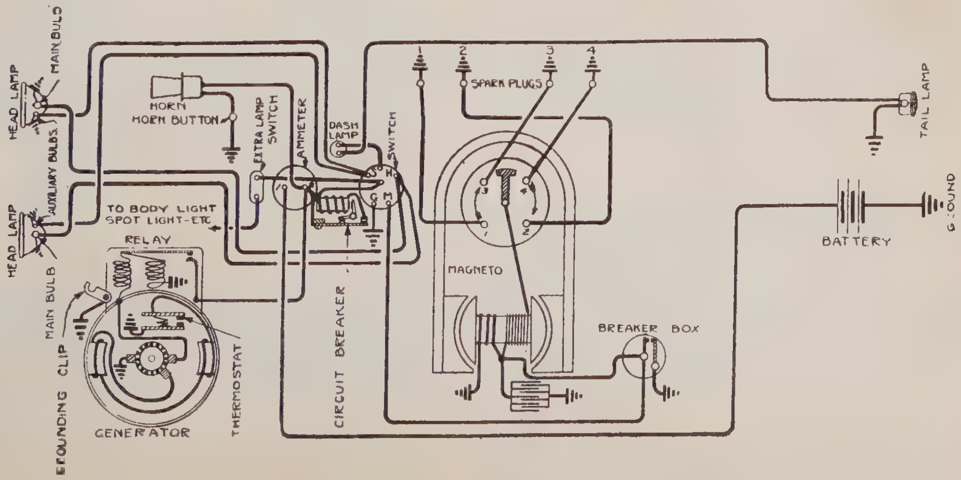


Fig. 15. Wiring diagram of G. M. C. truck.

G.M.C. Two-Range Truck Transmission

When a truck is operating under difficult road conditions, it is desirable to have a large gear reduction. When a truck is operating under good road conditions, it is desirable to have a small gear reduction.

In practical trucking, it is often necessary to operate the same truck part of the time under good road conditions, and part of the time under poor road conditions. Consequently it would be desirable to have a truck with two different transmissions, either of which could be used at the driver's option.

In order to accomplish this result, it is only necessary to take a standard transmission and have an extra pair of gears between the main shaft and the counter shaft. This is called the **two-range transmission.**

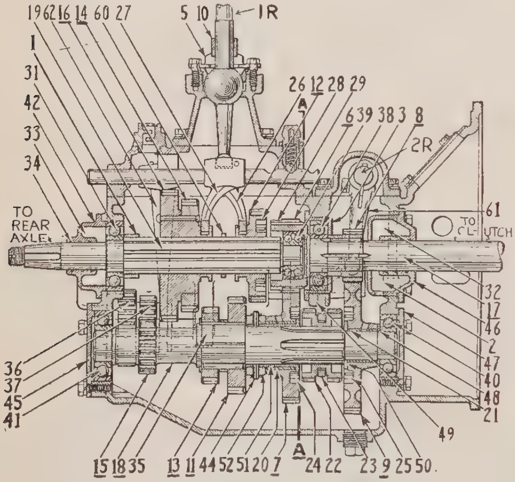


Fig. 16. G.M.C. Two-range transmission.

A sectional view of the transmission is shown in Fig. 16. To the left of the lines (**A** and **A**) the transmission is the same as a standard 4-speed transmission. However the gear (7), instead of being fastened solid on the countershaft, is permitted to rotate freely upon it except when it is engaged by the sliding clutch (22). To the standard transmission, the gears (8) and (9) have been added. The gear (9) is free to rotate on the countershaft unless engaged by the clutch (22).

Thus it is seen that the transmission can be operated either through the gears (6) and (7) or through the gears (8) and (9), simply by moving the clutch (22). This clutch is operated by a **range lever** which can be moved by the driver.

Gear Ratios

The various gear ratios obtainable will now be taken up. In Figs. 17 to 24, the two-range transmission for 2-ton trucks is shown diagrammatically. The numbers of the gears refer to the number of teeth on the gear. Thus gear 12 has 12 teeth; gear 33 has 33 teeth, etc. The dotted arrow shows the course of the power transmission. **The rear axle** of the 2-ton G.M.C. truck has a ratio of 7.25.

Transmission in Low Range

Let us put the range lever in low position. This will engage gear 33 (Fig. 17) (shown as gear 9 in Fig. 16) with the countershaft.

If the gear-shift lever is put in first speed, the transmission will be in the position shown in Fig. 17.

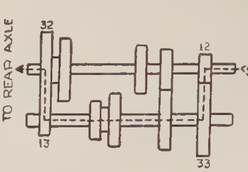


Fig. 17. Low—first.

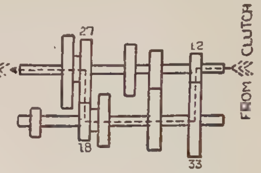


Fig. 18. Low—second.

The gear ratio effected will be:

1st speed: 7.25 (rear axle) x $\frac{33}{12}$ x $\frac{32}{13}$ = 49.08.

Shifting the gear lever to second speed, we get the position shown in Fig. 18. Here the ratio is:

2d speed: 7.25 x $\frac{33}{12}$ x $\frac{27}{18}$ = 29.91.

Shifting to third speed, we get the position shown in Fig. 19, with the ratio:

3d speed: 7.25 x $\frac{33}{12}$ x $\frac{22}{23}$ = 19.07.

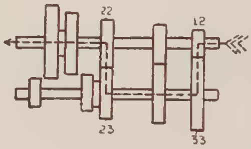


Fig. 19

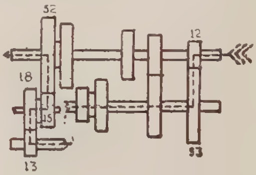


Fig. 20

Fig. 19. Low—third.
Fig. 20. Low—reverse.

Shifting to fourth speed, the power is transmitted directly through the main shaft, the countershaft playing no part. Since there is no reduction within the transmission, the total reduction is 7.25.

4th speed = 7.25.

By shifting to reverse, we introduce a double idler gear (18) and (15) (Fig. 20) between gears 13 and 32. The ratio here is:

Reverse: 7.25 x $\frac{33}{12}$ x $\frac{18}{13}$ x $\frac{32}{15}$ = 58.89.

Transmission in High Range

Let us now put the range lever in high position, thus disengaging gear 33 from the countershaft and engaging gear 28 (Fig. 21) (shown as gear 7 in Fig. 16) with the countershaft.

With the gear-shift lever in first speed (Fig. 21) the ratio will be:

1st speed: (Fig. 21) 7.25 x $\frac{28}{17}$ x $\frac{32}{13}$ = 29.39.

With the gear-shift lever in second speed (Fig. 22), the ratio will be:

2d speed (Fig. 22): 7.25 x $\frac{28}{17}$ x $\frac{27}{18}$ = 17.91.

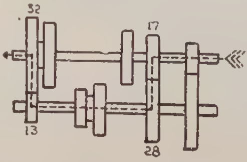


Fig. 21

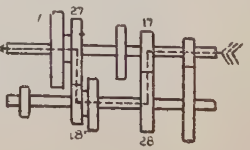


Fig. 22

Fig. 21. High—first.
Fig. 22. High—second.

With the gear-shift lever in third speed (Fig. 23), the ratio will be:

3d speed: (Fig. 23) $7.25 \times \frac{28}{17} \times \frac{22}{23} = 11.42.$

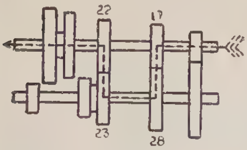


Fig. 23

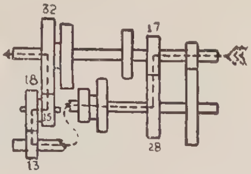


Fig. 24

Fig. 23. High—third.
Fig. 24. High—reverse.

In 4th speed we have the direct drive again, and consequently the ratio is 7.25.

In reverse (Fig. 24) the ratio is:

Reverse: $7.25 \times \frac{28}{17} \times \frac{18}{13} \times \frac{32}{15} = 35.27.$

Summing up the ratios, we have:

Speed	Ratio	
	High Range	Low Range
1st	29.39	49.08
2nd	17.91	29.91
3d	11.42	19.07
4th	7.25	7.25
Rev.	35.27	58.89

In moving a heavy load, a good method would be to start in low range, 1st speed; shift to 2d speed; shift to 3d speed; move the range lever to high range; shift to 4th speed.

G.M.C. Rear-Axle Adjustments

A general assembly of the rear axle showing the driving mechanism is illustrated in Fig. 25. Power is supplied by the propeller shaft to turn the worm which is shown above, having teeth in contact with the worm wheel.

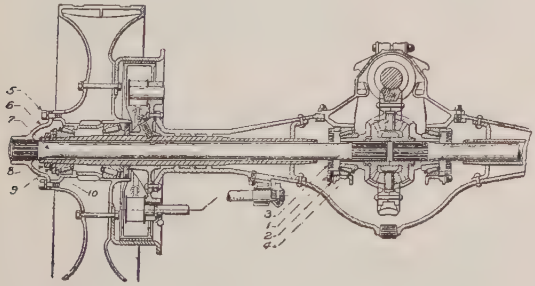


Fig. 25. G.M.C. 2-ton truck rear axle.

The worm wheel is mounted on the differential, and the hubs of the latter turn on roller bearings. This entire assembly of the worm, worm wheel, and the differential, is **a separate assembly in the differential carrier, and may be removed** as a unit by first pulling out the axle drive shafts and then removing the bolts which attach it to the top of the axle housing.

The axle driving shafts (7) are splined on the inner ends, and fit in corresponding splines in the hubs of the differential. The outer ends of these shafts transmit power to the wheels by means of steel flanges (6) splined and shrunk on the ends, which flanges are attached to the wheels by means of studs (5) in the end of the hub.

All gears run in an oil bath, the worm wheel acting as a carrier or pump which picks up the oil and carries it to the worm, which, because of the high speed at which it runs, throws some of it off on the worm housing from where it runs down through troughs to the front and rear worm bearings. From the outer ends of these bearings oil returns through the bearings. The differential housing should be kept filled with oil up to the level of the filler plug on the back of the housing.

The differential is of the bevel-gear type, using four pinions and two bevel gears, all of which are hardened.

The axle shafts are of the **full-floating type** made of chrome nickel steel heat-treated, and have no work other than to transmit power to the rear wheels.

The wheel bearings are carried on a heavy heat-treated nickel steel tube pressed in the axle housing and securely locked in place by the screw shown in Fig. 25.

Adjustment of Worm Shaft Bearings

Since Timken taper roller bearings are used, it is possible and necessary to have them properly adjusted. They should at all times allow a slight play between the worm and worm wheel, especially when the axle is cold, in order to allow for the expansion which occurs as a result of warming up when in operation.

The amount of this play may be determined by turning the propeller shaft by hand. If turning this shaft indicates too much or too little backlash, the bearings should be readjusted by means of the cup (V) Fig. 26. First, loosen the clamp bolt (**D**). Next, remove the lock (**B**), and then turn the adjusting cup (**V**), which has a right-hand thread, to the right until any end play in the shaft is entirely removed.

It is now necessary to readjust to get the proper amount of play to allow for heat expansion. To do this, back out the adjusting cup (**V**) three notches, or one quarter-turn, which is equal to .016″ end play. Replace the lock and bolt in their position.

Should oil leak out around the end of the worm shaft, the stuffing-box packing at this point may be tightened by screwing in the packing gland (**H**). **Caution:** Don't try to stop oil leaks by tightening adjusting bearing cup (**V**).

Adjustment of Differential Bearings

To adjust the differential bearings it is necessary to **remove the complete carrier assembly** from the axle.

To do this, first disconnect the universal joint from its flange on the worm shaft. Next, take off the hub stud nuts and remove both axle driving shafts (Fig. 25). When the bolts have been taken out of the carrier flange, the carrier assembly may be lifted out of the housing. Make all adjustments on the left-hand bearing only. (Fig. 25). **Do not touch the right-hand differential bearing,** as this will disturb the proper meshing of the worm and gear. (In determining Right and Left, always face the direction in which the car travels forward.)

Loosen the cap bolts (F) (Fig. 26). Remove the cap screw (1) and the lock (2) (Fig. 25). Turn the bearing adjuster (3) to the right, which will push the bearing cup (4) tighter against the bearing, thus removing end play. In making this adjustment, care should be exercised not to draw these bearings too tight, as it is necessary here also to allow for heat expansion resulting from warming up.

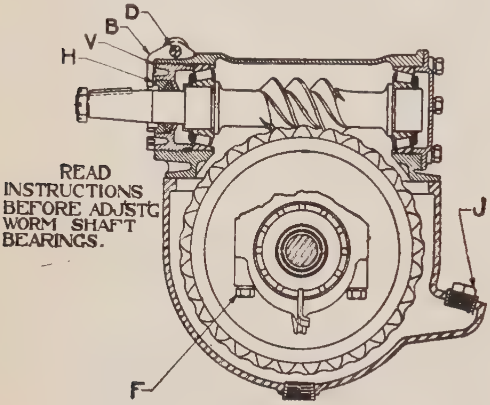


Fig. 26

When the adjuster (3) has been screwed up to take out all end play, it should be backed off so that there is a barely appreciable amount of end play, and should then be locked in this position.

It will be found, especially during warm weather, that the differential worm housing will become quite warm, but this is to be expected since considerable power is transmitted through these gears and bearings and, consequently, temperatures up to 180° are to be expected.

Adjustment of Rear-Wheel Bearings

The rear-wheel bearings can be adjusted by **jacking up the wheels until they are free from the floor.** By using a bar between the floor and the bottom of the wheel, it can be determined whether the wheel has any play or not. (These wheels are so heavy that it is difficult to determine this without the use of a bar.)

The wheel bearings should be so adjusted that there is a barely perceptible shake in the bearing.

If it is found that the bearings require readjustment, first take off the driving flange nuts (5) (Fig. 25) and remove the driving flange (6) together with the axle shaft (7). Next, using the special wrench in the tool kit, remove the nut (8), and then take off the washer (9). Again using the special wrench, tighten up the nut (10) until the required adjustment of the bearing is obtained. Then replace the washer (9), and tighten up the lock nut (8) solidly.

It is a good practice to examine the wheel bearings in the hubs at least every 6,000 miles, at which time the hubs and bearings should be thoroughly washed out and refilled with the proper lubricant, which is a light grease free from acid. Additional grease may be introduced at any time by removing the axle shafts.

G.M.C. ONE-TON TRUCK MODEL "K-16"

Specifications

Load capacity: 2,000 lbs., with additional maximum allowance of 900 lbs. for body equipment.

Road speed: 25 miles per hour.

Engine: G.M.C. design and manufacture; four-cylinder "L"-head, water cooled; bore 3½", stroke 5½".

Horse power: By S.A.E. formula, 19.6; actual horse power at governed speed, 32.5.

Cylinder and crank case: Cast in unit; cylinders, removable sleeve type.

Lubrication: Positive-pressure system from gear pump, forcing oil with constant pressure to all bearings of engine; chassis lubrication by pressure-gun system.

Governor: Fly-ball type of their own manufacture.

Carburetor and fuel supply: G.M.C. two-jet type of carburetor with special heated intake manifold; fuel feed from sheet-steel tank of 12½ gallons capacity.

Cooling: Combination pump-driven and thermo-siphon; pump capacity approximately 15 gallons per minute.

Radiator: Continuous fin, tubular type with core and steel separate; capacity 5⅛ gallons.

Ignition: High-tension magneto.

Clutch: Multiple-disk dry-plate type of their own manufacture.

Transmission: G.M.C. selective type, three speeds forward and one reverse; in unit with engine; provisions for tire pump and power takeoff.

Rear axle: Three-quarter floating bevel pinion drive with six-to-one gear ratio; drive through radius rods from rear axle to frame.

Frame: Pressed steel, reinforced.

Brakes: Two sets, external contracting for service, internal expanding for emergency; **interchangeable brake rods** (see "Brakes," page 915).

Wheels: Steel felloe with twelve interlocking wooden spokes.

Tires: 34" x 5" non-skid cord all around.

Wheel base: 132".

Road clearance: Rear axle 8¾".

Turning radius: 23 ft.

Weight of chassis: 3,250 lbs.

Controls: Left-hand steering and center control; spark and throttle levers located on segment with connections outside of steering column; foot throttle operated by driver's right foot; road speed controlled by governor; lights and ignition switches, ammeter, oil gauge, and choker lever located in instrument case on dash.

Equipment: Electric starting and lighting system of special design and manufacture, tool kit, horn, jack, and extra rim.

The most popular light-duty truck of the G.M.C. line is the one-ton model. The engine is identical in design (though smaller in construction) with the two-ton model. The transmission has three speeds ahead and one reverse, the gear-shift positions being S.A.E. standard (page 29). The rear axle is of the three-quarter floating type and has bevel-gear drive.

To Remove Axle Shafts

1. Remove the six nuts (6) (Fig. 27).

2. Pull the shaft with the flange out of the wheel. This may be done without jacking up the truck.

To Remove Rear Wheel

1. Remove the axle shafts as described above.

2. Straighten the bent-over ears on the lock of nut (7) (Fig. 27).

3. Unscrew nut (7); it has a left-hand thread on the right wheel and a right-hand thread on the left wheel.

4. Pull the wheel off.

When replacing the wheel, special care should be taken to see that the felts and retainers are in the proper position. Nut (7) should be drawn up tight against the bearing, as this bearing is non-adjustable. Bend over the ears of the lock to prevent nut (7) from turning.

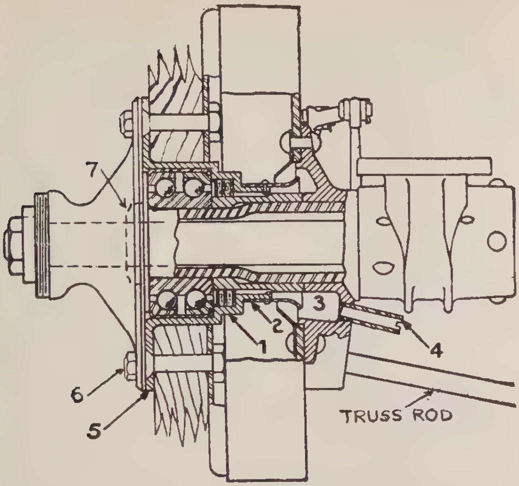


Fig. 27. Section of rear wheel of G.M.C. one-ton truck.

1. Felt washer retainer.
2. Oil shedder.
3. Grease recess.
4. Drain pipe.
5. Paper gasket.
6. Hub flange nut.
7. Wheel bearing nut.

A paper gasket at (5) and felt washers and retainers for them at (1) should prevent leakage of the wheel-bearing lubricant. Any grease which may leak past at (1) will be carried out by the oil shedder (2) into the recess (3) in the brake spider, from where it should drip on the ground from the end of the drain pipe (4). It should be impossible for any wheel-bearing leakage to get on either the internal or external brakes.

To Remove the Rear System from the Truck

1. Jack up the frame, thus taking the load off the springs.

2. Unbolt the spring clips from the rear-axle housing.

3. Block up the propeller shaft near the rear universal joint.

4. Disconnect the brake rods from the rear axle.

5. Disconnect the driving flange (9) (Fig. 28) from the rear universal joint.

6. Pull the entire rear system from the truck.

To Remove Driving Pinion Assembly

1. Remove the rear system as described above.

2. Remove the axle shafts and rear wheels as described above.

3. Remove the clevis pin from the front end of the left-hand internal brake rocker (inside the brake shoe), and then take off the truss rod (Fig. 27) nut behind it.

4. Replace the axle shafts in order to keep the differential bearings (1) and (2) (Fig. 28) from dropping out of place. If the bearings should drop down, they may be replaced by inserting a rod through the axle housing and raising them into place, so that the rear-axle shaft will slip through them.

5. Remove the two cap screws and four nuts which hold the pinion housing (3) (Fig. 28) to the differential housing.

6. Remove the bolts (4) which hold together differential housings (5) and (6).

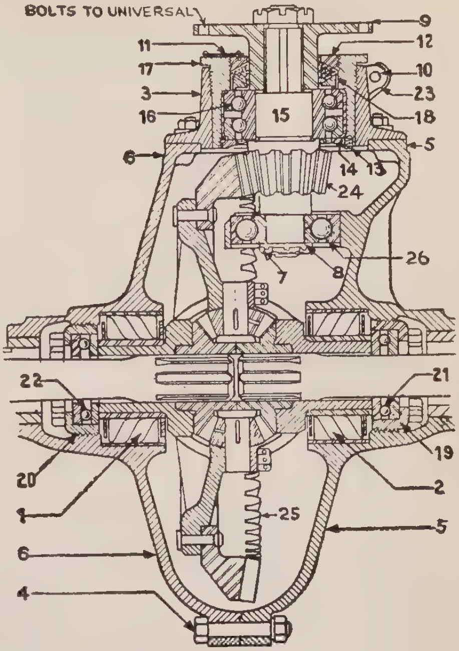


Fig. 28. Differential assembly of G.M.C. one-ton truck.

(1) Differential bearing, left.
(2) Differential bearing, right.
(3) Pinion housing
(4) Differential housing bolt.
(5) Differential housing, right half.
(6) Differential housing, left half.
(7) Rear pinion bearing nut.
(8) Pinion bearing nut lock.
(9) Driving flange.
(10) Bearing clamp bolt.
(11) Packing-nut spring lock.
(12) Pinion-shaft packing nut.
(13) Front-bearing lock nut screw.
(14) Front-bearing lock nut.
(15) Pinion shaft.
(16) Front bearing.
(17) Adjusting cage.
(18) Inner packing ring.
(19) Differential thrust-bearing adjusting nut, right.
(20) Differential thrust-bearing adjusting nut, left.
(21) Differential thrust bearing, right.
(22) Differential thrust bearing, left.
(23) Adjusting cage lock.
(24) Pinion.
(25) Ring gear.
(26) Rear pinion bearing.

7. Jar the housings apart with a lead hammer, and keep the differential assembly **to the left** while spreading the two halves of the housing. Do not attempt to remove the driving pinion until the ring gear is at least ½" to the left of the face of the right-hand housing (5).

8. At this point, remove the pinion-housing assembly (3) with all its parts.

To Disassemble the Pinion Assembly

1. Hold the assembly in a vise by clamping the driving flange (9) (Fig. 28).

2. Turn down the ears on the rear-bearing nut lock (8), and remove nut (7).

3. Remove the cotter pin and nut that hold the driving flange (9).

4. Hold the assembly in the vise by the housing flange (3).

5. Remove the driving flange (9).

6. Loosen the bearing clamp bolt (10).

7. Remove the spring lock (11) from the pinion-shaft packing nut (12).

8. Remove the front-bearing lock nut screw (13) (the small screw at the rear of the bearing cage).

9. Remove the front-bearing lock nut (14) with a small punch and hammer.

10. Use a hardwood block and hammer to drive the pinion shaft (15) and bearing (16) to the rear out of the cage (17).

If the adjusting cage (17) **is to be removed from the housing,** both should be punch-marked and the number of exposed threads noted, so that it may be returned to the same position.

The inner packing ring (18) for the pinion shaft is tap-fit in the cage. To remove it, use a hardwood block and drive from the inside of the cage.

Both bearings are press-fit on the shaft. When removing, be sure the strain comes on the inner race of the bearing.

Use a new nut lock (7), if available, when reassembling the rear bearing. If the old lock is used, break off all ears that were used previously.

In replacing the drive flange (9) fit nut (12) and the packing round it first, and insert the packing and flange together. **The pinion is integral with the shaft.**

To Remove Differential Assembly

1. Remove the drive-pinion assembly, as mentioned above.

2. Remove both axle shafts, as described above.

3. Spread the axle housing entirely apart and remove the differential assembly. **Do not disturb the differential thrust-bearing adjusting nuts** (19) **and** (20) **unless necessary** (Fig. 28).

4. Remove the Hyatt bearings (1) and (2) and the thrust bearings (21) and (22).

5. Insert the drive shafts in the axle housing when the thrust bearings are replaced, to prevent them from dropping out of position. If the thrust bearings drop out of position while assembling, they may be lifted into position by inserting a rod through the center of the housing.

When replacing a ring gear, care should be taken to see that the rivet heads are not over ⅛″ high on either side of the gear. Rivets should be driven hot.

To Adjust Bevel Gears

1. Place the differential assembly in the left differential housing (6) (Fig. 28), guiding the thrust bearing (22) into place by means of an iron rod.

2. Bolt the entire pinion assembly (3) to the left differential housing (6), thus holding the differential in place.

3. Remove bearing-clamp bolt (10) and adjusting cage lock (23).

4. Turn adjusting cage (17) to adjust pinion (24), so that the face of the pinion is flush with the face of ring gear (25).

5. Remove the plate in the differential housing above the thrust-bearing adjusting nut (20).

6. Unlock the adjusting nut (20).

7. Through the plate in the housing, turn adjusting nut (20) until the ring gear meshes properly with the pinion.

8. The mechanic should be able to spin the ring gear freely, and there should be a clearance of about .002″ in the "high spots." Do not allow too much backlash (play).

9. Lock adjusting nut (20).

10. Lock adjusting cage (17) with lock (23) and bearing-clamp bolt (10).

11. Remove pinion assembly (3) from differential housing (6).

12. Place pinion assembly (3) in the right half of the differential housing (5), inserting rear-pinion bearing (26) into its recess.

13. Assemble the right half of the differential housing (5) to the left half (6), guiding the thrust bearing (21) into position by means of an iron rod.

14. Draw up the adjusting nut (19) tightly.

15. Bolt the pinion housing (3) to the differential housing.

16. Back off the adjusting nut (19) until the differential assembly turns freely.

Note. For correct gear-tooth contacts, read pages 869, 874.

To prevent leakage, the pinion shaft is provided with a stuffing box into which screws the nut (12) which is locked in place by the snap ring (11). A special Mogul packing is provided for this purpose. The packing nut (12) should not be drawn in tighter than just sufficient to prevent leakage. **Do not attempt to prevent leakage by tightening adjusting cage** (17).

SPECIFICATIONS OF 1 1/2 AND 2-TON AUTOCARS

Types "XXI-F" and "XXI-G"[1]

Axles: Front, I-beam steel; rear, "Autocar" full-floating, double-reduction gear drive, compound bevel and spur gear, wheel and axle bearings, tapered roller type.

Bodies: Standard bodies always available; blueprints of special body designs furnished upon request.

Brakes: On rear wheels; service brake external, emergency internal.

Capacity: 11,000 lbs. over all—chassis, body, and load.

Carburetor: Plain tube, automatic float feed.

Clutch: "Autocar" triple dry-plate clutch.

Color: Chassis, "Autocar" red; body, optional.

Control: Steering gear and hand levers at right side; throttle control in steering wheel and accelerator pedal; clutch and service brake in foot pedals.

Cooling system: Vertical tube radiator, centrifugal water pump.

Equipment: Gas headlights and tank; three oil lamps; horn; kit of tools.

Frame: Reinforced pressed steel.

Gasoline capacity: 11 gallons.

Ignition: High-tension magneto—fixed spark.

Engine: Horizontal opposed, 4¾″ bore by 4½″ stroke; crank shaft mounted on annular ball bearings.

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[1] The only difference between types "XXI-F" and "XXI-G" is that the former has a 97″ wheel base, and the latter a 120″ wheel base.

Engine lubrication: Splash; gear-driven, force-feed lubricator of 1-gallon capacity, delivering oil through sight feed to the crank case.

Springs: Front, semi-elliptic; rear, platform springs.

Tires: Solid; front, 34″ x 4″; rear, 34″ x 5″, or pneumatic, 34″ x 5″ front and rear.

Transmission: Sliding-gear type; three speeds forward, one reverse; direct drive on high speed; tapered roller bearings.

Tread: 58″.

Wheel base: Type "XXI-F," 97″; type "XXI-G," 120″.

Wheels: Wood, artillery type.

The variety of bodies adapted to the Autocar chassis is indicated by the fact that Autocars are doing the hauling for concerns in all lines of business.

This truck differs from other trucks in the type of engine and the **double reduction of gears** in the rear axle.

Engine

The Autocar "F" and "G" engine (Fig. 30) is of the two-cylinder opposed type, 4¾″ bore (diameter of cylinder) by 4½″ stroke (length of piston travel). It is cooled by water, circulated by a pump through water jackets and radiators. A fan behind the radiator assists in cooling the water.

The crank case is divided horizontally into two parts: the upper part contains the timing gears and gears for driving the magneto and lubricator; the lower part holds the crank shaft and cam shaft. To this lower part are bolted the cylinders. For access to the crank shaft, the magneto, lubricator, and upper part of the crank case can be removed.

The connecting-rod bearings are lubricated by two dippers on each connecting-rod cap dipping into the oil in the crank case. The cylinders, pistons, and timing gears are lubricated by splash from the crank shaft. To maintain the proper level of oil, the automatic lubricator pumps oil into the crank case when the engine is running.

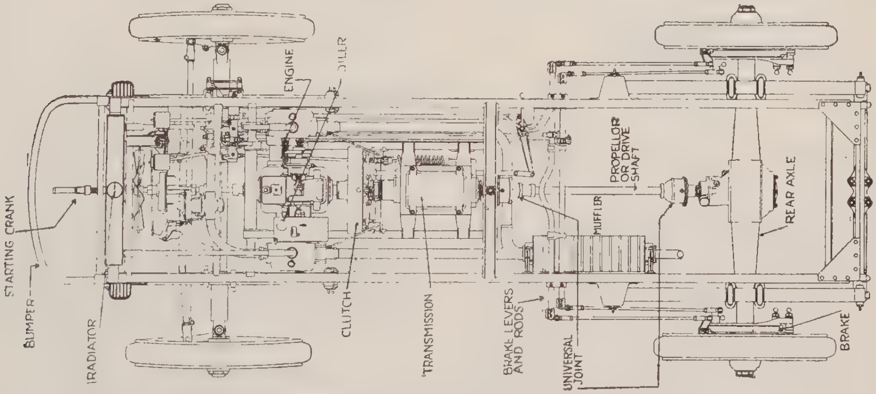

Fig. 29. Top view of Autocar chassis.

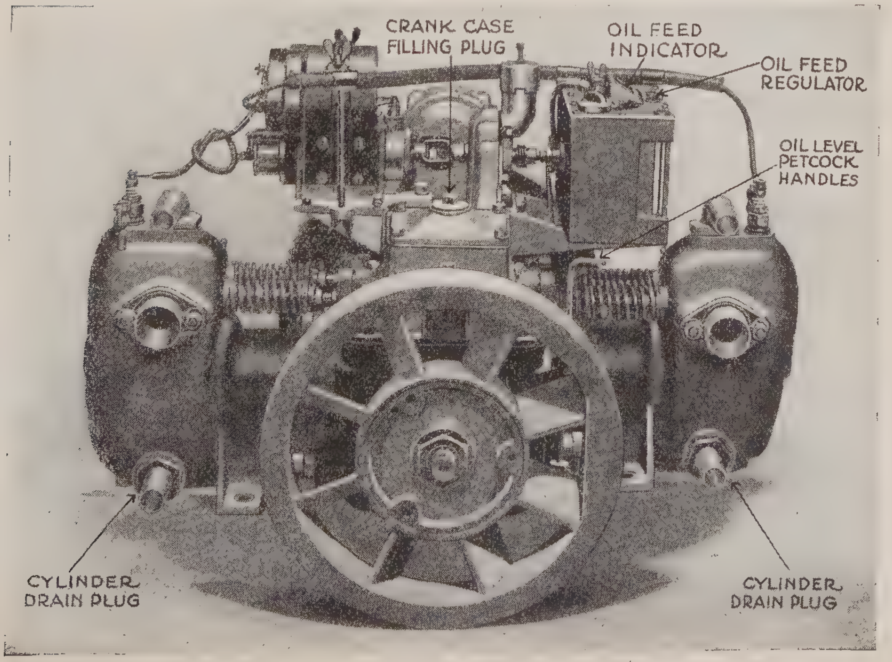

Fig. 30. Side view of the Autocar "F" and "G" engine.

Timing of Magneto (Types "F" and "G")

When either setting the valves or timing the magneto on the "F" engine, it is important to use the marks on the face of the front flywheel as reference points. This arrangement is shown in the illustration (Fig. 31).

Before setting the magneto, open both cylinder priming cocks and turn the flywheel in the running direction until the inlet valve (front valve) of the cylinder under the magneto, which is No. 1 cylinder, opens and closes; continue turning in the same direction until the line on the flywheel, marked (**A**) (Fig. 31) is directly under the flywheel pointer. This position must be exact. Loosen the nut on the magneto coupling and yoke studs, as well as the small screws on the magneto bracket that hold the base of the instrument in place. Place a small chisel or screwdriver between the magneto coupling and lock nut and tap gently to loosen the coupling, so that the armature may be turned freely.

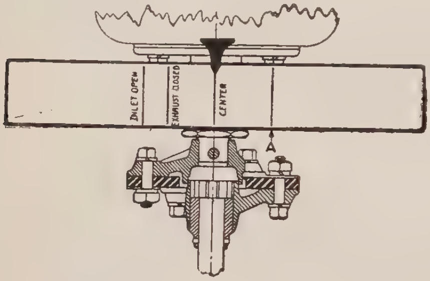

Fig. 31. Magneto ignition timing on the Autocar.

Remove the breaker-box cover and distributor disk, turn the armature in the running direction, using the small magneto wrench on the breaker screw, until the platinum points start to break or separate. Be sure that the distributor brush is on No. 1 contact, which is the one nearer the gasoline tank. Hold firmly in this position with the small magneto wrench, and tighten the coupling nut with the wrench provided for this purpose.

Verify the adjustment by turning the engine backward slightly and then slowly forward, so that the line on the flywheel, marked (**A**) in the illustration again coincides with the pointer. If when in this position the platinum points are starting to open and the distributor is on No. 1 contact, the timing with respect to the ignition is correct.

Replace the distributor-breaker cover and attach the wires. The short wire connects the No. 1 cylinder with the No. 1 contact point on the distributor, and the long wire, the No. 2 cylinder with the No. 2 contact point on the distributor.

Push the magneto back to the coupling, being sure to see that it is located in the center of the magneto bracket. Tighten the screws on the bracket at the magneto base and lock with the lock nuts. Tighten the yoke bolts and apply the ground wire to the breaker-box cover.

Cam-Shaft Setting (Types "F" and "G")

When replacement of a crank-shaft gear, cam-shaft gear, or crank shaft in either repair work or rebuilding is required, it is recommended that the following procedure be followed in determining the correct setting of the cam shaft with respect to the crank shaft.

The rear cam-shaft bearing being assembled in place, turn the crank shaft until the crank pins are exactly on outer dead center. Check this condition by measuring from the finished edge of the case to each of the crank pins. Allow the cam shaft to enter the rear bearing a short distance, and turn until the inlet cam begins to act on No. 1 cylinder. In this position turn the cam shaft until the acting face of the inlet cam is at right angles to the finished surface of the crank case. A small steel square should be used to find the correct position.

Having obtained this adjustment, allow the cam-shaft gear to mesh with the crank-shaft gear. It may be necessary to rotate the crank shaft slightly in the **running** direction in order to permit this meshing to take place. The front cam-shaft bearing may then be assembled and locked in position.

It is necessary to provide perceptible backlash between the cam-shaft gear and the crank-shaft gear, otherwise rapid wear and a noisy condition will result. If a slight shake cannot be detected by the hand, place a .0025" shim between the cam-shaft bearings and the crank case. There must also be end play from .005" to .015" between the shoulders of the cam shaft and the cam-shaft bearings. If such is not the case, correct the difficulty by backing off the cam-shaft gear slightly, or filing the ends of the cam-shaft bearings as circumstances may require.

When the setting is completed, it is considered good practice to mark the gears at points of contact for future reference.

Valve Setting (Types "F" and "G")

In replacing a front flywheel, installing a new cam-shaft gear, crank-shaft gear, or crank shaft, it is necessary to mark on the flywheel those positions which must be used in connection with valve setting and magneto timing. These points are "Center," "Exhaust Closed," "Inlet Open," and a line used in making the spark adjustment.

To determine the "Center" position, remove the cylinder-head plug, and insert through the cylinder-head hole a small steel scale, allowing it to rest against the head of the piston. Rotate the crank shaft, observing the travel of the steel scale, and when dead center is passed continue to turn until some convenient scale graduation appears opposite the face of the plug counter-bore, which is used as a reference point.

Note this position on the flywheel rim by making a temporary mark at the point indicated by the flywheel pointer. Turn the flywheel in the opposite direction until dead center is again passed and the scale returns to the graduation previously noted. The corresponding point on the flywheel rim is to be marked as before. Half-way between the two marks on the flywheel scribe a line and mark it "Center."

Measure ahead on the rim two inches from "Center," and scribe another line. This latter is used as a reference point in magneto setting.

With the cam shaft properly set and the crank case upper section assembled in position, turn the flywheel until both valve plungers of No. 1 cylinder have completed their inward travel. Adjust the valve-plunger foot screws to the same clearance for both inlet and exhaust valves, .015" to .025" being a conveniently obtainable interval.

Turn the flywheel until the cam shaft is acting on both the No. 1 cylinder cams, the inlet being just ready to open and the exhaust just closing. Using from one to two thicknesses of newspaper between the adjusting screws of the cam plungers and the valve stems on No. 1 side, find the two points, by rotating the flywheel through a slight angle, at which these shims may be just pulled out, and mark the corresponding positions temporarily on the rim of the flywheel, referring of course to the flywheel pointer. From the mid-point of these marks measure 5/16" to each side, and lay off temporary lines.

The line on the right must not be more than 2 5/16" nor less than 1 5/16" from the "Center" line, these limits being required owing to the necessary tolerance allowed in manufacture of the parts. Should the limits be exceeded, shift the cam-shaft gear one tooth in the direction which will correct the difficulty. Assuming that the point so reached fulfills these conditions, scribe a line through it, and the other point 5/8" distant to the left. Mark the one on the left "Inlet Open" and the other "Exhaust Closed."

It is now necessary to set all valve-plunger foot screws to the clearance required under operating conditions. Rotate the flywheel until the cams engage the plungers on the cylinder being adjusted, and the flywheel pointer is midway between the "Inlet Open" and "Exhaust Closed" line. Adjust the valve-plunger foot screws for .005" clearance between the head of the screw and the end of the valve stem, this being the amount adopted by the factory as standard.

Note. When this work is being done with the engine in the car, use two levers on the crank webs and check with a scriber in the spark-plug holes.

Rear Axle and Gearing

The rear axle contains a double set of gears (Fig. 32). A bevel pinion (**P**) connected with the end of the drive shaft (**S**) meshes with a bevel gear (**B**) on a short jack shaft, and thus drives the latter. This in turn drives the differential assembly through a pair of **spur gears** (**SG1**) and (**SG2**)

The inner ends of the two driving axles (**A**) are mounted in this differential assembly and transmit the drive from it to the wheels.

The jack shaft is mounted on adjustable taper roller bearings, and by removing the rear cover it can be examined without dismantling the axle proper. The bevel pinion is mounted in a cage and can be removed by unscrewing the cap screws in the flange of the cage.

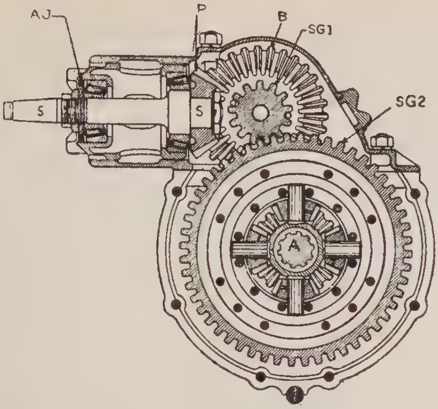

Fig. 32. Autocar double set of gears in rear axle. Termed "double reduction drive to differential."

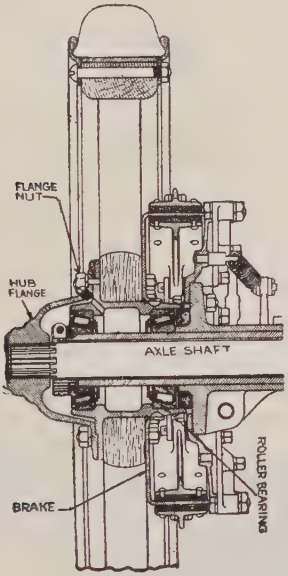

Fig. 33. Rear wheel and axle shaft of the Autocar.

The driving axle shafts (Fig 33) **can be removed** by unscrewing the flange nuts holding the axle or hub flange to the wheel, and pulling out the axle and flange as a unit.

Pinion-shaft adjustment is made by adding or removing paper gaskets between the gear cover and the pinion-shaft housing. Looseness in the pinion shaft can be adjusted at (**AJ**) (Fig. 32).

Transmission

The Autocar 1½ and 2-ton trucks are equipped with a progressive type of transmission (Fig. 34).

In the transmission there are three shafts: The **clutch shaft** (**A**), which extends through the front of the case, on the outer end of which the clutch is mounted; the **main shaft** (**B**), projecting through the rear of the case in line with the clutch shaft, and through which the power is transmitted to the driving shaft, and then to the rear axle; and lastly, the **counter shaft** (**C**), located directly below the main shaft.

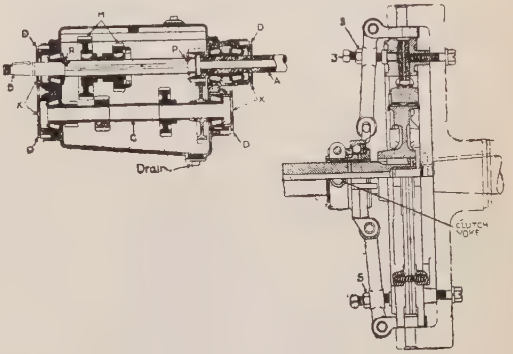

Fig. 34. Autocar progressive-type **transmission** to the left, and Autocar **clutch** to the right.

Clutch

The clutch is of the "Autocar" triple plate type. It consists of two cast-iron plates, faced with asbestos fabric, carried on four keys in the flywheel, and one steel plate between them mounted in slots milled in the spider on the clutch-shaft end. These plates, when clamped together by means of the eight springs contained in the removable plate bolted to the face of the flywheel, produce the friction for driving, power being transmitted through the steel plate through the spider mounted on the end of the clutch shaft.

The clutch is released by the trunnion block or clutch yoke, operated by the clutch pedal, acting against four arms carried on the floating ring, and bearing against the four keys in the flywheel. This block is provided with ample ball-thrust bearings to compensate for the pressure of the clutch spring.

Adjustment of the clutch is made at set screw (3) after loosening lock nut (5).

INTERNATIONAL ONE-TON TRUCK, MODEL "21" (FORMERLY MODEL "H")

This truck is one of six different sizes manufactured by the International Harvester Co. of Chicago, Ill., and is probably the most popular model or size.

Specifications

Maximum capacity: 2,000 lbs.

Wheel base: 115″, regular; 128″, special.

Frame: Pressed-steel channel, extra strong, 5″ deep, with 5 cross-members and two braces at rear.

Engine: Four-cylinder, cast en-block L-head type; engine and transmission mounted on sub-frame suspended from three points on main frame.

Bearings: Three crank-shaft bearings: rear, 1¾″ x 4⅛″; center, 1¾″ x 2¼″; front, 1¾″ x 3¼″.

Lubrication: Forced lubrication by pump to main bearings with overflow to troughs into which the lower ends of the connecting rods dip, making a splash system to the cylinders and crank shaft. Submerged type of plunger pump.

Ignition: High-tension Bosch, magneto on cross-shaft in front of engine.

Cooling: Water-cooled; centrifugal pump; large vertical tube radiator and fan; pump on cross-shaft in front of engine; total cooling system capacity is 4¼ gals.

Governor: Fly-ball centrifugal type; limits speed to 21.8 m.p.h.

Clutch: Dry-plate multiple disk; asbestos lined.

Transmission: Sliding gear, selective type; direct on high.

Gear reduction: Engine to rear wheels, 6.86 to 1 on high.

Axles: Front, I-beam heat-treated steel drop-forging; rear, heat-treated steel drop-forging for carrying the load and live axle for transmitting the power.

Internal gear drive: Tubular propeller shaft with universal joints at each end; power transmitted through differential and drive shafts to pinions meshing with internal gear on each rear wheel.

Control: Left-hand drive, spark and throttle levers on steering wheel, foot accelerator, service brake, and clutch operated by foot pedals; gear change and emergency brake levers in the center of driving compartment.

Brakes: Service and emergency; internal expanding, self-adjusting.

Springs: Half-elliptic, front, 2¼" x 41¼"; rear, 2½" x 54", with quarter-elliptic auxiliary springs 2¼" x 30½".

Wheels: Artillery type, 36" diameter, with 3½" front and 3½" rear pressed-on solid tires.

Fuel capacity: 17-gallon tank on dash.

Regular equipment: Front fenders, oil tail lamp, horn, tools, two gas headlamps, and Prest-O-Lite tank.

Special equipment: Supplied at additional cost: open express body; front section and seat; open and enclosed cabs; full-length top; side, front, and rear screens for full-length top; electric lighting and starting outfit; power tire pump; hub odometer; oil dash lamps; windshield; skid chains; pneumatic tires and oversize solid tires; suitable bodies can be secured for every hauling purpose.

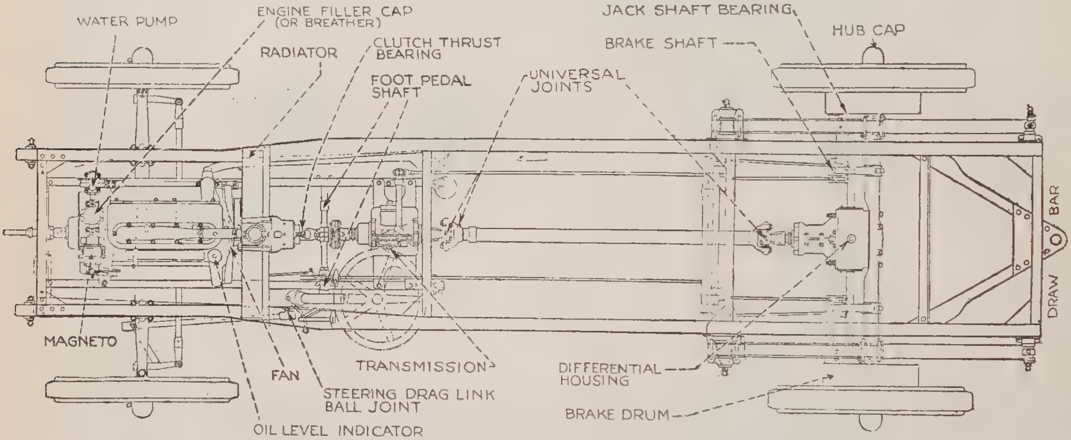

Fig. 35. Top view of International one-ton truck chassis.

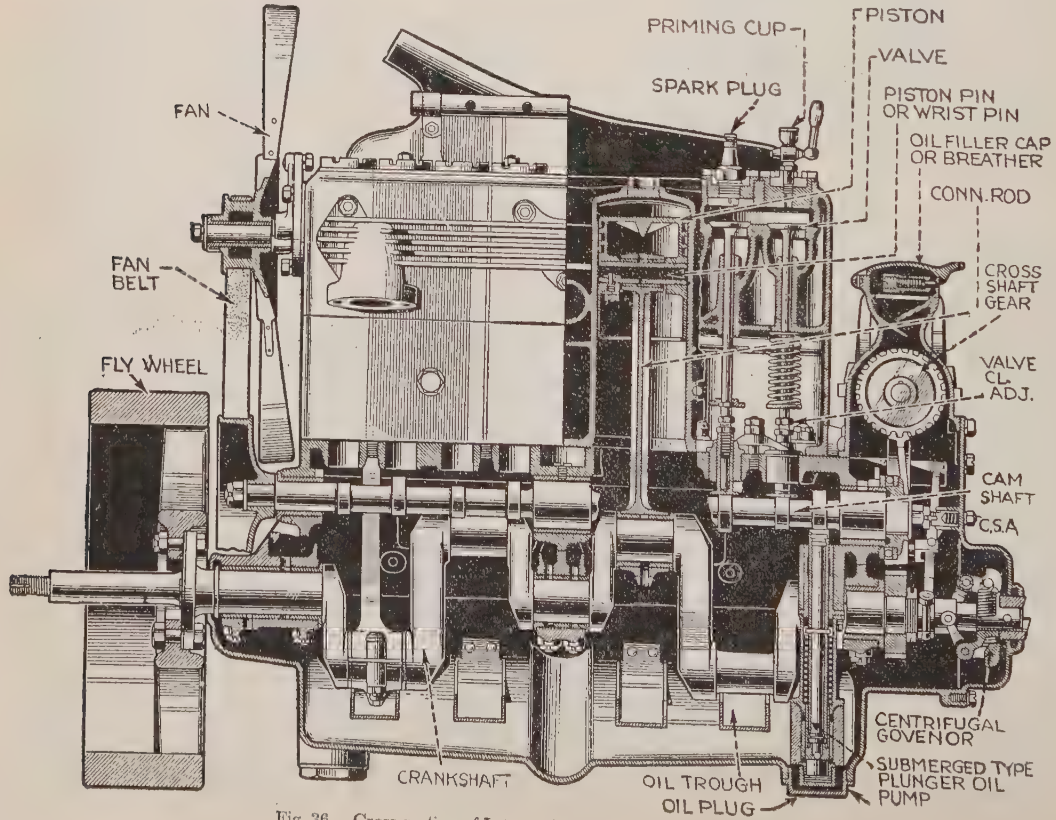

Fig. 36. Cross-section of International one-ton truck engine.

Engine

The engine is of the L-head type; bore, 3½″, stroke, 5¼″; firing order, 1, 2, 4, 3.

The fan is mounted on the rear of the engine block. The wrist pins are keyed to the pistons, the connecting rods being fitted with phosphor-bronze bushings at the piston end. The connecting-rod bearings are of tin babbitt and are fitted with shims to permit adjustment.

To remove pistons and connecting rods:

1. Remove the crank-case bolts and drop the crank case.
2. Remove the connecting-rod bearing caps.
3. Remove the connecting rods with the pistons from underneath the engine.

A submerged plunger type of **oil pump** in the right front corner is driven by a cam on the cam shaft and draws oil through a gauze strainer, delivering (through a tube cast in the crank case) to each of the troughs into which the connecting rods dip as the crank shaft revolves. The crank-shaft bearings have large oil pockets above them which receive oil splashed up by the connecting rods. The pistons are also oiled by splash.

By unscrewing the cap below the pump, the screen can be taken out for cleaning.

The centrifugal governor is carried at the front end of the crank shaft and acts directly upon a sliding sleeve, which moves one end of a pivoted lever, to the other end of which is attached a rod working in a tubular casing and operating the governor throttle. A spring working with the rod, and accessible through a cover directly under the magneto, allows of slight adjustments of speed. The seals locking the screws will disclose any unauthorized tampering with these parts.

Cam-shaft end-thrust play can be taken up with the cam-shaft end-thrust adjustment screw (C.S.A.) (Fig. 36). A similar adjustment is also shown on the model "L4" Continental engine (Fig. 55, page 937).

Fuel System

A 17-gallon gasoline tank is mounted on the dash and feeds by gravity to the carburetor. Underneath the tank is a **combination strainer and reserve valve,** as shown in Fig. 37.

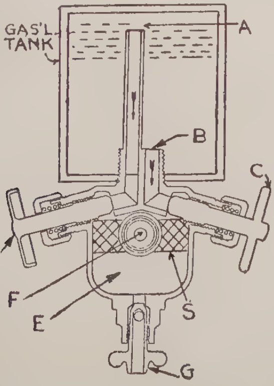

Fig. 37. Combination gasoline strainer and reserve valve on one-ton International truck.

When the engine is to be started, the valve (**D**) (Fig. 37) is opened, thus allowing the gasoline to enter at (**A**), pass through strainer (**S**), and through outlet (**F**) to the carburetor. When the level in the tank reaches point (**A**), the flow of gasoline to the carburetor will cease and the engine will stop, thus notifying the driver that he has only about two gallons of gasoline left. The valve (**C**) is then opened, permitting the gasoline to enter at the lower level (**B**), and consequently using the remaining two gallons. Matter which does not pass through the strainer will collect in sediment chamber (**E**), and can be emptied through the needle drain valve (**G**).

Ensign Carburetor

The Ensign type "D" 1¼″ carburetor is used, and operates as follows: the fuel enters and passes upward through screen (**B**) (Fig. 38) and downward through the float-controlled needle valve (**D**), into the float chamber.

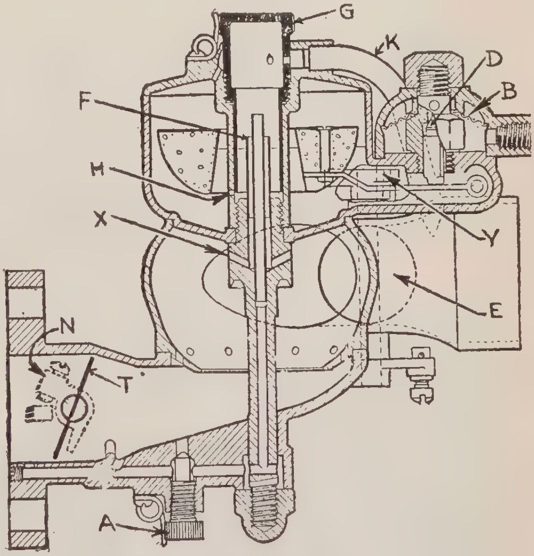

Fig. 38. Ensign carburetor as used on International truck.

A, Idling adjustment screw.
B, Strainer screen.
D, Float needle valve.
E, Starting shutter.
F, Suction tube.
G, Fuel adjustment sleeve.
H, Fuel orifice.
K, Compensating air tube.
N, Throttle stop.
T, Throttle.
Y, Stop finger.
X, Suction outlet.

The float maintains the fuel level 1/32″ below the top of the suction tube (**F**), which opens through holes (**X**) at its lower end into the centrifugal chamber. The suction tube is surrounded by a larger tube, into which the fuel enters through small fuel hole (**H**). The effective opening of this hole is controlled by a gas-adjusting tube (**G**), shown in solid black, which can be screwed up and down by its knurled head. This tube performs the function of the usual gas-adjusting needle valve. A compensating air tube (**K**) is connected to the interior of the gas-adjusting tube through an automatic valve which lifts when the air speed through the carburetor becomes high enough, and lowers the vacuum in the gas-adjusting tube, preventing the formation of too rich a mixture.

Adjustment is made at the factory. If tampered with and the engine does not start to operate properly, readjust as follows:

Before starting, be certain that the idling adjustment screw (**A**) on the bottom of the throttle tube is closed; that is, that it is turned clockwise (to the right) to seat. Turn the fuel adjusting sleeve (**G**) clockwise to the closed position, then open two (2) turns counter-clockwise, which will give a full opening to the fuel orifice (**H**). Be sure that starting shutter (**E**) is open with stop finger (**Y**) against the stop lug when "control" is down.

To start the engine, close the starting shutter by pulling up the "control," and open the throttle one-quarter to one-half. After the engine starts, push down the control about half-way. The handling of this starting shutter is largely dependent on temperature. As soon as the engine warms up slightly, push the "control" all the way down, warm the engine up, running slightly above idling speed until the mixing chamber of the carburetor is warm, then open the throttle to about one-third engine speed (this must be done with retarded spark).

Now thin the mixture by turning sleeve (**G**) clockwise until the best engine speed is obtained with this throttle setting. Slow down the engine and adjust the screw in the throttle stop (**N**) for idling position, then adjust the idling mixture by opening the adjustment screw (**A**) counter-clockwise to a point where the engine idles evenly and without loading up. Too thin an idling mixture will result in a "flat spot," or hesitation when accelerating. The top of the **cork float** is set 7/16" below the top of the bowl, and should not be changed.

Clutch

The clutch is of the dry-plate disk type as shown in Fig. 39. Pressure is applied through the action of three springs (**A**) (Fig. 39), which can be adjusted by the spring screw nuts (**B**). Care should be taken to keep them adjusted evenly.

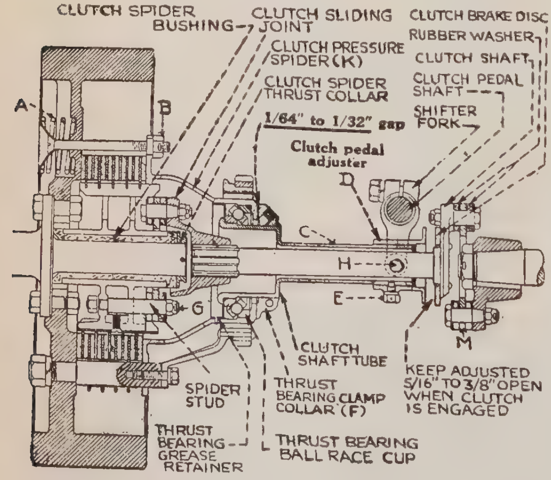
CLUTCH SPIDER BUSHING
CLUTCH SLIDING JOINT
CLUTCH BRAKE DISC
RUBBER WASHER
CLUTCH PRESSURE SPIDER (K)
CLUTCH SHAFT
CLUTCH SPIDER THRUST COLLAR
CLUTCH PEDAL SHAFT
A
B
1/64" to 1/32" gap
SHIFTER FORK
Clutch pedal adjuster
D
C
H
E
G
M
CLUTCH SHAFT TUBE
SPIDER STUD
THRUST BEARING CLAMP COLLAR (F)
KEEP ADJUSTED 5/16" TO 3/8" OPEN WHEN CLUTCH IS ENGAGED
THRUST BEARING GREASE RETAINER
THRUST BEARING BALL RACE CUP

Fig. 39. Dry-plate disk clutch used on International one-ton truck.

Adjusting: As the asbestos facings wear down, the clutch pedal will work back and finally hang up against the floor boards, preventing the clutch from engaging. It can be returned to the proper position by screwing the clutch-shaft tube (**C**) (Fig. 39) out of the clutch-pedal adjuster (**D**) the necessary amount. See that the clutch-pedal adjuster lock screw (**E**) enters the slot and is wired fast.

Clutch brake: The flange on the end of the clutch shaft is provided with an asbestos facing with which a flange on the clutch adjuster (**D**) can be made to engage by pressing the clutch pedal clear down. As the clutch adjuster does not revolve, it serves as a brake on the clutch. Do not bring this brake into action when coasting; simply press the clutch pedal lightly, just enough to disengage the clutch.

The clutch spider has oil-soaked wood bushings which should not need lubrication, although oil will not injure them. The declutching mechanism is provided with a grease cup which should be given a turn or two every day.

To remove clutch: Take off the spring adjusting nuts (**B**) loosen clamp collar (**F**), slip the clutch pressure spider (**K**) back, removing the starter sprocket spider, if used. Take nut (**G**) off the clutch spider stud. At the other end of the shaft remove the joint ring (**M**) and back out the clutch shifter pivot screws (**H**). The entire center section can now be dropped out, after which the removal of a cotter pin in the collar permits the detachment of the clutch spider and disks.

Transmission

The transmission has three speeds forward and one reverse. The gear shift is standard S.A.E.

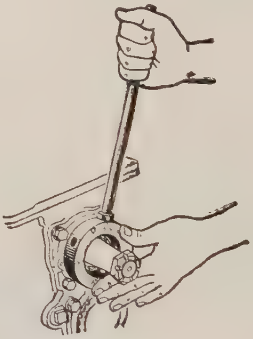

Fig. 40. Showing adjustment of roller bearings on transmission main shaft with a spanner wrench.

Adjusting bearings: Timken roller bearings are used throughout, and those on the main shaft are adjusted by the spanner nuts just outside the case at the front end (Fig. 40). Turning the notched plate outside at the rear adjusts both bearings on the square shaft.

The notched plates turn to the left to tighten the bearings. Be sure that the locking plates are in position before leaving the job, as these hold the adjustment. The inside horned nut at the rear end is a packing device. The counter-shaft bearings are adjusted at the rear by the same kind of device as used on the main shaft.

Great care must be taken not to get the bearings adjusted too tight.

Rear Axle

The rear axle is of the internal gear type. The load is carried on a drop-forged, heat-treated alloy-steel solid axle. Power is transmitted from the differential (Fig. 42) to the driving pinion shaft. The driving pinion meshes with the internal gear, as shown in Fig. 45.

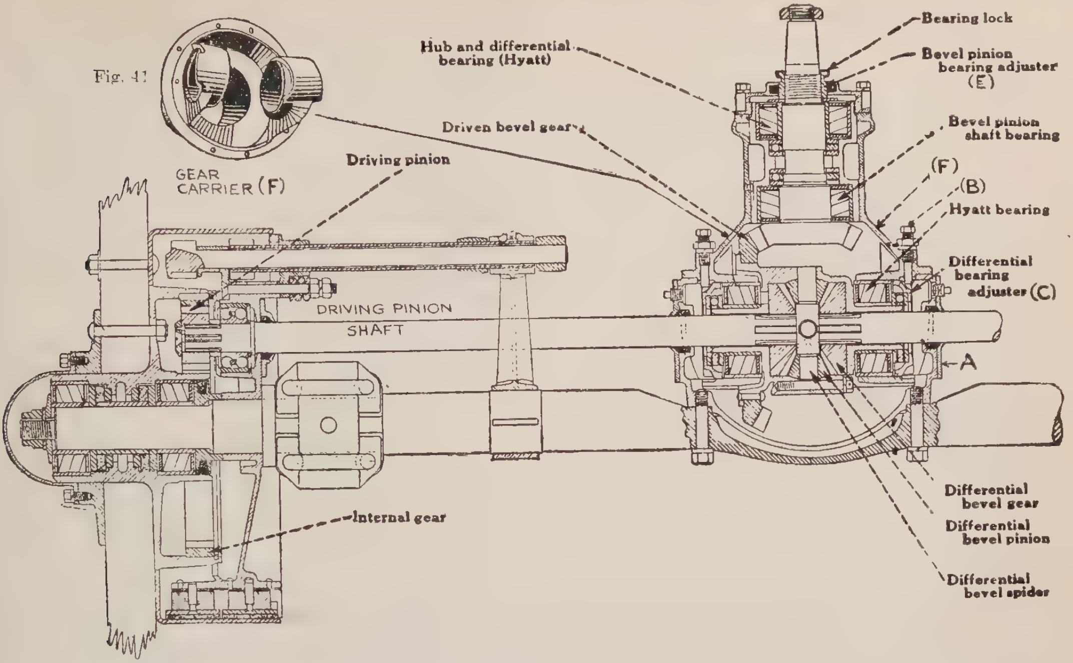

Fig. 41

GEAR CARRIER (F)
Hub and differential bearing (Hyatt)
Driven bevel gear
Driving pinion
DRIVING PINION SHAFT
Internal gear
Bearing lock
Bevel pinion bearing adjuster (E)
Bevel pinion shaft bearing
(F)
(B)
Hyatt bearing
Differential bearing adjuster (C)
A
Differential bevel gear
Differential bevel pinion
Differential bevel spider

Fig. 42

Fig. 41. Rear view of differential carrier. Top sectional view is shown in Fig. 42.
Fig. 42. Sectional view of rear-axle assembly on International one-ton truck.

Adjusting gears: Remove the drive-shaft packing plate (**A**) and back off lock screw (**B**) (Fig. 42) on each side of the differential housing; the adjusting ring (**C**) is then accessible through openings in the housing. These rings **adjust** the bevel gear sidewise, and take up any play in the thrust bearings.

The bevel-drive pinion is adjusted by (**E**) (Figs. 42 and 43). Remove the cap screws locking this piece. To back the pinion **out,** turn (**E**) to the right. To force it **in,** turn to the left.

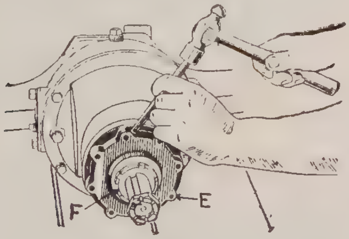

Fig. 43. Forcing the bevel pinion in by rotating the adjusting ring in the left-hand direction.

Put the lock screws back in and draw up, forcing the pinion and bearing assembly forward. There are three tapped holes close together for each screw, so that a close adjustment can be made. Pull (**E**) hard against the case with the lock screws.

The best way to determine whether the adjustment is perfect is to cover the teeth of one gear with a light coating of Prussian blue and then, after assembling, to turn the gears a few revolutions. When the blue is transferred to the other gear uniformly, from end to end of the teeth, the adjustment is right.

Be careful to have the adjustments securely locked before assembling finally, and be particularly careful that there is no pressure exerted by the adjusting nuts on the thrust bearings. If there is you may have to take the axle down again shortly, and put in new bearings.

The notched nut (**F**) (Fig. 43) **adjusts the thrust bearings only.**

While an experienced man can adjust the gearing without removing it, it is much more readily done by getting it out where it can be seen. To do this, jack up the axle, remove the wheels, remove the bolts fastening the bearing retainer to the brake anchor, and pull out drive pinion and shaft. Unbolt the gear carrier (**F**) from the housing, when the carrier with the assembly gears can be pulled forward. **Do not remove the bolts holding the housing to the axle.**

In replacing the wheels, first **be sure that the spacer and sleeve are in proper position;** then screw the axle nut up hard, and lock with the cotter pin. This does not apply to old-style axles.

To Remove Internal Gear from Wheel

1. Pry out the locking ring (Fig, 44).
2. Pry or pull out the internal gear (Fig. 45).

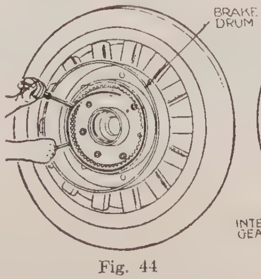

Fig. 44

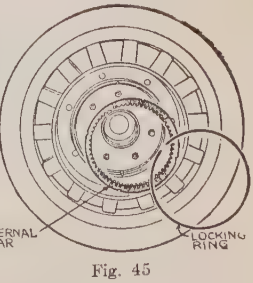

Fig. 45

Fig. 44. Showing how to pry out the gear-locking ring.
Fig. 45. Showing the ring and the internal gear removed.

3. Insert the new gear, using partly inserted round keys to locate the gear with reference to the key ways.

4. Drive the gear and keys home with a soft hammer or by using a block of wood to strike against.

5. See that the locking ring is down in its groove and that the cotter pin is inserted in the hub rim.

See illustration, Fig. 42, showing location of the internal gear, driving pinion, and drive shaft.

WHITE 3/4-TON TRUCK

Specifications

Frame: Pressed alloy steel.

Axles: Front, one-piece drop-forged I-beam alloy steel, heat treated; rear, special white type, trussed.

Springs: Semi-elliptic.

Wheels: Artillery type, fitted with ball bearings.

Tires: Pneumatic, 34″ x 5″, cord.

Capacity: 1,500 lbs.

Carburetor: White aspirating type, meaning a spray type of jet.

Ignition: High-tension magneto of the Eisemann, Bosch, or Teagle make.

Cooling: Water circulation by gear-driven centrifugal pump; cellular radiator supported on springs.

Steering: Left-side drive; worm and sector type, "fore-and-aft" method.

Brakes: Foot brakes contracting on drums on each rear wheel; hand brakes expanding on drums on each rear wheel.

Drive: Shaft drive final drive by bevel gears.

Gasoline tank: Capacity 15 gallons; gravity feed to the carburetor.

Chassis dimensions:

Wheel base: 133½ in.

Gauge: 56 in.

Length over all: 14 ft. 3 in.

Width over all: 5 ft. 6 in.

Dash to rear of frame: 10 ft. 10⅜ in.

Dash to center of rear axle: 8 ft. 7 in.

Rear of seat to rear of frame: 7 ft. 1⅜ in.

Extreme width of frame—34 in.

Height of top of frame in rear: 32¾ in.

Weight of chassis: 3,200 lbs.

Engine

The engine is of the 4-cylinder, 8-valve, L-head type; bore 3¾″; stroke, 5⅛″; cast-iron pistons.

When the valves are closed the **clearance** between the valve stem and the tappet should be .010″ (engine cold).

The clearance on the diameter of all connecting-rod bearings should be between .001″ and .002″.

Crank shaft: The White ¾-ton crank shaft is noteworthy in that it runs on **two ball bearings** (2) and (3) (Fig. 47). This necessitates a short, stiff crank shaft.

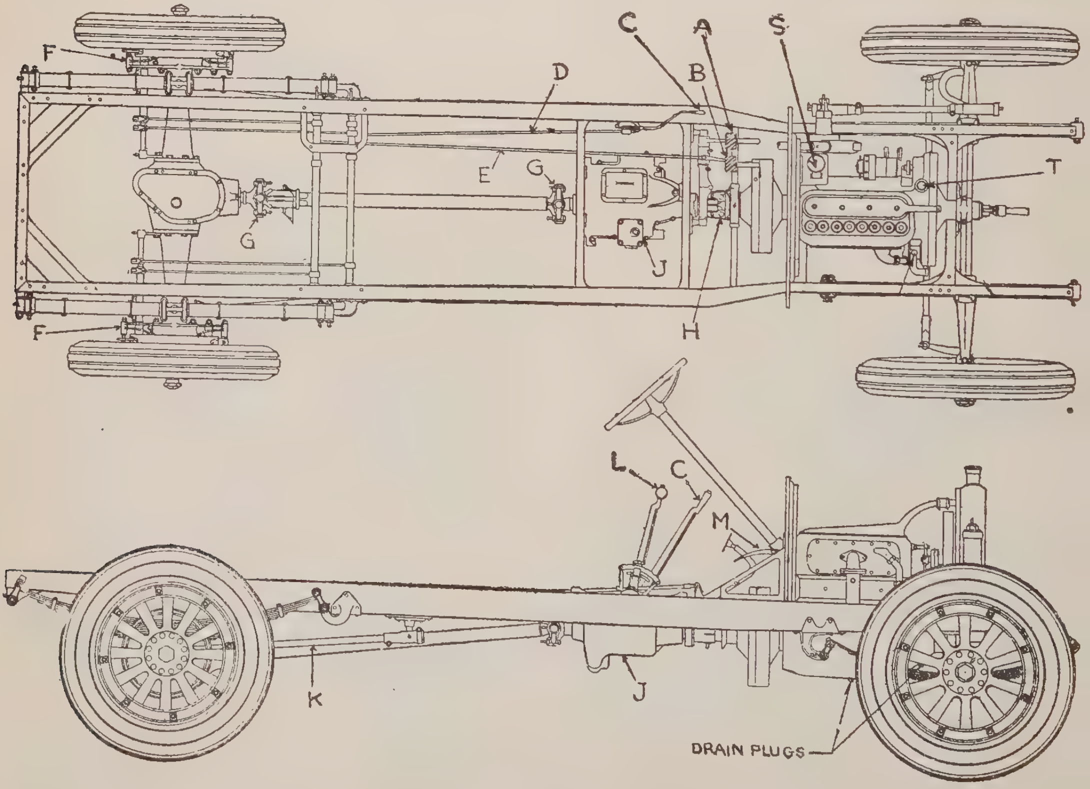

Fig. 46. Top and side view of chassis of the ¾-ton White truck.

A, Clutch pedal.
B, Foot-brake pedal.
C, Hand-brake lever.
D, Hand-brake rod.
E, Foot-brake rod.
F, Brake drums.
G, Universal joints.
H, Clutch coupling.
J, Transmission.
K, Radius rod.
L, Gear-shift lever.
M, Foot throttle.
S, Oil Reservoir.
T, Crank-case oil filler.

If it were desired to have a three-bearing crank shaft on ball bearings, it would be impossible to slip a ball race on the center bearing of a one-piece shaft. In order to obtain a three-bearing support with ball bearings, a built-up crank shaft must be used, that is, the shaft is made in two pieces; then after the center bearing is in place, the parts must be joined by some means such as disks. Therefore with the White crank shaft, using two ball bearings, the crank shaft is made very heavy in order to withstand the power impulses without "whipping" at high speeds.

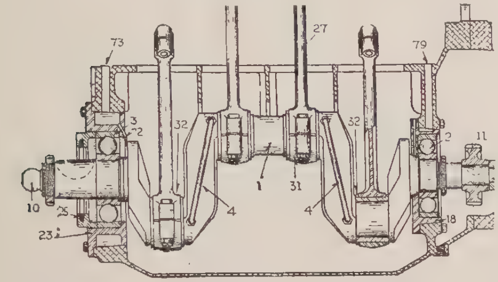

Fig. 47. Ball-bearing crank shaft.

(1) Crank shaft.
(2) Crank-shaft bearing.
(3) Crank-shaft bearing.
(4) Crank-shaft oil tube.
(10) Clutch-shaft ball.
(11) Crank-shaft gear.
(25) Crank-shaft rear bearing-ring felt washer
(23) Crank-shaft rear bearing case.
(27) Connecting rod.
(31) Connecting-rod bearing cap
(32) Connecting-rod bearing.
(72) Crank-shaft bearing oil tubes.
(73) Oil port, rear.
(79) Oil port, front.

Lubrication: Oil is supplied to a gear-driven plunger pump by the reservoir (S) (Fig. 46). The pump forces it through sight oil feeds on the dash, thence to the oil ports (73) and (79) (Fig. 47). After dropping on the conical surfaces at the end of the crank shaft, it is carried by centrifugal force through passages in the crank shaft to the connecting-rod bearings (32) (Fig. 47), thence through oil tubes (4) (Fig. 47) to the remaining connecting-rod bearings. From the connecting-rod bearings, the oil is thrown off in a spray, thus lubricating the cylinder walls and maintaining the oil level in the crank case.

The ball bearings (2) and (3) (Fig. 47) receive lubrication from the splash and from some of the oil thrown off by the crank shaft.

The only purpose of the oil in the crank case is to act as a cooling agent, and consequently it should not be too full, as explained later under the subject of general lubrication.

Transmission

The transmission is of the selective type, and has four speeds forward and one reverse. Direct drive is on the third gear, **fourth speed being geared up.** Third speed is always used when running loaded or when running light at ordinary speeds. The only time to use fourth speed is when running light on a good level road at a high rate of speed. The various gear-shift positions are shown in Fig. 48.

The total gear reductions are: first speed, 18.6; second speed, 8.57; third speed, 5.36; fourth speed, 3.99; reverse, 25.18.

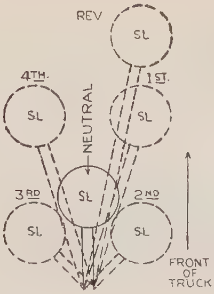

Fig. 48. Gear-shift positions of ¾-ton White (not a standard S.A.E.)

Rear Axle

The rear drive is through a bevel-gear drive. Adjustments are made as on a passenger car. The differential gears are of the straight-toothed, three-quarter floating type.

Clutch

The single-plate type, operating in oil, is similar in construction to the White 3½-ton clutch, shown in Fig. 52, page 935.

Fill the clutch through the oil plug (7) (Fig. 52) with one pint of light engine oil. After the first 500 miles, and then after each 2,000 miles, drain the oil from the clutch and refill with one pint of kerosene. Allow the engine to run at a moderate speed for one minute, meantime engaging and releasing the clutch a few times. Then stop the engine and drain the kerosene, and refill with light engine oil.

Clutch Adjustment

The space between the clutch cover (see Fig. 52 [5], page 935) **and the shoulder of the clutch flange** (29) can be adjusted to its proper width (between ¼″ and ⅜″) by depressing the clutch pedal as far as possible and removing the friction-plate ring lock (14), while in this position. A section of the notched friction-plate ring (12) (which can be turned by means of a screw-driver) will appear through the opening. To increase the space above mentioned, turn the ring in a clockwise direction, and to decrease it, turn counter-clockwise.

The clutch foot lever, which can be moved after loosening the binder bolt, at its connection to the shaft, should be ½″ from the floor board when the the clutch is thrown in.

The clutch brake may be adjusted by turning the threaded clutch brake-band pull rod so that the brake shoe comes into contact with the clutch coupling ring only on the extreme outward throw of the clutch.

Rear Wheels

The rear wheels (Fig. 49) are fastened to the rear axle spindles by a square and taper.

To remove the wheel and spindle, jack up the end of the rear axle and loosen the nuts (70) on the two bracket **hook bolts.** These bolts are located on the ends of the axle sleeves near the wheel. The outside ends of the hook bolts fit into grooved slots in a plate which holds the bearing in position. When these hook bolts are loosened the "L"-head of the bolts can be turned out of the slot, and the wheel and spindle can be pulled off.

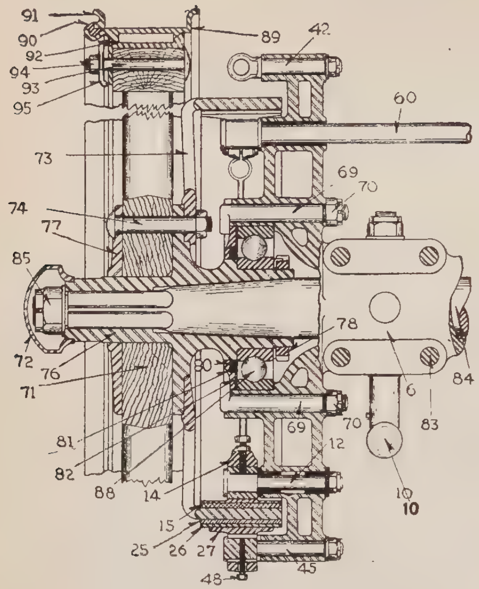

Fig. 49. Rear wheel of White ¾-ton truck.

(6) Spindle bracket R.H.
(14) Brake ring with lining
(15) Brake-ring lining
(25) Foot-brake lining
(26) Foot-brake band complete
(27) Foot-brake guide
(42) Foot-brake guide stud
(69) Rear wheel hook bolt
(70) Rear wheel hook bolt nut
(71) Rear wheel
(72) Rear wheel hub cap
(73) Brake drum
(74) Brake-drum bolt
(76) Rear wheel hub R.H. and L.H.
(77) Rear wheel hub flange
(78) Rear wheel hub locknut (R.H. thread)
(80) Rear wheel bearing retainer
(81) Rear wheel bearing retainer felt washer
(82) Rear wheel bearing retainer felt retainer
(83) Rear spring clip and nut
(84) Rear-axle spindle
(85) Rear-axle spindle nut
(88) Rear wheel bearing
(89) Rim
(90) Rim locking ring
(91) Rim side ring
(92) Rim clamping ring
(93) Rim bolt
(94) Rim bolt nut
(95) Rim clamp

A tight fit of the driving spindle in the rear-wheel hub must be maintained at all times in order that the driving strain be evenly distributed throughout the entire length of the hub. If the spindle is allowed to work loose, the hub becomes distorted and enlarged, allowing the entire driving strain to be taken by the square section of the spindle. This condition may result in a fracture.

The fit of the spindle is obtained by tightening the spindle nut (85), and by making sure that the spindle nut washer is tight against the wheel hub (76). The fit should be checked occasionally, especially during the first 1,000 miles of driving with a new truck..

Occasionally examine the spring clips which hold the spring to the seat and see that they are kept tight. Loose spring clips may allow the axle to shift and cause shearing of the spring center bolt or a breaking of the spring plates.

Lubricating Instructions

Engine: Place the truck on a level space. Open the crank-case overflow valve by pulling out the valve stem under the radiator. Pour filtered, medium heavy engine oil into the crank case through the filler (T) (Fig. 46) on top of the timing-gear case until it is even with, but not above, the level of the overflow valve. Pour the same kind of oil into the oil reservoir (S) (Fig. 46) until it is full.

Transmission: Fill the transmission case with transmission oil, through the filling hole on top, up to the level of the oil-level plug on the side. After each 1,000 miles, add sufficient oil to maintain this level. After each 5,000 miles, drain the case through the drain-hole plug in the bottom, cleanse, and refill.

Rear axle: Fill the rear-axle case with transmission oil through the filler-cap hole on top of the rear axle housing up to the oil-level plug on the side. Examine this case after each 1,000 miles, and add enough oil to maintain this level. After every 5,000 miles, drain it out through the plug at bottom, cleanse, and refill.

Grease lubricators: Fill with soft cup grease, using a grease gun (18) and (19) (Fig. 53, page 935).

WHITE 3 TO 3½ TON TRUCK

Specifications

Frame: Standard I-Beam; channel steel bumper.

Axles: Front, straight type solid drop-forged alloy steel; rear, steel housing.

Springs: Semi-elliptic.

Wheels: Metal, fitted with ball bearings.

Tires: Front, 36″ x 5″ solid; rear, 40″ x 5″ dual solid pressed-on type.

Capacity: 7,000 lbs.

Carburetor: White aspirating type (meaning that a spray jet is used).

Ignition: High-tension magneto of the Eisemann, Bosch, or Teagle make.

Cooling: Water circulation by gear-driven centrifugal pump; radiator, of the vertical tube type supported on springs.

Steering: Left-side drive; worm and sector type, "fore-and-aft" method.

Brakes: Foot brakes contracting on drums on drive shaft; hand brakes expanding on drums on each rear wheel.

Drive: Double reduction-gear drive by shaft to full-floating type of rear axle.

Gasoline system: Tank 32½ gals. capacity; feed by vacuum system.

Chassis dimensions:

Wheel base: 174 in
Gauge: Front wheels, center to center of tires, 64½ in.; rear wheels, center to center of wheels, 61⅞ in.
Length over all: 22 ft. 3 in.
Width over all: 6 ft. 2 in.
Dash to rear of frame: 17 ft. 5 in.
Dash to center of rear axle: 12 ft. 7½ in.
Rear of seat to rear of frame: 13 ft. 8 in.
Extreme width of frame: 42 3/16 in.
Height of top of frame in rear: 37 in.
Weight of chassis: 7,300 lbs.

Engine

Engine has four cylinders, eight valves, and is of the L-head type; bore, 3¾″; stroke, 5¾″. The cylinder head is detachable.

When the valves are closed, the **clearance between the valve stems and tappets** should be .010″, when the engine is cold.

Clearance on the diameter of all connecting-rod bearings should be between .001″ and .002″.

The crank shaft has a three-bearing support and soft metal bearings.

Engine Lubrication System

Pressure feed: The engine and clutch are lubricated by a pressure feed. The oil is taken from the crank-case sump by a gear-type oil pump mounted on the cam shaft, and is forced back to the clutch-shaft bearing and forward to the cam-shaft bearings, timing-gear bearings, and main bearings, thence through the oil ways in the crank shaft to the connecting-rod bearings.

Oil spray from the bearings provides lubrication for all other engine and clutch parts. The oil drains from the clutch mechanism on to the flywheel, by which it is picked up and carried back into the crank case. The oil then drains back to the crank-case sump through a circular strainer or screen, which effectively eliminates all dirt and sediment.

Oil level: The amount of oil in the crank-case sump is shown by a float-actuated oil-level indicator on the left side of the engine frame.

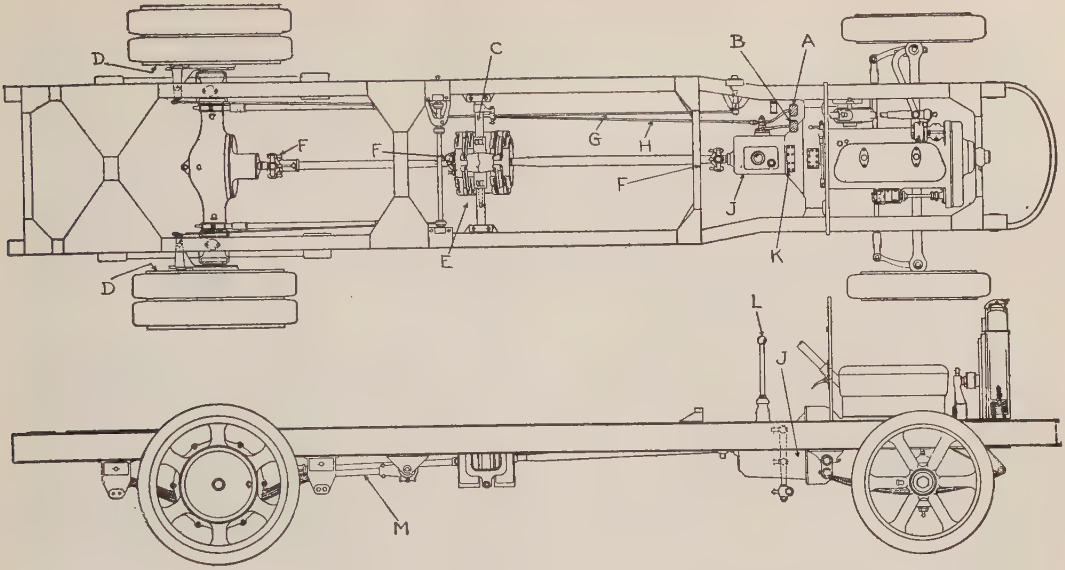

Fig. 50. Chassis views of 3½-ton White truck.

A, Clutch pedal.
B, Foot-brake pedal.
C, Foot-brake shaft.
D, Hand-brake drums.
E, Foot-brake bands.
F, Universal joints.
G, Hand-brake rod.
J, Transmission.
K, Transmission hand hole.
L, Gear-shift lever.
M, Radius tube.

Pressure: The pressure should not exceed 20 lbs., and under ordinary operating conditions 10 to 15 lbs. is sufficient. The oil will, however, show a somewhat higher pressure when cold.

Adjustment: The oil pressure is adjusted by an oil by-pass on the left side of the crank case. Loosen the jamb nut, and turn the screw to the right to increase the pressure, or to the left to decrease it, after which the lock nut must be tightened to maintain the adjustment.

Note. It is very important that the oil be thoroughly warmed when adjustment is made.

Transmission

This is of the selective type, with **four speeds** forward and one reverse. The direct drive is on the fourth speed, the **total gear reduction** being 11.6 on fourth, 19.9 on third, 31.55 on second, 47.85 on first, and 61.5 on reverse.

The gear-shift positions are standard, as shown in Fig. 4, page 912.

Rear Axle

The rear axle is of the **double-reduction** type and is shown in Fig. 51.

(1) Rear axle housing
(3) Rear axle housing pipe plug
(4) Rear axle housing shaft case
(7) Rear axle compensating case bearing (313)
(8) Rear axle compensating case bearing lock nut
(11) Rear axle housing bevel gear pinion
(12) Rear axle housing bevel drive gear
(14) Rear axle housing bevel gear cage

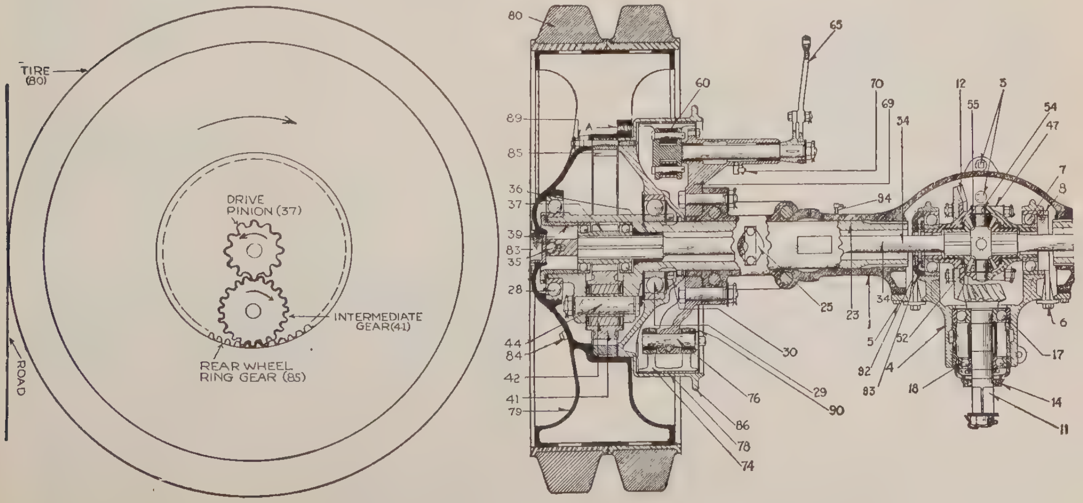

Fig. 51. "Double-reduction drive to rear wheels" on White 3½-ton truck.

(17) Rear axle housing bevel gear cage bearing (410)
(18) Rear axle housing bevel gear cage bearing (310)
(23) Rear axle housing tube R.H.
(25) Rear axle housing tube locks
(28) Rear axle housing tube bearings
(29) Rear axle housing tube bearings
(30) Rear axle housing tube bearing lock nut.
(34) Rear axle housing tube spindles
(35) Rear axle housing tube spindle steel ball,
(36) Rear axle housing tube spindle bushings
(37) Rear axle housing tube spindle drive pinion with bearing
(39) Rear axle housing tube pinion gear bearing nut
(41) Rear axle housing tube intermediate gears
(42) Rear axle housing tube intermediate gear roller bearing
(44) Rear axle housing tube intermediate gear pins
(47) Rear axle compensating case R.H.
(52) Rear axle compensating case gear
(54) Rear axle compensating case spider
(55) Rear axle compensating case spider pinion
(60) Rear axle brake operating shaft link
(65) Rear axle operating shaft adjusting lever
(69) Rear axle brake support brackets
(70) Rear axle brake support bracket grease oiler
(74) Rear axle brake shoes
(76) Rear axle brake shoe pivot pin
(78) Rear axle brake shoe lining
(79) Rear wheels
(80) Rear wheel tires (40 x 5 Dual)
(83) Rear wheel hub caps and gaskets
(84) Rear wheel oil drain plug
(85) Rear wheel ring gear
(86) Rear wheel drum covers
(90) Rear wheel drum and cover plate
(92) Rear axle compensating case thrust bearing
(93) Rear axle thrust bearing nut

The first reduction takes place in the bevel gears in the center of the axle, the **second reduction** being obtained by means of three gears in the rear wheels. The power is delivered from the driving shaft bevel pinion (11) (Fig 51) and the bevel gear (12) by means of the differential gears (52) and (55) to the full-floating type driving spindles (34). These spindles transmit the power to the drive pinion (37).

This drive pinion meshes with an intermediate gear (41), which in turn meshes with the main driving ring gear (85) which is bolted to and drives the rear wheels. All moving parts run immersed in a bath of oil.

Maintenance of Rear System

To drain the wheels: Jack up one or both rear wheels, turn them until the pipe plug (84) (Fig. 51) is at top center; remove the plug and replace it with a piece of ¾″ pipe approximately 7″ long; then turn the wheel until the pipe is at bottom center, and the oil will drain out clear of the wheel rim.

To remove spindles (34) (Fig. 51): Take out the wheel center plugs (83), then carefully remove the ball (35). Screw into the end of the spindle (34) a standard ⅝″ bolt or rod, and then proceed to remove the spindle from the axle tube (23). After the splined end of the spindle leaves the differential gears (52), the spindle will have to be turned slightly so that it will enter the oil-retaining plug (36), and the driving pinion (37), to permit complete removal.

To remove wheels: Take off the hexagon nuts (89) (Fig. 51); then place set screws (29) (Fig. 53) in lug holes (A) (Fig. 51). Turn up equally, in rotation (a few turns at a time) on all three screws by means of the socket wrench, furnished with the equipment. This is very important as it allows the wheel to leave the ball bearing (28) without injury. The removal of the wheels can be greatly assisted by placing a four-castered dolly, a plank with rollers, or a piece of sheet iron under them, which, by lowering the jack, will take the weight of the wheel and permit it to slide off the studs (89) very easily.

To remove main driving-ring gear (23) (Fig. 51): This gear comes off with the wheel and can be very readily removed by means of wedges or flat chisels.

Note. When reassembling the wheel, inspect the ring-gear gaskets and make sure that they are in good condition. Put the gaskets and ring gear on studs before replacing the wheel, to avoid injury to the former.

To remove axle housing tube (23) (Fig. 51): Remove the axle tube locks (25), and loosen the nuts on the rear spring U-bolts, both of which are absolutely necessary in order to remove the tubes. The tube position is maintained by means of a spline in the axle housing, which necessitates the tube being pulled out straight about 6 inches.

Note. After the splined end of the tube leaves the spline of the housing, there is nothing to prevent the intermediate gear dropping from the horizontal to a vertical position.

Caution: It is important that the mechanic, for his own safety, exercise care in performing this operation.

To remove brake drums (86) (Fig. 51): After removing the tube, stand it on end and the brake drum will slide off.

To remove intermediate gear (41) (Fig. 51): Remove the bearing (29), by unscrewing the bearing lock nuts (30). The bearing and inner bearing washers can then be moved along the axle tube a sufficient distance to allow the pin (44) to clear it. The intermediate gear and bearing (42) will then slide out from between the supporting lugs of the axle tube.

To remove driving pinions (37) (Fig. 51): To remove the driving pinions, the intermediate gears must first be removed; then remove the driving-pinion-bearing lock nuts (39) (Fig. 51), and the driving pinions, complete with the ball bearings, can be taken out of the tube as an assembled unit.

To remove differential and bevel gears (11), (12), (52), (55), etc. (Fig. 51): First remove the spindles (34), as already instructed, sufficiently to clear the differential-housing bearing lock nuts (8) and (93); then remove the cap screws (5), and the differential housing (4) can be removed from the axle housing (1), as a complete assembly.

To remove driving shaft and bevel pinion (11) (Fig. 51): First loosen the binder bolt (6), then unscrew the retaining sleeve (14), and it can then be removed complete with the shaft, the bevel pinion and the bearings (17) (18) all a self-contained unit.

Adjustments: The meshing of the bevel driving gears can be adjusted by removing the lock nut locks and turning the differential-housing bearing lock nuts (8) and (93) (Fig. 51) by inserting a small bar in lock opening in the differential housing. The locks must then be replaced to lock the bearing lock nuts and maintain the adjustment.

Caution: Care should be exercised in noting the position of the bevel gears before removing the differential unit. They must be replaced in their original position in order to prevent reverse motion of the wheels.

Clutch

The clutch is of the **single-plate type, operating in** oil.

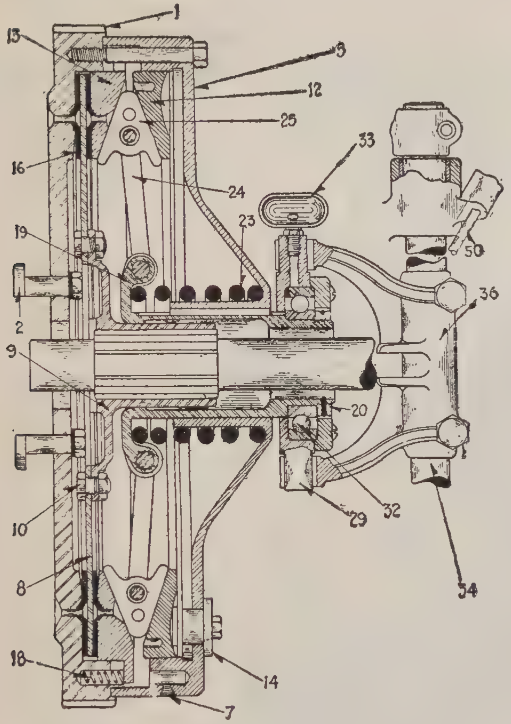

Fig. 52. Single-plate clutch operating in oil.

(1) Clutch flywheel
(2) Clutch flywheel bolt
(5) Clutch flywheel cover
(7) Clutch flywheel plug
(8) Clutch friction plate
(9) Clutch friction plate hub
(10) Clutch friction plate hub bolt
(12) Clutch friction plate ring (notched)
(13) Clutch friction plate ring (plain)
(14) Clutch friction plate ring lock
(16) Clutch friction plate shoe
(18) Clutch friction plate spring
(19) Clutch toggle spider
(20) Clutch toggle spider lock nut
(23) Clutch toggle spider spring
(24) Clutch toggle spider strap
(25) Clutch toggle spider wedge
(29) Clutch pull-out shoe
(32) Clutch pull-out shoe bearing (No. 211)
(33) Clutch pull-out shoe oil cup
(34) Clutch pull-out shaft
(36) Clutch pull-out shaft yoke
(50) Clutch oil tube

To adjust clutch: After removing the hand-hole cover (K) (Fig. 50) and turning the clutch until the ring lock appears, the space between the flywheel cover (5) (Fig. 52) and the clutch pull-out shoe (29) can be adjusted to its proper width (between ¼″ and ⅜″) by depressing the clutch pedal as far as possible and removing the friction plate ring lock (14), while in this position. A section of the notched friction plate ring (12), (which can be turned by means of a screwdriver) will appear through the opening. To increase the space mentioned above, which adjustment will bring the clutch brake into action sooner, turn the ring in a clockwise direction, and to decrease it, turn it counter-clockwise.

The clutch foot lever, which can be moved after removing the rod end pins at the bottom of the clutch foot lever, should be ½″ from the floor board when the clutch is thrown in.

The clutch brake may be adjusted by turning the threaded clutch brake-band pull-rod, so that the brake shoe comes into contact with the clutch coupling ring only on the extreme outward throw of the clutch.

Oil for the clutch is furnished by force from the engine base.

Lubricating Instructions

Engine: Pour filtered medium-heavy engine oil into the crank case sump through the filling hole until the oil-level indicator, on the left side of the engine frame, shows it to be full.

Rear axle: The best lubricant is composed of 50 per cent straight mineral cylinder stock of as low a cold test as possible and 50 per cent of the oil used for the engine. Fill each rear wheel with two quarts through the pipe-plug hole (84) (Fig. 51). Likewise put one gallon of the same mixture in the center housing through the filling hole (3). Every 5,000 miles, remove the drain plugs (3) and (84), cleanse, and refill.

Transmission: Fill the transmission case with transmission oil through the filling hole on top to the level of the overflow plug on the left-hand side of the case. Each 1,000 miles, add sufficient oil to maintain this level; and each 5,000 miles, drain the case through the drain-plug hole in the bottom, cleanse, and refill.

Grease lubricator: Fill with soft cup grease, using a grease gun (18) (19) (Fig. 53).

Truck Driver's Tool Equipment

A good set of tools should be carried on every truck. A well-assorted set is shown in the illustration below (Fig. 53). This is the tool equipment as supplied by The White Co. with all of its trucks.

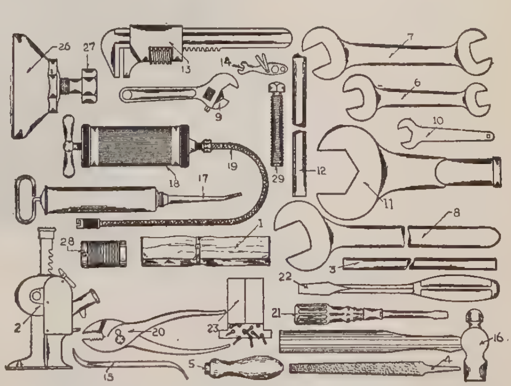

Fig. 53. The White truck tool equipment.

(1) 1 Canvas tool bag
(2) 1 Jack
(3) 1 Jack handle
(4) 1 Half-round file
(5) 1 File handle
(6) 1 Open-end wrench No. 30 (11/16″ x ⅞″)
(7) 1 Open-end wrench (15/16″ x 1⅛″)
(8) 1 Open-end wrench No. 35 (1¼″)
(9) 1 Open-end adjustable wrench (6″ long)
(10) 2 Valve-lift adjusting wrenches (11/16″)
(11) 1 Hub wrench (3¼″)
(12) 1 Hub wrench handle
(13) 1 Auto wrench (14″)
(14) 1 Magneto wrench
(15) 1 Cotter-pin extractor
(16) 1 Hammer
(17) 1 Oil gun
(18) 1 Alemite grease gun
(19) 1 Alemite grease gun tubing
(20) 1 Pliers (8″)
(21) 1 Screwdriver, small (3″)
(22) 1 Screwdriver, large (9″)
(23) 1 Package assorted cotter pins
(24) Not furnished
(25) Not furnished
(26) 1 Front wheel puller
(27) 1 Front wheel-puller screw
(28) 1 Spool of wire (No. 18)
(29) 3 Set screws (¾″-10)

A MODERN TRUCK ENGINE: CONTINENTAL MODEL "L4" RED SEAL

This engine will be used as an example of the construction of a modern truck engine. For a description of the Continental passenger-car engines, see pages 93 and 94.

Specifications

Cylinders: four, 4½" bore, 5½" stroke; displacement, 350 cu. in.; **Power,** S.A.E. rating, 32.4; Brake h.p., 25.5 at 600 r.p.m., 37.0 at 1,000 r.p.m., 42.0 at 1,200 r.p.m., 43.0 at 1,300 r.p.m.; **Weight,** 807 lbs.; **Cooling,** centrifugal pump; **Lubrication,** "full force" pressure feed (see Fig. 55); **Carburetor,** vertical outlet, 1¼" S.A.E. flange; **Ignition,** provisions for magneto or engine driven distributor; **Generator,** crank case accommodates any standard make; **Starter,** fly-wheel housing accommodates any standard make with Bendix drive; **Clutch,** multiple disk or 12" plate type can be used; **Suspension,** three-point; **Construction,** unit power plant with enclosed flywheel.

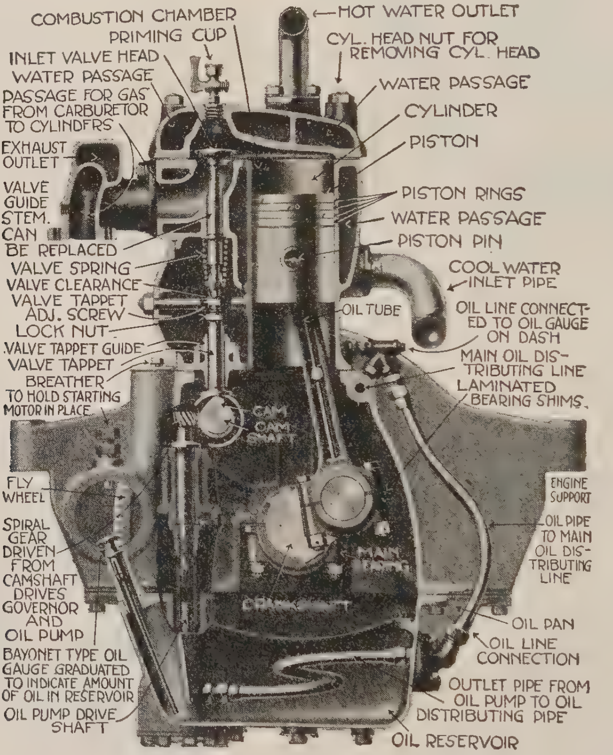
COMBUSTION CHAMBER
PRIMING CUP
INLET VALVE HEAD
WATER PASSAGE
PASSAGE FOR GAS FROM CARBURETOR TO CYLINDERS
EXHAUST OUTLET
VALVE GUIDE STEM. CAN BE REPLACED
VALVE SPRING
VALVE CLEARANCE
VALVE TAPPET ADJ. SCREW
LOCK NUT
VALVE TAPPET GUIDE
VALVE TAPPET
BREATHER
TO HOLD STARTING MOTOR IN PLACE
FLY WHEEL
SPIRAL GEAR DRIVEN FROM CAMSHAFT DRIVES GOVERNOR AND OIL PUMP
BAYONET TYPE OIL GAUGE GRADUATED TO INDICATE AMOUNT OF OIL IN RESERVOIR
OIL PUMP DRIVE SHAFT
HOT WATER OUTLET
CYL. HEAD NUT FOR REMOVING CYL. HEAD
WATER PASSAGE
CYLINDER
PISTON
PISTON RINGS
WATER PASSAGE
PISTON PIN
COOL WATER INLET PIPE
OIL TUBE
OIL LINE CONNECTED TO OIL GAUGE ON DASH
MAIN OIL DISTRIBUTING LINE
LAMINATED BEARING SHIMS
CAM
CAM SHAFT
ENGINE SUPPORT
OIL PIPE TO MAIN OIL DISTRIBUTING LINE
MAIN
CRANKSHAFT
OIL PAN
OIL LINE CONNECTION
OUTLET PIPE FROM OIL PUMP TO OIL DISTRIBUTING PIPE
OIL RESERVOIR

Fig. 54. **Front sectional view of model "L4," four-cylinder "Red Seal" Continental engine.** Model "L4" is designed especially for trucks with a carrying capacity of 3½ tons.

Lubrication

The main oil distributing line runs the full length of, and is cast integral with, the crank case. The passage is lined with steel to eliminate seepage. From this reservoir, secondary leads, cast in the crank case and lined with steel, run to the three main bearings of the crank shaft and to the gear case. Through passages drilled in the crank shaft, oil is supplied under pressure to the connecting-rod crankpin bearings. **Piston pins are supplied with oil** through separate lines running up the connecting rod from the lower end bearing. The cam-shaft bearings and cylinder walls are lubricated by the oil spray thrown off by the connecting-rod bearings.

The oil-pressure regulating valve, with adjustment at the top of the gear case, distributes oil over the timing gears and timing-gear bearings. An individual line, connecting with the main reservoir, takes care of the governor-drive gears.

Oil-pressure adjustment: At the factory adjustment is made at the oil-pressure adjustment screw to show 7 lbs. at 600 r.p.m. Higher pressures can be expected of a cold engine. Under ordinary operating conditions, the pressure may range from 7 lbs. to 30 lbs., depending on the viscosity of the oil and the general condition of the engine. Adjust when the oil reservoir is filled with fresh oil and the engine is warm.

After releasing the lock nut, the adjusting screw should be turned down to increase the pressure, or up to decrease the pressure, until the correct amount is indicated by the gauge on the dash. When the correct pressure is indicated, be sure to turn the adjusting-screw lock nut down until tight.

Valve Timing—Continental Model "L4"

Inlet opens 10° after top; **closes** 20° after bottom. **Exhaust opens** 36° before bottom; **closes** 5° after top.

The **inlet** open period is 190° and the **exhaust** open period is 221°. **Firing order** is 1, 3, 4, 2. **Greatest torque** is at 625 r.p.m. **Carburetor** flange opening is 1¼" (S.A.E. flange—see page 1051).

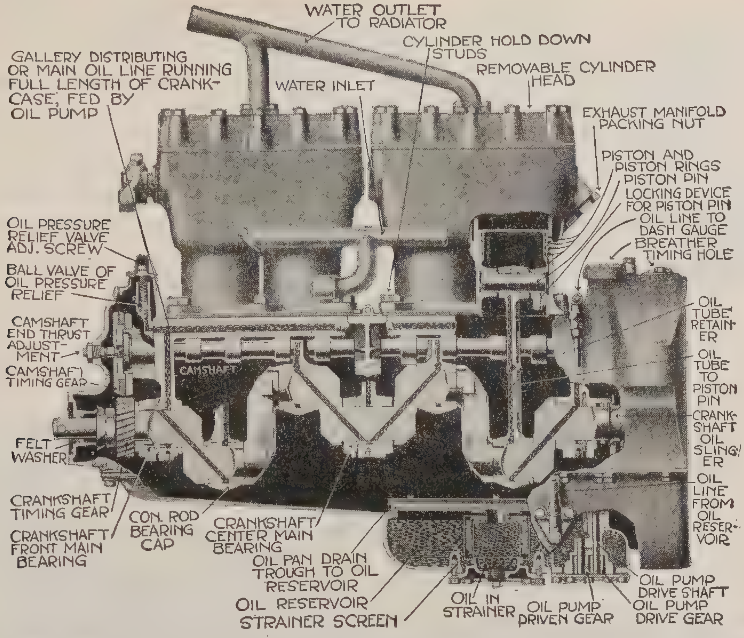
WATER OUTLET TO RADIATOR
CYLINDER HOLD DOWN STUDS
GALLERY DISTRIBUTING OR MAIN OIL LINE RUNNING FULL LENGTH OF CRANK-CASE, FED BY OIL PUMP
WATER INLET
REMOVABLE CYLINDER HEAD
EXHAUST MANIFOLD PACKING NUT
PISTON AND PISTON RINGS
PISTON PIN
LOCKING DEVICE FOR PISTON PIN
OIL LINE TO DASH GAUGE
BREATHER
TIMING HOLE
OIL PRESSURE RELIEF VALVE ADJ. SCREW
BALL VALVE OF OIL PRESSURE RELIEF
CAMSHAFT END THRUST ADJUSTMENT
CAMSHAFT TIMING GEAR
CAMSHAFT
OIL TUBE RETAINER
OIL TUBE TO PISTON PIN
CRANKSHAFT OIL SLINGER
OIL LINE FROM OIL RESERVOIR
FELT WASHER
CRANKSHAFT TIMING GEAR
CRANKSHAFT FRONT MAIN BEARING
CON. ROD BEARING CAP
CRANKSHAFT CENTER MAIN BEARING
OIL PAN DRAIN TROUGH TO OIL RESERVOIR
OIL RESERVOIR STRAINER SCREEN
OIL IN STRAINER
OIL PUMP DRIVEN GEAR
OIL PUMP DRIVE SHAFT
OIL PUMP DRIVE GEAR

Fig. 55. **Longitudinal sectional view showing lubrication system of model "L4," four-cylinder "Red Seal" Continental engine.** Lubrication of model "L4" engine is provided with a pressure-feed oiling system, or what is termed **"full force feed."** The gear-type oil pump is **submerged** in the oil in the reservoir and is automatically primed, and supplies oil positively under a pressure varying from **7 lbs. to 30 lbs.** Note that the **end play in the cam shaft is adjustable** by means of the cam-shaft end-thrust adjusting screw.

Continental "Red Seal" Model "J4" Engine

The model "J4" (not illustrated) is a smaller model, designed for truck use. **Type:** 4-cylinder, vertical, L-head. **Size:** 3¾″ bore by 5″ stroke. **Power:** S.A.E. rating, 22.5 h.p.

Questions and Answers on Continental Engines[1]

Q. 1: What is the difference between engines designed for passenger cars and engines designed for trucks or for other heavy duty work?

Ans.: **Passenger-car engines** are constructed more lightly than commercial truck engines. The **elimination of unnecessary weight** is a most important item in passenger-car design, as **comfort and performance** are primary requirements. Weight distribution, as it affects the balance of the car, is another important item which affects directly the performance of the vehicle. Then, too, a passenger-car engine is seldom called upon for maximum power at any speed, and only a small percentage of the developed power is used under normal driving conditions. Consequently the resistance offered the power impulses is small in proportion to the developed power of the engine. In design, the weight and strength of the reciprocating parts are in proportion to the resistance offered the power impulses in average service, with a suitable factor of safety to withstand the heavy duty often encountered by passenger cars when going up hills and through bad roads. A motor of this type accelerates quickly and is usually capable of higher speeds than are developed by truck motors of the same bore and stroke.

Truck engines, on the other hand, are called upon for a larger percentage of their developed power at practically all times. For this reason, the **moving parts are more generous in size,** and the engine is otherwise designed to withstand greater strains. Performance, acceleration, flexibility, are not the important requirements of a commercial vehicle. There must be ample power, however. **Dependability and long life** are essentials. The engine must operate at full speed with maximum efficiency, day after day, for long periods of time, under a great many unfavorable weather and road conditions. This calls for more adequate cooling facilities, generous bearing surfaces, and more rugged construction throughout. See also page 911 of this instruction.

Q. 2: How is the oil pressure regulated?

Ans.: The flow of oil from the pump increases or decreases in direct proportion to the speed of the engine. Consequently, the oil pressure varies accordingly, as the capacity of the oiling system, accurately predetermined for each given engine, is a constant and fixed quantity. To prevent an excessive oil pressure, an automatic relief valve is connected to the oil line. This valve is located in the gear-case cover, but is adjusted from the outside of the engine. Regulation of this valve is taken care of through a screw held in place by a lock nut. The screw controls the tension of the coil spring against which the **ball valve automatically opens in proportion to the pressure,** and allows the surplus oil to flow over the timing gears, thereby maintaining in the oil lines the most effective pressure for adequately lubricating all moving parts.

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[1] See pages 93 and 94 for the Continental passenger-car engine, model "7R."

Q. 3: If adjustment of the oil pressure is required, when should it be made?

Ans.: The ideal time for adjusting oil pressure is when the engine is filled with fresh oil and after it has been operating long enough to have attained its normal running temperature.

Q. 4: What are the correct oil pressures for "Red Seal" Continental motors?

Ans.: The correct oil pressure to maintain depends first upon the type of oiling system used in the engine. Continental motors in use today are provided with one of two types of lubrication.

The first, a **combination splash and force-feed system,** usually includes a plunger-type oil pump and might be termed a low-pressure system. The oil gauge will usually show a reading of from 2 lbs. to 7 lbs.

The second, a **full force-feed system,** usually includes a gear-type oil pump and might be termed medium or high pressure. Engines so equipped will usually operate under a pressure from 10 lbs. to 30 lbs. In every case the pressure is influenced to some extent by the speed of the vehicle, the viscosity of the oil, and the general condition of the engine.

Q. 5: Can valve guides be replaced and what are they made of? Are valve plunger guides replaced and what are they made of?

Ans.: Both valve guides and valve tappet guides are made of a refined grey iron. They can easily be replaced.

Q. 6: Are governors used on Continental motors?

Ans.: Motors designed for passenger-car service are not adapted to governor installation.

Motors designed for commercial vehicle work, however, have provision for standard types of engine-driven mechanically operated governors. The maximum speed is 1,300 r.p.m., usually governed to 1,200 r.p.m.

Q. 7: What is the bore of the cylinder of the "L4" in decimals?

Ans.: The bore is 4.500″ (four inches and five hundred one-thousandths, or 4½″).

Q. 8: What is the standard clearance of the piston?

Ans.: The standard clearance on the "L4" is .004″.

Q. 9: What would the standard piston then measure at the skirt?

Ans.: It would measure 4.500″ − .004″=4.496″.

Note that an allowable limit of .002″ is usually permitted for the cylinder bore and the piston, and the standard piston will usually measure **4.498″**.

Q. 10: What sizes of oversize pistons are furnished by the Continental Motors Corporation?

Ans.: .002″, .003″, .005″, .010″, .020″, .022″, .025″, .027″, .030″, .035″, .040″, .045″.

Q. 11: What would they measure, expressed in decimals?

Ans.: If the standard-size piston is 4.498″, the .002″ oversize would be 4.498″+.002″=4.500″.

.003″ oversize; 4.498+.003=4.501″
.005″ oversize; 4.498+.005=4.503″
.010″ oversize; 4.498+.010=4.508″
.020″ oversize; 4.498+.020=4.518″
.022″ oversize; 4.498+.022=4.520″
.025″ oversize; 4.498+.025=4.523″
.027″ oversize; 4.498+.027=4.525″
.030″ oversize; 4.498+.030=4.528″
.035″ oversize; 4.498+.035=4.533″
.040″ oversize; 4.498+.040=4.538″
.045″ oversize; 4.498+.045=4.543″

See also Index for other Questions and Answers on Continental engines.

EXAMPLE OF ADJUSTING A LIGHT TRUCK AND TRACTOR ENGINE (WAUKESHA)

There are many different makes of truck engines. It is impossible to show them all. We will, therefore, select the **Waukesha** as an example of how adjustments are made, such as taking up on the bearings, etc.

Although the construction may vary on different engines, the same principle of making these adjustments will apply to many of the other engines on the market. See also discussion of the **Continental model "L4" engine** (page 936), which is a very popular engine in use on many different makes of trucks.

How to Put Oil in Engine

Remove the breather cap (A) (Fig. 58). Pour oil into the breather until the needle float in gauge (B) comes up to within ¼″ of the top of the glass.

Remove the crank-case hand-hole plate (Fig. 62), and fill each trough under the connecting rods.

Use a thinner oil in winter and a heavier one in summer.

(C) (Fig. 58) represent water drains for cleaning sediment or rust from the water jacket and circulating water pump, and also for draining in winter to prevent freezing.

Engine Oiling System Inspection

Drain the oil—remove the oil pan so that you can inspect thoroughly. When the system is running properly, a stream of oil is constantly forced through holes (A) (Fig. 59). Inspect each oil hole carefully and see that they are not clogged or partially clogged up. A piece of waste or dirt may have worked into one of the holes, preventing the flow of oil entirely.

To test the oil flow: With some oil in the oil pan, turn the oil pump shaft with a pair of pliers as shown. If the oil discharges through all of the holes, the pump and oil line are working properly.

Clean the screen (3M) (Fig. 59): This should be cleaned often with gasoline, say every three months, if the engine is run regularly every day. When removing the screen for cleaning, be sure to retain the supporting spring inside and to make sure of an oil-tight joint being established between the oil-pump screen-flange gasket and the crank case (see Fig. 59).

The oil pump is located at the lower left side of the engine, when standing in rear of it (see Fig. 62 and Fig. 57). It is driven by a cam shaft (see Fig. 57).

The system described above is the oiling system of the models "L," "M," "P," "N," "R," "S," "O," "SU4R," "RU4R," "LU4," "MU4," and "PU4" Waukesha engine.

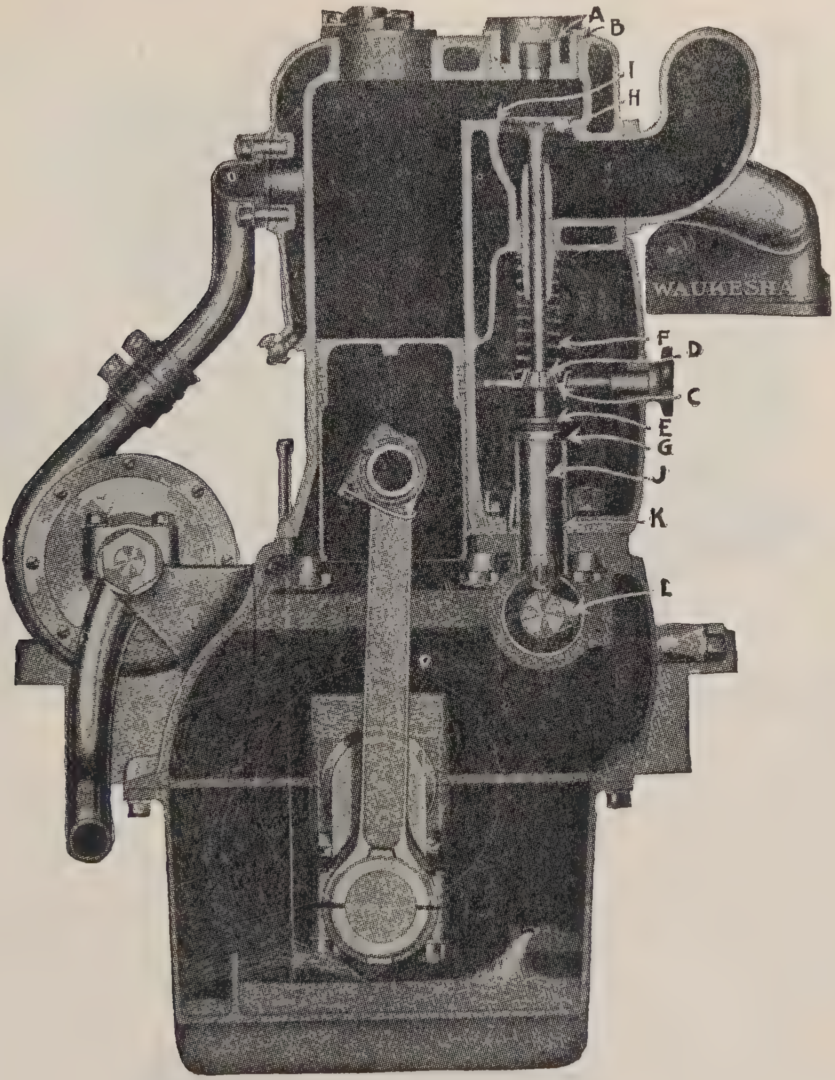


Fig. 56. **Front-end sectional view of the Waukesha 4-cylinder engine.** Lubrication is of the splash system: (**F**) valve spring; (**D**) valve spring retainer; (**C**) valve spring cap; (**E**) lifter adjusting screw; (**G**) lock nut; (**J**) valve lifter; (**K**) valve guide; (**L**) cam on cam shaft; (**A**) valve cap; (**B**) copper gasket; (**I**) valve seat; (**H**) valve face. Water circulating pump on left.

Kinds of Oil to Use

For pleasure cars, thin; for trucks, thicker; for tractors (gasoline), heavy; for tractors (kerosene), heaviest. When kerosene is used, clean the oil pan often and put in fresh oil (see page 167).

To Get at the Gears

Take off the front gear cover carefully. See that no bolts or nuts are mislaid or lost. Also be careful, in taking off the ball-race on the governor, to see that none of the bearings drop out. Do not put the front gear cover on again until you are absolutely sure that every one of the ball bearings is in place, and that the paper gasket is in good condition to prevent oil leaks.

Be sure to mark the gears. It is very important that the gears be kept in exactly the same position as when you received the engine. Mark each gear as shown in Fig. 60, that is, mark the center gear (**A**) (**B**) (**C**), as shown; then mark the same letter on the gear that connects at the particular point.

In putting the gears on again, see that the connections are **A-A, B-B, C-C,** just as marked.

In marking the gears, put the letter on the cog of one gear and on the corresponding space where this tooth meshes on the connecting gear, just as shown in Fig. 60**A**.

Operation of Waukesha Governor

Two circular weights back in the case behind gear (**O**) (Fig. 61) are held by—and swivel about—the two pins marked (**K**). These weights fly out at speed—moving the part (**A**) outward. This action presses the ball-bearing thrust contained in retainer (**B**) outward in proportion.

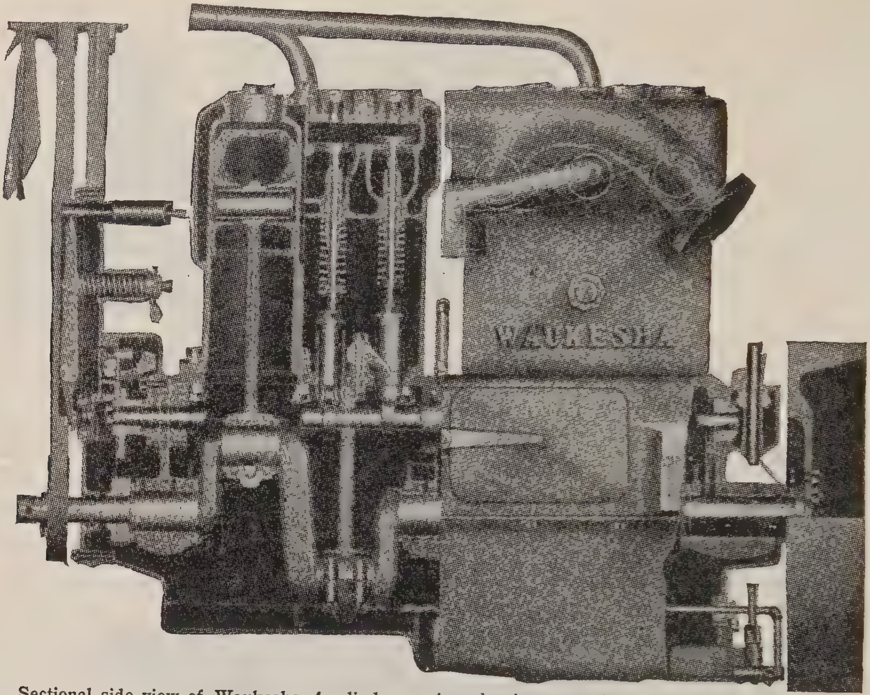


Fig. 57. **Sectional side view of Waukesha 4-cylinder engine** showing operation and interior construction. Note the governor fulcrum and the oil pump, the latter being at the lower flywheel end.

The lever (**D**) swivels on the fulcrum (**C**). The movement of (**A**) causes a movement of rod (**R**) in the direction indicated by the arrow. The movement of rod (**R**) closes valve (**h**), which is of the butterfly type, and swivels on shaft (**S**).

The adjustment for speed is made by turning screw (**L**). Turning (**L**) in the direction indicated by the arrow causes the engine to speed up, while turning (**L**) in the opposite direction causes the engine to slow down.

The governor is locked by locking nut (**G**). It is further possible to lock and seal the whole arrangement by passing a seal wire through the hole in the spring housing, and through the hole in nut (**G**).

(**F**) is a spring, the tension of which governs the speed of the engine. The governor is of the throttling type, and controls the amount of gas to the cylinder; it would, therefore, be termed a throttling type of governor of the centrifugal type—but by weights, instead of by balls.

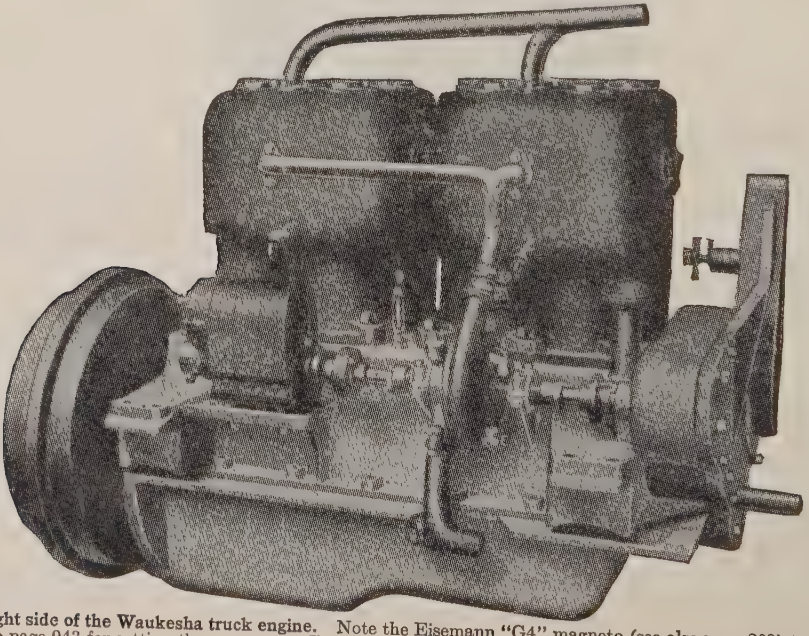


Fig. 58. **Right side of the Waukesha truck engine.** Note the Eisemann "G4" magneto (see also page 269) type used on this engine. See also page 943 for setting the magneto. The circulating pump and magneto are driven from gear (**2C**) (Fig. 60).

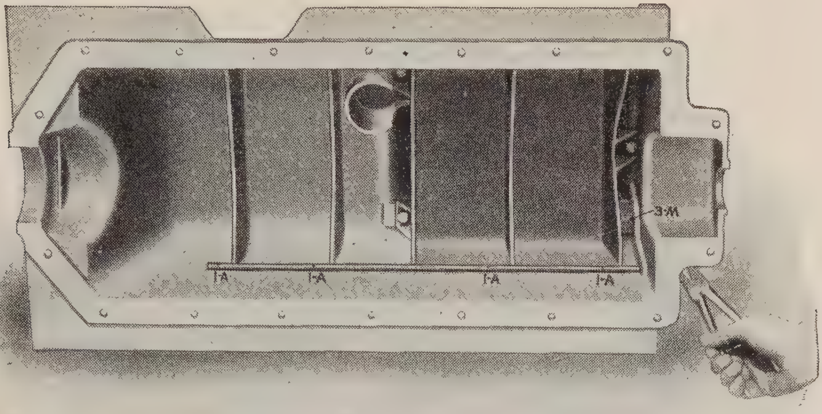


Fig. 59. Oil pan removed.

How to Time the Valves

All Waukesha engines have cylinders numbered 1-2-3-4, starting at the front, or gear end and reading toward the flywheel end.

Timing Valves by Flywheel Marks

As a rule, the flywheels are marked as to when the valves should open. The following method is applied in case the flywheel and the timing gears are not marked.

First: Turn the engine over until No. 1 piston is on upper dead center (Fig. 63). In order to determine when the piston is at upper dead center, remove the cylinder-head plug and insert a steel rule (**R**) (Fig. 62), or any marked stick. Rotate the crank shaft and watch while the rule (**R**) comes up. When it ceases to rise, the piston will be at upper dead center.

Draw two lines across the back side of the flywheel (Fig. 63); next measure off 53° on each side of the center line at the lower half of the flywheel.

Second: On the illustration (Fig. 62) note the pointer (**A**) (also called a trammel; see also page 66). This pointer points to the exact top center of the flywheel. The arrow on the dead center line (Fig. 63), shows where pointer (**A**) points, looking at the back side of the flywheel. Turn the engine over slowly until the arrow (**A**) points directly on line No. 3, as indicated in Fig. 63.

Third: Remove the idler gear (**A, B, C**) (Fig. 60). See that the push rod (**J**) (Fig. 62) is in its lowest possible position. Place a thin piece of paper between the push rod (**J**) and the valve stem (**X**) (Fig. 62). Turn the cam-shaft gear (**O**) (Fig. 61) slowly toward the right until the paper which is placed between the push rod (**J**) and the valve stem (**X**) is held tightly. Be sure that the valve stem (**X**) has not risen any. Also be sure that the cam-shaft gear retains its position and that the piece of paper is still held tightly between the push rod and the valve stem. There should be about .003″ to .004″ clearance for the inlet and .005″ to .007″ on the exhaust.

Fourth: Place a wooden wedge between the cam-shaft gear and the case, in order to keep this setting. This will give the free use of both hands for replacing the idler gear. Replace the idler gear.

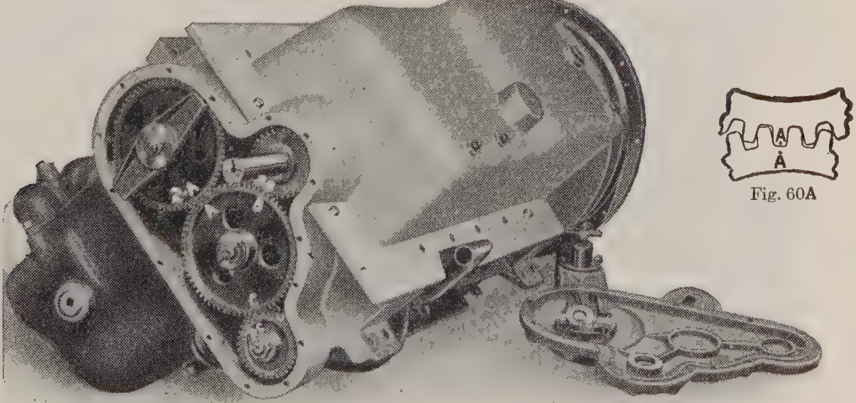


Fig. 60A

Fig. 60. Showing how the gears are meshed. Engine is up-side-down. The small gear (2C) drives the magneto and circulating pump; the next gear to it is the idler gear which is placed between the small crank-shaft gears (2B) and (2C). The gear on which the governor is attached (2A) is the gear which drives the cam shaft and oil pump, and is driven by the idler gear. Therefore the cam-shaft gear (2A) revolves at one-half the speed of the crank-shaft gear (2B).

Fig 60**A**. Shows how the tooth of one gear, marked (A) must mesh between two gear teeth marked (A). Note in Fig. 60 that **A** and **A, B** and **B**, and **C** and **C** must mesh in this manner.

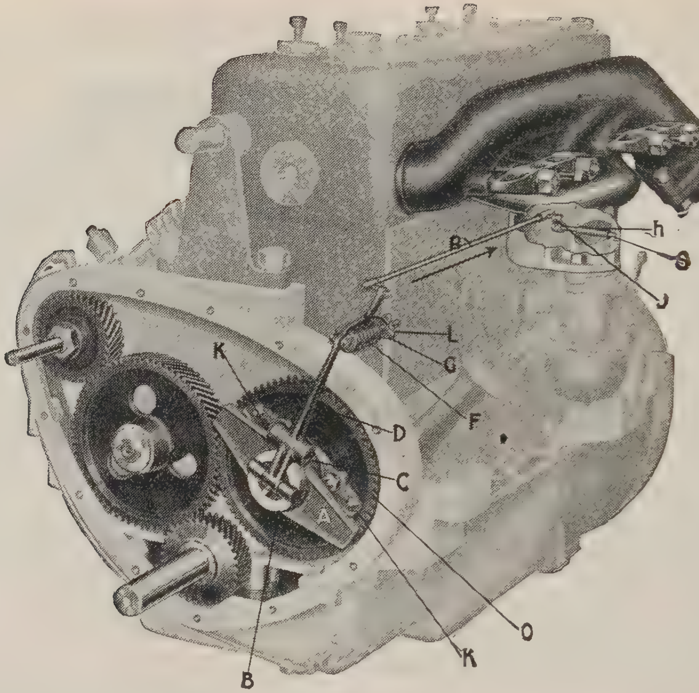


Fig. 61. Front view of engine with gear-case cover removed, **showing gears and governor action.** The large idler gear between the two small gears drives the large cam gear and magneto and circulating pump gear.

Fifth: Give the engine a slight turn (say about one half-inch on the flywheel); now see if the exhaust valve (**X**) has risen any. It should, if the foregoing instructions have been carefully carried out. You can now replace the gear-case cover and the cylinder-head plug.

Timing Valves by Position of Piston

If it is impossible to get at the flywheel, remove the cylinder-head plug, insert a ruler as shown in Fig. 62. When the upper dead center has been determined, measure the distance from the top of the piston to the top of the cylinder. For example, let us say it is 2″. See arrow marked (**D**) (Fig. 62).

Now slowly turn the engine over until the distance from the top of the piston to the top of the cylinder measures $7\frac{5}{8}''$. This means that the piston has made a drop of $5\frac{7}{8}''$, at which place the exhaust valve (**X**) should just start to open. In order to set the valve and complete the timing, refer

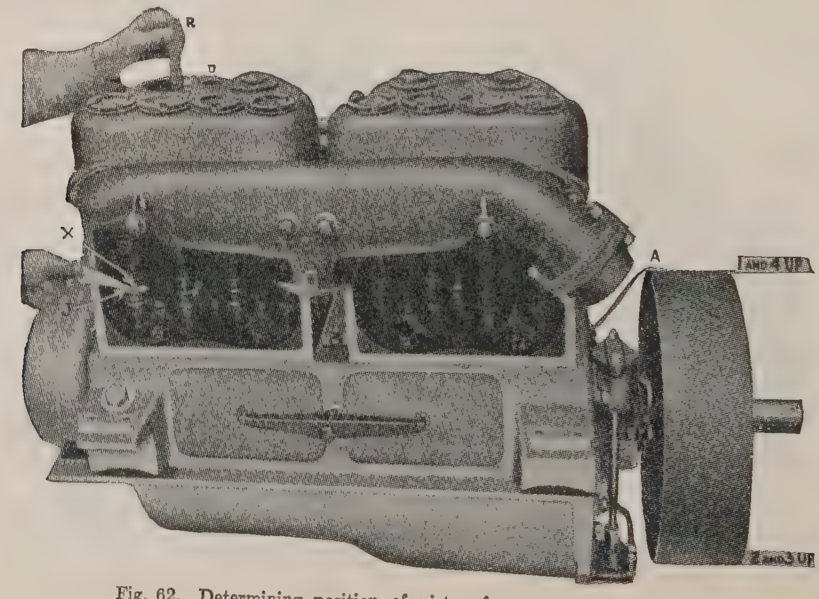


Fig. 62. Determining position of piston for purpose of timing valves.

to paragraphs, "Third," "Fourth," and "Fifth," pages 941 and 942.

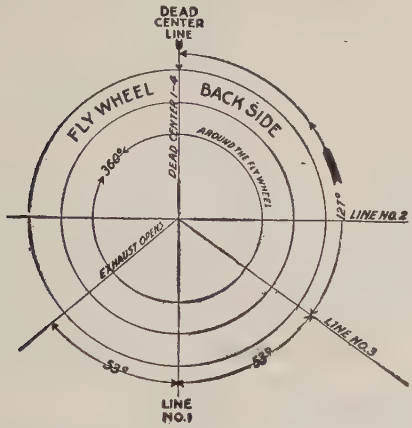


Fig. 63. Valve timing diagram of Waukesha engine models "L-LU4," "M-MU4," and "P-PU4."

This setting pertains only to models "L-LU4," "M-MU4," and "P-PU4."

For models "O-OU4-OU4R," "S-SU4-SU4R," "R-RU4-RU4R," "N-NU4-NU4R," the piston should drop $4\frac{7}{8}''$ from upper dead center; that is, the exhaust valve should open 50° before the piston reaches the bottom dead center after the explosion has taken place.

For models "T" and "TU4," "B" and "BU4," the piston should drop 4.644″ or $4\frac{41}{64}''$ from upper dead center; or the exhaust valve should open 45° before the piston reaches the bottom dead center after the explosion has taken place.

In all cases, in resetting the valves, the magneto will have to be retimed; for this operation see Fig. 64.

Example of Setting Time of Spark by Position of Piston (Magneto Ignition)

The engine used in this example is the Waukesha 4-cylinder truck and tractor engine, using a high-tension magneto for ignition.

In case the magneto has been removed from the engine and its connections have not been previously marked, it can be retimed as follows:

First: Open all the priming cups on top of the cylinders and turn the engine over slowly until the compression stroke begins in No. 1 cylinder. This can be ascertained by holding the thumb tightly over the priming cup of this cylinder and observing that both the valves remain closed (see Fig. 64).

When the compression stroke begins on No. 1 cylinder, **stop** and remove the cylinder head plug; now insert a ruler and slowly turn the engine until the piston comes to upper dead center, or when the ruler ceases its upward movement (see Fig. 62).

Second: Now measure the distance from the top of the piston to the top of the cylinder. For example, let us say that the distance measures 2″ from the top of the piston to the top of the cylinder. Turn the crank over until it measures $2\frac{1}{8}''$. This

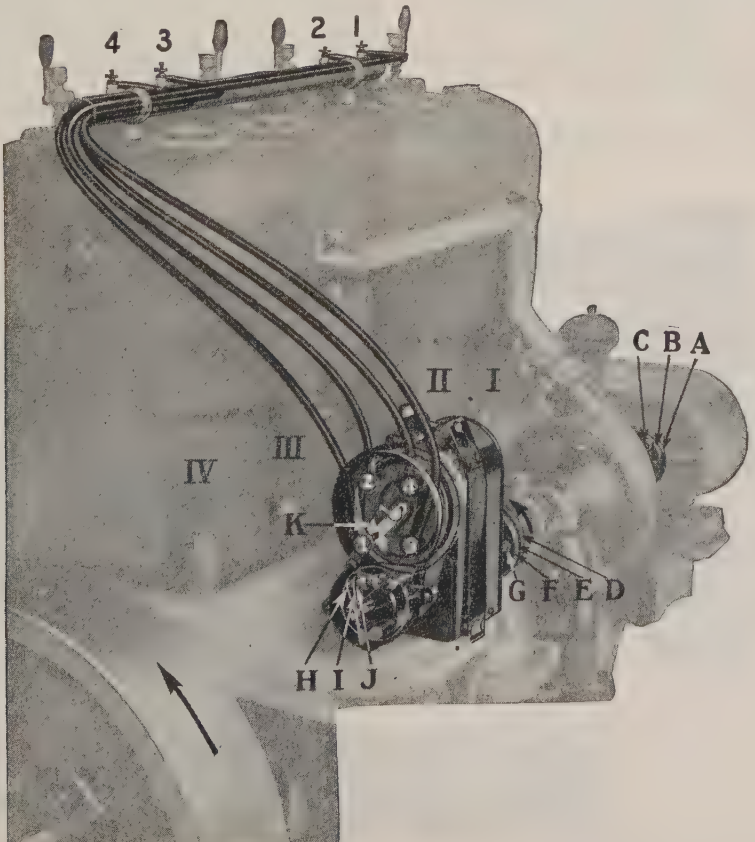


Fig. 64. Magneto setting and timing.

means that the piston has made a drop of ⅛″ after top, on firing or power stroke, at which point the spark should occur. Replace the cylinder-head plug to prevent any objects from falling in the cylinder.

Third: Remove the bolts (C) which connect the flanges (A) and (B); then connect the leather coupling (G, F, E, D) next to the magneto. The magneto is driven by a gear in front of the engine, which is driven from the crank-shaft gear, with an idler gear between.

Fourth: Set the breaker (or interrupter) cam in such a position that the distributor arm (K) will come on the No. 1 cylinder high-tension terminal in the distributor, and so that the contact screws (H-J) of the interrupter are just starting to open. Letter (I) represents the opening between the platinum contacts (H and J) with the spark lever in the **fully retarded position.**

Fifth: Replace the two bolts (C) in the flanges (A-B); that is, one on either side of the coupling.

Sixth: Attach the wire which leads from the spark plug on No. 1 cylinder to the terminal marked No. 1 in the distributor plate; No. 2 spark-plug wire to the terminal marked No. 2; No. 3 spark-plug wire to the terminal marked No. 4; and No. 4 spark-plug wire to the terminal marked No. 3.

How to Adjust Loose Connecting Rods and Main Bearings of Waukesha Engine

Connecting rods and main bearings may be adjusted without taking the engine out of the chassis as shown in Fig. 65. However, this does not hold true where it is impossible to work at the engine from below.

The following instructions will give a good idea **how to proceed in order properly to adjust the connecting rods and main bearings** not only on this engine but other engines.

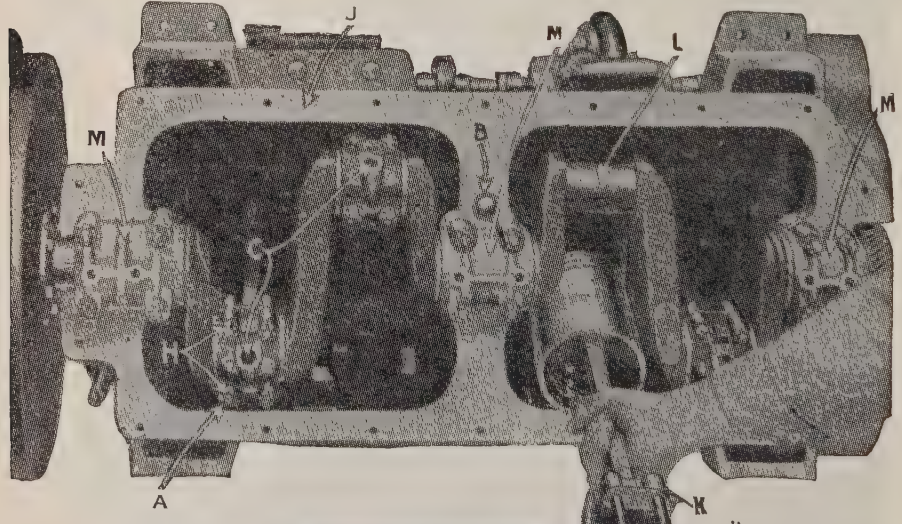
First: Drain off the oil by removing the drain or pipe plugs from the bottom of the oil pan; then place a small lift jack under the pan to keep it from dropping before all the oil pan bolts that support it have been removed. It is advisable to tie up the oil float (B) as high as possible, to prevent it from dropping into the oil pan while the latter is being removed (this can be done by unscrewing the holder of the oil-gauge glass) and thus prevent the possibility of it being damaged or bent. This also makes it easier when you are ready to replace the oil pan. Open all four compression cups on top of the cylinders.

Second: After removing the pan, scrape off the gasket from the bottom edge (J) of the crank case, and clean away all dust and dirt so that it will not get into the bearings. Clean your hands and tools before working on the bearings, and never use cotton waste or any rags which might leave shreds behind, as these might cause serious trouble to the oiling system.

Third: When working on bearings, it is a good plan to pull out the pistons and clean off the rings and piston heads. Always oil **the piston rings** before replacing the piston.

Fourth: Pull out the cotter pins (A) and unscrew the four nuts (H) (always use a socket wrench for this operation as open-end wrenches are apt to destroy the nuts); when taking off the cap be careful not to lose any shims or liners (F), and keep them in place on (K) until ready to remove them.

On this engine, as well as on most all engines, laminated shims are used between the connecting rods and their caps, allowing one to adjust the bearings to within .002″. **Laminated shims** vary in thickness, and are made up of a series of small shims —.002″ in thickness—which are pressed together as one piece. In taking the loose play out of the bearings, one can peel these shims off (Fig. 66) to any extent required to have a perfect adjustment on the bearings. Never peel off any more of the shims at one time than is necessary. Take out the shims to the extent you think necessary to take up the wear, being careful to remove an equal amount of **shims** on each side of the cap.



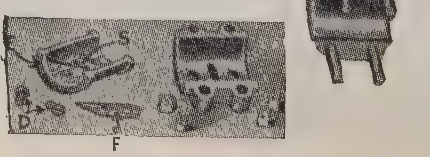


Fig. 65

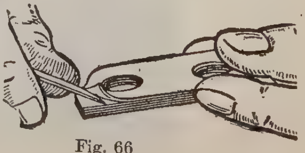


Fig. 66

Fig. 65. Showing lower part of crank case with oil pan removed; Fig. 66. Peeling off a laminated shim, as described in text.

Before replacing the cap, see that the thin shims are placed between two heavy ones, with which the connecting rods are always supplied. Replace the cap and draw it up as tightly as possible, using all four nuts, and drawing them up evenly and firmly.

Now try turning the engine over by hand in order to find out whether you have the bearings too tight or not. It should turn easily, as this represents only one tight bearing; when this bearing is right, loosen it, and proceed to fit the other bearings in the same manner.

After each bearing has been fitted and tested, draw up firmly all the nuts and use new cotter pins only; never back up the nuts to insert the cotter pins. Always draw up to the next notch. Never use wire in the connecting-rod nuts, as it will interfere with the oiling system. Have the cotter pins well bent apart, so that they cannot back out when the engine runs.

How to Replace Worn or Damaged Main Bearings

First: Take the engine out of the chassis, and before removing the pan, draw off all the oil. Refer to page 938 for instructions for removing the oil pan.

Second: Take out all spark plugs, priming cups, etc., on top of the cylinders. Now stand the engine on its head, and place props under the engine arms to keep it from wobbling while work is being done.

Third: Remove the oil pan and take out all pistons, and be sure that they are all marked so that they will be put back into their respective places. Remove the gear case as shown in Fig 60.

It is most important, before removing the crank shaft, to mark all the gears in accordance with instructions on page 941, otherwise there is a possibility of getting the engine out of time.

Take off the flywheel, but be sure that you have it marked with the flange on the crank shaft, as it is very important that the flywheel should be replaced in the same position as when you take it off.

Fourth: Take off the three main bearing caps (**M**) (as illustrated in Fig 65), and remove the crank shaft. Stand the crank shaft up on end and place it safely aside, as a fall might spring it out of shape, and later you would wonder why the bearings could not be fitted with the proper alignment. Remove the idler gear marked (**A-B-C**) (Fig. 60).

Take out the screws to remove the damaged bearing. Clean away all dirt and grit with gasoline; fit in one-half of the new bearing in the crank case. This operation is the same as described for replacing the connecting-rod bearings (page 944).

After the bearing has been fitted in the crank case, replace the crank shaft. Apply Prussian blue or red lead to the crank-shaft bearing surface and scrape off the "spottings" in the same way as in fitting new connecting-rod bearings. Strict attention must be paid to see that the new bearing does not rest too high in the case so as to throw the other two bearings out of line, nor should the bearing be too low.

Should the bearing be too high, either the two other bearings will have to be raised by shimming them up, or the new bearing must be scraped until the three bearings are on the same level. The crank shaft must fit the half of the main bearings in the crank case perfectly before you proceed to fit the caps.

Always fit the rear main bearing cap first, and tighten it up as much as possible without stripping the bolt threads. When the bearing has been properly fitted, the crank shaft will permit moving with one hand. If the shaft cannot be turned with one hand, the contact between the bearing surfaces is evidently too close, and the cap requires shimming. On the other hand, if the crank shaft moves too easily, some shims must be removed to permit it to set closer.

After removing the cap observe whether the blue "spottings" indicate a full bearing the length of the cap. If they do not, the bearing will have to be scraped. Lay the rear bearing aside, and proceed to adjust the center bearing in the same manner. Repeat this operation with the front bearing, with the two other bearings laid aside.

When the proper results have been obtained with the bearings, **replace the idler gear** and be sure that the connections (**A-A**) (**B-B**) (**C-C**) correspond, as shown in Fig. 60).

You can now replace the caps and insert the cotter pins, or wire. Be sure, when you replace the pistons, that the heads and the rings are free from grit and carbon and also oil each piston ring carefully.

Fifth: Oil the bearings well by means of an oil can, and turn the engine over (by using the crank handle) several revolutions before replacing the oil pan.

Sixth: Are you sure that holes (**C**) in all four connecting-rod bearing caps are facing the direction in which the engine runs? This is important, because, when the engine runs, oil is forced into these holes to lubricate the bearings; if one of these holes should face in the opposite direction, that bearing would get practically no oil, the bearing would heat up, and would soon cut out, resulting in a costly repair.

Seventh: Refer to the oiling system, page 938, before replacing the pan.

How to Replace Worn or Damaged Connecting-Rod Bearings

First: Remove the oil pan, as instructed on page 938; then take off the cap and pull out the piston, as shown in Fig. 65.

Second: Take out the screws (**D,** lower illustration in Fig. 65) in order to remove bearing (**E**). Be sure to fit the bearing half with the large oil hole (**S**) in the cap, and the other half in the connecting rod (**K**).

The back side of the bearing must have a perfect or snug fit in the connecting rod, otherwise it will be impossible to get a perfect, permanent bearing on the crank pin (**L**). Fitting the back of the bearing is practically on the same order as fitting the bearing to the crank pin. Using Prussian blue or red lead in the rod and cap will enable you to find the high spots between the cap and the bearings; these high spots must be draw-filed (see Index).

Third: Put in the screws (**D**) very firmly, and be sure that the heads are lower than the bearing surface so that they do not come in contact with the crank shaft. Next draw a file across the top of the cap and the rod to have the bearing flush with it.

Fourth: Without replacing the piston in the cylinder, fit the bearing to the crank pin (**L**); if the bearing is too wide, the ends will have to be draw-filed. Be careful not to file off too much. By applying Prussian blue or red lead to the crank-pin surface, it will enable you to fit the bearing to the pin to determine whether a perfect bearing surface is obtained. Remove the rod and observe whether the blue or red "spottings" indicate a bearing the full length of the cap. If they do not, the babbit should be scraped until a perfect bearing surface is obtained.

Adjust the bearing to the crank pin so that it can be moved to and fro freely, but at the same time it must not be loose.

Remove the connecting rod and replace the piston, and give the bearing the same adjustment as you did when the piston was out; then turn the engine over by hand several times to make sure that no binding takes place.

Do not be afraid of getting the connecting-rod bolts too tight, as the shims under the cap will prevent the metal from being drawn into too close contact.

GOVERNORS

Governors are sometimes used on trucks, tractors, taxicabs, and marine and stationary engines.

Purpose of the Governor

There are two reasons for using a governor: one, to regulate the vehicle speed, the other, to regulate the engine speed. The governor is set at whatever speed the car owner desires, is then sealed, and the driver can never exceed the speed for which the governor is set. The engine type of governor (Figs. 67, 68, and 69) is used to prevent undue racing of the engine when changing gears or releasing the clutch. The average driver will work his engine at high speeds a great deal more than is necessary, straining the entire mechanism of the car, and wasting both fuel and oil. By governing the engine speed, the vehicle speed is also limited.

Anything which tends to decrease the speed of the engine, namely, going up hill, through a mudhole, or with an added load, in turn **causes a decrease in the speed of the engine and a consequent decrease in the speed of the gases,** when immediately the governor opens the throttle to admit a sufficient amount of gas to maintain the speed at which the adjustment was made.

Engine drive—(Figs. 67, 68, and 69): This type of governor regulates the number of revolutions of the engine, and will keep it running at a definite, safe speed, regardless of the load it is pulling, even if the throttle is wide open. The regular **hand-throttle lever or accelerator** may be used for lower speeds. Should the clutch be suddenly released when the engine is pulling a load or running at maximum speed, the engine positively cannot race. The engine governor also limits the vehicle speed, because the engine cannot exceed the set speed.

Transmission governor drive (seldom used) is where the governor on the engine is driven by a flexible shaft and gears from the transmission or front axle.

THE SIMPLEX, DUPLEX AND McCANN GOVERNORS

The governor (Fig. 67) is placed between the carburetor and the intake manifold. It operates on the centrifugal principle. As the speed increases, the weights (W) cause the valve (T), which is of a grid construction, to close the gas passage (G0 and G1) gradually, thereby cutting off the flow of gas to the inlet manifold. Therefore it would be termed a "throttling-type governor, centrifugal type."

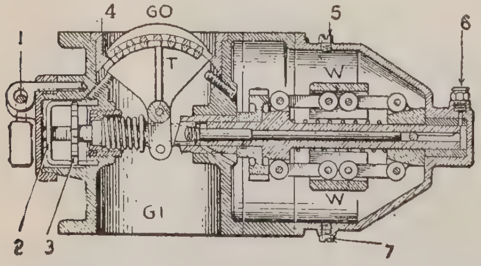


Fig. 67. **The Duplex governor:** (1) locking pin; (2) yoke; (3) hand wheel; (4) valve seat; (5) oil entrance; (6) oil cap; (7) oil discharge.

On the Simplex single-drive governor, the shaft is attached to the engine or vehicle in any manner desired.

On the Duplex double-drive governor,[1] one shaft is attached to the engine and the other is attached to the vehicle, at the wheel or transmission.

The difference between Duplex and Simplex is that with the former you can control both the **engine** and the **vehicle speeds,** whereas with the latter, either the **engine or the vehicle speeds** can be controlled.

On high gear, with a truck running at 12 m.p.h., the engine may turn over only at 900 r.p.m., but for low-gear service the engine may be governed for 1,400 r.p.m. Therefore you would be able to maintain 12 m.p.h. even in second gear.

The governor is a telltale on carburetion. If it surges, it may result from one of five causes: the mixture is too rich; the governor lubrication is bad; the ignition is faulty; the governor valve is dirty; or the cable drive is not steady and free from backlash.

To Set and Care for the Simplex or Duplex Governor

To set: First get the consent of the factory, otherwise you may lose your guarantee. Turn the hand wheel (3) out for higher, and in for lower speeds. Do not fail to lock the hand wheel with the yoke (2) after setting, if a locking spring is not provided, and see that the yoke does not bind on the hand wheel. The locking pin and seal (1) are for the protection of the governor and the engine. Do not touch the valve screws (4).

To operate the engine with a governor: For best economy, run the vehicle on governor speed as much as possible. Bring the vehicle speed up to set a maximum governor speed with the throttle lever and then advance the spark and throttle to the best normal running positions.

Do not over advance the throttle, as the engine might "hunt" with a heavy load on low piston speed. Find the best throttle position, and mark it.

Lubricate weekly at (5) by filling the chamber with medium cylinder oil; 600-W is preferred for summer, and in winter add an equal amount of light machine oil. Every 1,000 miles remove drain (7), fill half-full of light machine oil, run for ten minutes to clean the interior, and drain out. Then refill as above.

To clean the governor valve: If necessary, pour kerosene into the air inlet of the carburetor while the engine is running, varying the speed.

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[1] Duplex Engine Governor Co., 36 Flatbush Ave., Extension, Brooklyn, N.Y.

McCann Suction Type of Governor

This governor is mounted on the carburetor (Fig. 19, page 39). When the engine is turning slowly, the full current of gas from the carburetor, as controlled by the throttle, is allowed to pass to the cylinders.

As the speed increases, resulting **suction** causes piston (**P**) to rise against the pressure of spring (**S**), thus gradually cutting off the supply of gas through the perforations, until, at maximum speed-setting, the engine cannot be further accelerated. This is termed a "suction type of governor."

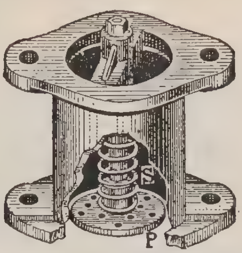

Fig. 68. The McCann governor.

CARE AND INSTALLATION OF PIERCE CENTRIFUGAL ENGINE[1] GOVERNOR

Mounting governor: Use thin gaskets of blotting paper only. **Do not use shellac**—it will cause the governor valve to stick.

Flexible drive shaft: There should be no bends in the shaft within 2″ from either end, nor should the shaft be bent into a circle of less than a 10″ radius. Make all bends as easy and large as possible.

Solid drive shaft: In mounting a solid shaft, be sure that the shaft ends properly engage in the governor, the right-angle drive, and the engine connection, and see that the lock nuts on the tube are tight. Do not screw the tube up tight enough to cause the shaft or gears to bind.

Oiling governor equipment: Before the governor is put into active service, see that the case contains about 4 oz. of good light oil (light Polarine preferred) that is not affected by change in temperature. Put in one or two ounces of oil every thousand miles. The flexible shaft should be kept packed with Artic No. 3, or a good graphite grease, renewing it every 2,000 miles. Oil the gear bearings, the right angle drives, or the engine connections, each week through the oil holes provided.

Loose connections: When driving gears or brackets are used, examine them regularly to see that none work loose and that the gears are kept in perfect alignment and are meshing properly. If a belt is used, keep it tight and free from oil or grease, to prevent slipping.

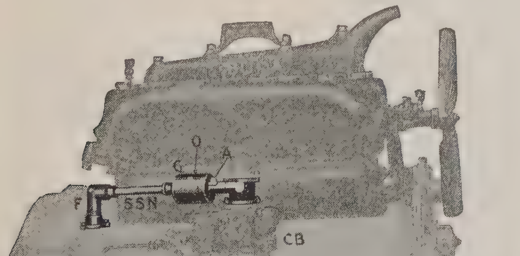

Fig. 69. Engine speed controlled by governor (**G**) driven from gear on cam shaft through adapter (**F**) and solid shaft (**S-S-N**). (**O**) oil cup; (**A**) adjusting screw and seal. The governor can be driven from any rotating part of the engine.

Regulating governor speed: Should it be desirable to change the speed adjustment, cut the wire that seals the adjusting screw and pull off the cap that it holds in place. The adjusting screw (**A**) (Fig. 70) will then be exposed. Turning this screw to the right, or clockwise, decreases the speed; turning to the left, or counter-clockwise, increases the speed. When proper adjustment has been made, replace the cap and seal it, so that the adjustment cannot be tampered with or be affected by vibration.

Note. The governor does not interfere with the regular spark or throttle levers, or with the accelerator control by hand or foot. See paragraph, "Engine drive," page 946.

Operation of Pierce Engine Governor

The governor valve box (Fig. 67) is mounted between the carburetor and the intake manifold, and is connected to the driving shaft by means of either a solid shaft (**SSN**) (Fig. 69) or a flexible shaft (**SH**) (Fig. 70), depending on the type of installation.

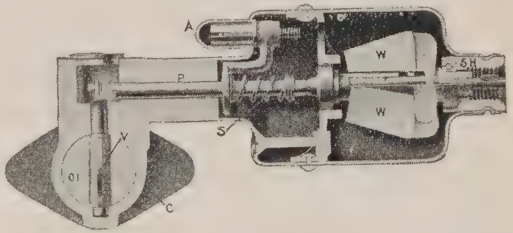

Fig. 70. **Cross-section of Pierce governor:** (**C**) connects between flanges on the inlet manifold and carburetor; (**O1**) is the passage opening for gas; (**V**) butterfly valve; (**P**) plunger operating the valve bell crank; (**S**) spring; (**A**) screw for adjusting the spring tension; (**W**) centrifugal weights; (**SH**) where driving shaft connects.

Normally the butterfly valve (**V**) (Fig. 70) is in a position that does not obstruct the flow of gas, but it closes so as to reduce the valve port area just as soon as the vehicle or engine reaches the predetermined speed. The valve is actuated by what is known as the flyball or centrifugal principle. On the controller shaft are two weights (**W**) (Fig. 70) which are so pivoted that as the velocity of the shaft increases they are swung outward, forcing a plunger (**P**) (Fig. 70) forward, which in turn closes the butterfly valve (**V**) (Fig. 70). The plunger is forced against a spring (**S**), calibrated to a standard pressure, so that as the speed is lessened the weights return to their original position and the valve is again wide open.

Governor Drive Methods

Engine governor drive controls the speed of the engine regardless of the speed of the car, and is the method usually employed. See "Engine drive," page 946.

Transmission governor drive controls the speed of the car by connection to the transmission (see page 946). When operating on low or second gear, the speed of the car will be so low that it will not affect the governor; when in high gear the car attains sufficient speed to cause the governor to act on the engine (seldom used).

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[1] Pierce Engine Governor Co., Anderson, Ind.

PIERCE CLUTCH GOVERNOR

Heretofore the name "governor" has always been associated with devices that automatically control the speed of engines, motors, or other power generating mechanism.

The new Pierce clutch governor performs an entirely different function. As the name indicates, **it regulates the action of the clutch,** and it does this in a manner that makes the clutch mechanism on passenger cars, motor trucks, and tractors practically automatic.

Inexperienced drivers usually have a lot of trouble operating the clutch. Watch them and you will notice that nearly every one engages the clutch too quickly. As a result, they either kill the engine or give the car a vicious jerk that wrenches the transmission and rear axle and causes the rear wheels to spin. Repeat this performance a few times and you have a noisy transmission or differential, badly worn tires, and perhaps a broken axle or torque shaft.

What the clutch governor is: The Pierce clutch governor is in reality a specially designed dash pot (Fig. 71) about 2″ in diameter and 6″ long. The base is attached to a bracket (fastened either to the transmission case or to the frame of the car) and has a pivoted action. The other end connects to an extension on the bottom of the clutch pedal. Inside the dash pot is a fluid on which changes in temperature have practically no effect.

As the clutch pedal is pressed down, the piston inside the cylinder rises with absolutely no resistance, since the fluid passes freely through the poppet valves in the piston head. When the pedal is released, the piston starts to travel downward and forces the fluid through a bypass. A screw adjustment is provided so that the passage of the fluid can be regulated to suit each type of clutch.

The cylinder walls have a series of pockets, and the actual travel of the piston against resistance is only ⅜″ just before the clutch engages.

Its effect on the clutch action: The Pierce clutch governor does what the most expert driver often neglects to do—it engages the clutch gently, without jerk or jar, and always just the same.

Instructions for Installing

The governor is not a part of the clutch—nor can it improve or damage any make of clutch. It is merely to prevent abuse of the clutch—to prevent too sudden engaging through either carelessness, accident, or ignorance of the driver—and to avoid "killing" the motor, spinning the rear wheels, or wrenching the transmission and rear axle members when starting.

Do not allow the connections at either top or bottom of the governor to become tight. If these bind when the clutch pedal moves forward or backward, the governor will not operate properly.

Before starting to install the governor, take a screwdriver and entirely close the needle valve (**D**) shown in Fig. 71. When this is done, it is almost impossible to force the piston down by hand. Also loosen lock nut (**B**) just below the clevis (**A**).

Adjustments

After the Pierce clutch governor has been installed in accordance with previous instructions, see that it is carefully adjusted before anyone attempts to drive the car.

Having entirely closed the needle valve (**D**) (Fig. 71) as previously instructed, start the engine and let it idle at rather slow speed. It will be much easier if one man can sit in the seat to handle the car, engaging and disengaging the clutch, while another man adjusts the clutch governor. Disengage the clutch and place the gear shift in first speed forward. As the clutch is engaged and disengaged, with the fingers turn the knurled dust cap (**C**) to right or left, adjusting it until the governor causes the clutch pedal to pause slightly, just for an instant before the clutch takes hold and the car begins to move forward. Then tighten lock nut (**B**) firmly against clevis (**A**).

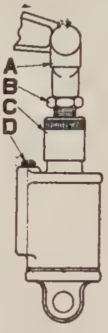

Fig. 71

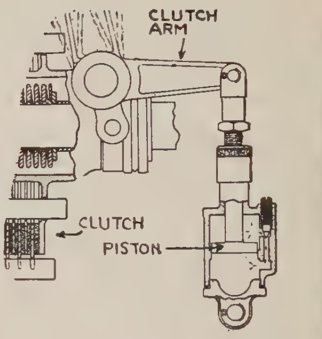

Fig. 72

Fig. 71. The clutch governor.

Fig. 72. Showing the governor piston rod connected to the lower clutch pedal or arm. The illustration shows the position of the piston as the clutch is **engaging.** This is where the strongest resistance is offered to the piston's travel, causing it to pause a second just as the clutch engages, so there can be no tendency to "grab." After the car has started, the clutch pedal travels slowly backward until it reaches normal position, and the piston is again as shown in Fig. 73.

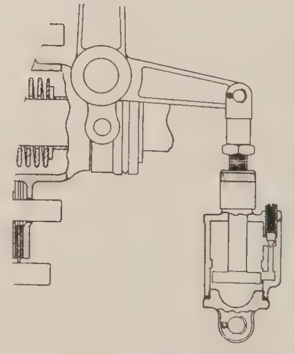

Fig. 73

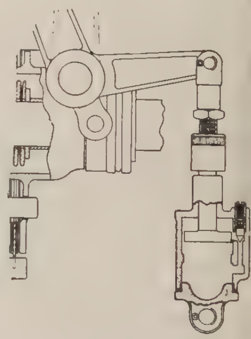

Fig. 74

Fig. 73. Showing position of piston when clutch **is engaged.**

Fig. 74. Showing position of piston when clutch **is disengaged** for changing gears.

If the clutch engages too slowly for satisfactory operation on the road, the needle valve (**D**) may be opened about one-eighth turn. When proper adjustment is obtained, the governor will automatically start the car as quickly as possible without spinning the rear wheels on first speed forward—operating the clutch under ideal conditions always.

Do not attempt to change the position of the needle valve (**D**) until you are sure that proper adjustment cannot be obtained by lengthening or shortening the piston rod (turning knurled dust cap (**C**) backward or forward), as this will take care of 90 per cent of all adjustments necessary.

Fluid inside governor: This is a special refrigerating oil on which extreme changes of temperature have practically no effect. Tests show no difference in operation at temperatures of 98° or 0°.

Readjusting after service: Should the car at any time show a tendency to start too suddenly, or with a jerk, loosen the lock nut (**B**) below clevis (**A**) (Fig. 71) and with the fingers turn the knurled dust cap (**C**) to the left from one to three complete turns. This will lengthen the piston rod and make the clutch slower in engaging.

If the car is too slow in starting after the clutch pedal is released, reverse the adjustment.

Changing speed on hills: When properly adjusted, it is possible to shift from high to lower speeds without any jerk, unnecessary strain, or loss of momentum.

Without the clutch governor, if the driver is too slow in changing gears, the car will lose momentum and may even start to roll backward. The same will be true if the governor operates too slowly. This can be instantly remedied by following instruction for "Readjusting after service."

THE MONARCH GOVERNORS[1]

The Monarch governor differs from the Pierce and Simplex, in that the speed of the ingoing gas is utilized as the motive power for operating the control member.

There are no connections to any moving parts of the engine or vehicle, neither are there revolving parts, such as centrifugal weights or balls.

The location of the governor is between the carburetor and the inlet pipe. When installing, the adjustment is made when a change in the maximum speed of engine is desired.

Monarch Governor (Model "G")

Essentially it consists of the spring (1), the rocker arm (2), the conoid (3), the butterfly (4), and cone (5). The spring is of the conventional compression type, and makes possible a wide range of governed engine speeds.

Suitable **adjustment** is secured by removing the cap at the bottom of the spring housing and turning the slotted screw provided for this purpose.

The rocker arm (2) is provided at either end with a hardened ball-point bearing that oscillates in a hardened steel cup. (Fig. 75.)

The conoid or governing member (3) in conjunction with cone (5) controls the governor action. Held normally in a wide-open position by the spring, the conoid is acted upon by the velocity of the explosive charge passing from the carburetor to the engine. The increase of velocity overcomes the resistance of the spring, and causes the conoid to rise in the tapered cone, closing the butterfly to which it is connected; thus the speed of the engine is controlled.

The short over-all length of the Monarch governor is 2¾" in the one-inch size.

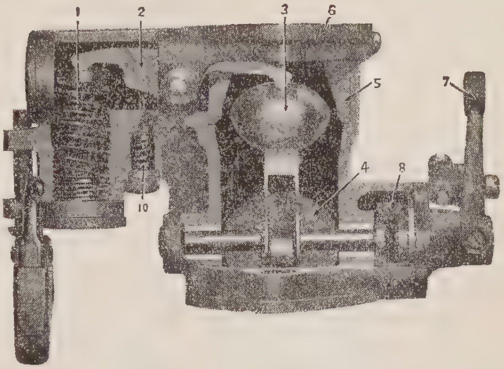

Fig. 75. **Monarch governor, model "G":** (1) spring; (2) rocker arm; (3) conoid; (4) butterfly valve; (5) cone; (6) to intake manifold of engine; (7) manual throttle control lever; (8) manual control lever clutch; (9) to carburetor; (10) bumper spring.

The Monarch Governor (Model "D")

The location of the governor is between the carburetor and the inlet pipe. When installing, the adjustment is made when a change in the maximum speed of engine is desired.

Operation: When the engine is started and the throttle is in wide-open position, the speed of the gases lifts the disk (**A**) in the tapered chamber (**B**) to a position the height of which is determined by the amount of spring tension, and it is held in that position by the speed of the gases while the engine is running. Thus the throttle (**F**) is held in a corresponding position, limiting the supply of gas.

Anything which tends to decrease the speed of the engine, namely, going up hill, through a mud-hole, or an additional load, in turn causes a decrease in the

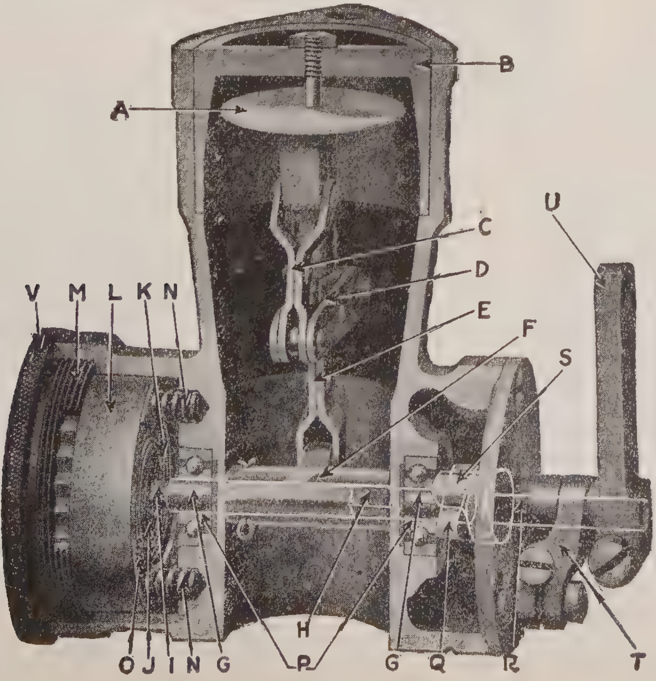

Fig. 76. Monarch model "D" governor.

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[1] Monarch Governor Co., Detroit, Mich.

speed of the engine and a consequent decrease in the speed of the gases. In such a case, the disk drops immediately and opens the throttle to admit a sufficient amount of gas to maintain the speed at which the adjustment was made before the additional load was added. The same is also true when the engine is instantly relieved of its load; the speed of the gases increases and raises the disk to the position required to maintain its fixed maximum. It is therefore evident that, with an adjustment of spring tension made to produce a certain engin speed, that speed will be maintained regardless o load.

Adjustment

To adjust the governor to produce any required engine speed remove the lock and lock pin, unscrew the cover (V), push in o the finger boss on the spring housing (L), and turn in the direc tion indicated by the arrows "Fast" and "Slow" to increase o decrease the speed, always being sure that the control lever i in a wide-open position when the adjustment is made; and b sure that the cover (V), the lock pin, and the lock are in plac before the truck is put in service.

TRUCK DRIVE CHAINS

Chains in general use for the drive system of a chain-driven truck are the roller type of chain.

Roller chains are divided in two types: the **riveted** type, and the **detachable,** or cotter-pin, type.

The riveted type is used where there is no occasion to take it apart frequently.

The detachable or cotter-pin type of roller chain is more generally used because of the ease with which such chains can be separated at each link for the purpose of repair (see Fig. 77).

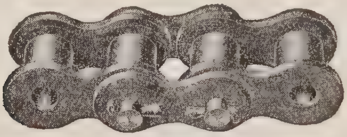

Fig. 77. The Baldwin roller chain of the detachable cotter-pin type.

In the detachable or cotter-pin type the side links are riveted to the studs on only one side of the chain, while on the other side the links are pressed moderately hard over the studs and are retained by cotter pins, as shown in Fig. 77.

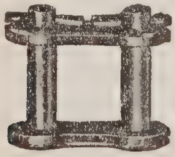

Fig. 78

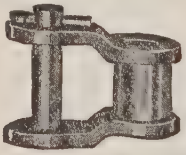

Fig. 79

Fig. 78. Connecting link.
Fig. 79. Offset connecting link.
These are also termed "master links."

The parts of the roller chain of the detachable cotter-pin type are as follows:

A roller is the round part between the link plates and is that part which rolls between the teeth of the sprocket.

A bushing is the part inside of the roller through which the pins are inserted.

A pin-link plate is the plate on each side of the roller.

A pin is the part which passes through the bushings in the rollers and in which the cotter pins are inserted at one end.

A pin-link cap is the same as a pin-link plate, except that it is the plate on the side where the cotter pins are next to it.

A connecting link is shown in Fig. 78. It is used to disconnect, add to, or take out two pitches or two rollers.

An offset connecting link is shown in Fig. 79. It is used to disconnect, add to, or take out one pitch, or one roller.

Pitch is the distance from center to center of the rivets of roller chains and from center to center of the alternate rivets on the block chains (the block chain is not shown; with this type a block is used instead of a roller).

Width is the actual distance between the two inside plates, or the nominal width of roller.

Diameter of the roller is the roller's actual diameter.

Thus, when ordering chains, the three dimension just mentioned are always given.

The sizes of roller chains are usually given in tw ways: the manufacturer's standard, and the Baldwin standard, as tabulated in the list below.

Manufacturers' Standard Roller Chains

Chain No.		Chain Pitch	Roller		Width Over Pins	Approx. Ultimate Strength	Weight Per Foot
Mfrs. Standard No.	Present Baldwin No.	Inch	Width Inch	Diam. Inch	Inch	Lbs.	Lbs.
2	113	½	¼	.306	.625	1,200	.294
2½	108	⅝	⅜	.400	.87	4,500	.564
3	9	¾	½	15/32	1.14	7,500	1.00
4	27	1	⅝	⅝	1.50	12,500	1.89
5	38	1¼	¾	¾	1.81	20,000	2.97
6	51	1½	1	⅞	2.24	25,000	4.38
7	52	1¾	1	1	2.24	36,000	4.80
8	53	2	1¼	1⅛	2.68	42,500	6.90
10	63	2½	1½	1 9/16	3.18	95,000	9.34

1 ton; pitch 1"; di. 9/16 or ⅝"; width ⅜ to ¾".
2 ton; pitch 1¼"; di. ⅝ or ¾" ; width ½ to ¾".
3 ton; pitch 1¾"; di. 1"; width ¾ to 1".
5 ton; pitch 2"; di. 1⅛"; width ⅞ to 1¼".

Note. The symbol "di." refers to the diameter of the rolle and "width" refers to the width of the roller.

To remove a chain, the master link cotter pi (sometimes a wire clip) is removed and the maste or connecting link is withdrawn.

The detachable chain can be lengthened o shortened with ease, whereas with the riveted chai the task is not so easy—a special tool must be use

Care of Drive Chains

If chains could be protected from dust and be ru in an oil bath, they would last much longer, but n method of doing this has yet been successfull devised. A case or housing cannot be fitted aroun the chain, because the construction would also r quire it to contain the brakes as well as the sprocke and it would also be necessary to surround the axl

When a chain becomes too slack, the chain an sprocket are bound to suffer in consequence.

When a chain is worn, an uneven or jerkin motion is imparted to the drive system when slowin down, coasting, and suddenly picking up speed, et Therefore a chain should be well lubricated and ke adjusted.

Cleaning and Lubricating Drive Chains

Tallow gives a chain the best protection against dust and grit. It is melted, and the chain (after being cleaned by soaking in kerosene) is laid in the liquid tallow. Then hang it up to dry, and later wipe off the surplus grease (see also Index under "Cleaning chains."

The teeth of the sprockets when worn, may be remedied in some instances by reversing.

A new chain will stretch—a link should be removed after it is well set. The rivets are cut with a chisel. Master links should be carried.

Adjusting chain tension: Slight play is necessary, but equal slack should be in each chain. A chain should be loose enough to run easily, without climbing the sprocket tooth. Adjustment is usually made by the radius rod, or by large adjusting screws provided for the purpose.

The enlarged section in the middle portion of the radius rod is an elongated nut, which is tapped with both right and left-hand threads. The rods have threads cut on them to correspond. Turning the nut in one direction lengthens the rod, and turning it in the opposite direction shortens it. The principle is identically the same as in a turn buckle. This, however, is a much stronger construction.

Chain manufacturers are Baldwin Chain and Mfg. Co., Worcester, Mass.; Whitney Mfg. Co., Hartford, Conn.; Diamond Chain Co., Indianapolis, Ind.

Miscellaneous

Springs: Inasmuch as the springs of a truck are subjected to considerable strain, they should be kept in good condition. A method usually employed is to raise the frame of the car with a jack, as shown in Fig. 80, which causes the leaves of spring to separate. Graphite is then inserted between the leaves and is wiped dry after removing the jacks. The spring-clip nuts should be tight.

When replacing the gearbox on trucks having separate jackshaft brackets (as in the chain-drive Mack), it is advisable to test the jackshaft and gearbox alignment (Fig. 81).

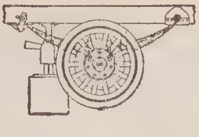

Fig. 80

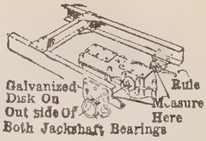

Fig. 81

To do this, cut two disks of 1/64" galvanized iron to fit the outer bores of the jackshaft brackets, and drill a small hole through the center of each. These disks are placed in the outer bores of each bracket, and a fine thread is passed through the drilled holes and the gearbox in the manner illustrated. Measurements from the outside of the bearings to the thread show when the alignment is perfect.

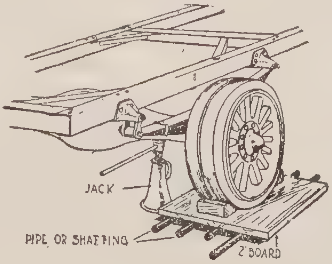

Fig. 82

To assist in removing heavy truck wheels, a simple skid can be made (Fig. 82) by placing a 2" board on top of a series of rollers made of old shafting or heavy pipe. Chocks are fastened to the board to prevent the wheel rolling.

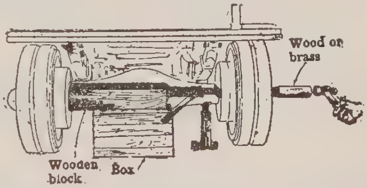

Fig. 83. Removing stubborn truck wheels.

To remove wheels from a truck axle when stuck or rusted on, see Fig. 83

DUMP BODY AND HOIST

A dump body is used for hauling coal, sand, gravel, etc. The body is made to fit on a hinge at the rear of the chassis, as shown in Fig. 84. A hydraulic hoist, which derives its power from the engine raises the front end of the body. The operator can raise the body and dump its contents in about thirty seconds. Hoists which can be operated by hand are also in use.

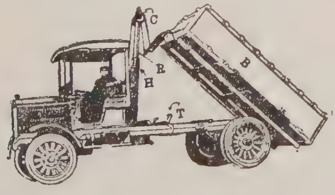

Fig. 84. Dump body with hydraulic hoist.

The principle of operation of the hydraulic hoist is shown in Fig. 85. It is essentially identical in principle of construction with that of a hydraulic elevator.

To raise the body: An oil pump (gear type) at the base of the cylinder (**H**) draws oil from the top of the cylinder at (1) and forces it into the lower part at (2), raising the piston, which in turn raises the rod (**R**) to which is attached grooved pulleys, in which grooves the cables (**C**) are placed. One end of the cable is attached to a stationary rod (**U**), and the other end to the body. As the rod (**R**) is raised, the body is also raised.

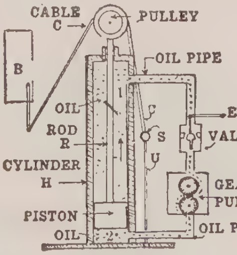

Fig. 85. Diagram of hydraulic hoist.

To hold the body at any desired angle: The oil pump is shut off and the valve closed.

To lower body: The drive of the oil pump is shut off and the valve (by-pass valve) is opened by a lever (**E**). The weight of the body forces the piston down, driving the oil back to the upper part of the cylinder. **The oil pump** is driven from the gears in the transmission by a special and separate arrangement whereby the car is not driven when in operation. The cylinder is usually filled within ½" of the top with ice machine oil.

WINCH EQUIPMENT

A winch (Fig. 86) is a drum located under the rear end of the frame, supplied with 200 or more feet of ⅝″ cable, for unloading and loading heavy material and for various other purposes.

The power for driving the winch (on the F. W. D. truck) is taken from gears in the transmission (T) through (D), which is equipped with a separate clutch to a "power take-off" drive shaft to the gears in housing (V), which connects to the winch through a spur gear (G).

The winch is controlled by means of the clutch foot pedal, after the clutch in (D) has been engaged.

The winch may be operated while the truck is eithe standing still or in motion, but not when the transmission is on high speed. Diameter of the winch drum, 7¾″; length, 22¾″; total gear reduction to winch, 33.2:1.

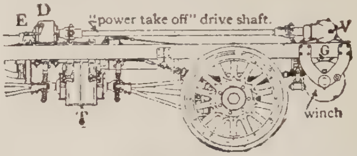

Fig. 86

TRAILERS

Trailers are attached to the rear of cars, and are now extensively used. They are particularly desirable where goods of relatively light weight and great bulk have to be carried; also where the hauls are short and the time required for loading is great. In the latter case, the truck is equipped with two or more trailers, so that one trailer can be hauled while the others are being loaded and unloaded. The trailer can be adapted to many uses.

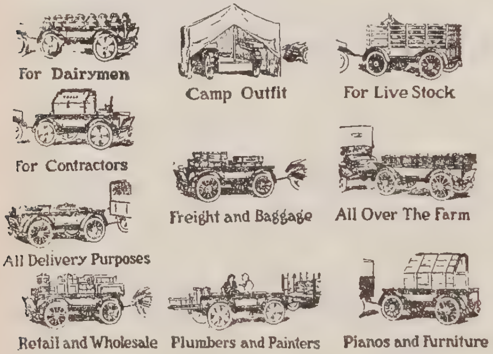

Fig. 87

There are three general designs, as follows: The **four-wheel trailer** has a large possible field of utility and can be used in practically any service, for instance, the freight and baggage, by dairymen contractors, for live stock, pianos, and furniture by plumbers and painters, for farm products, and fo camp outfits.

The two-wheel trailer has the load balanced on it axle.

The semi-trailer also uses two wheels, but the load is not balanced over its axle; rather, the front end of the load rests on the tractor vehicle.

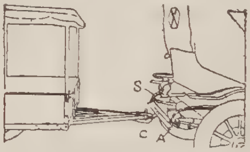

Fig. 88

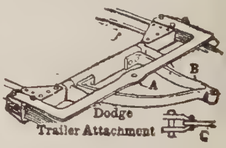

Fig. 89

Trailer attachments: Fig. 88 shows a traile attached to the rear of a car by means of a piece o angle iron (A) which is attached to springs (S) This is not recommended, as the strain is too grea on the springs. Fig. 89 shows two methods which are better. (C) is one type of coupling.

Addresses of some of the trailer manufacturer are: Highway Trailer Corp., Edgerton, Wis.; Kin Trailer Co., 741 Main St., Ann Arbor, Mich.; Lapee Trailer Corp., Fair St., Lapeer, Mich.; Lee Traile and Body Co., 2343 S. La Salle St., Chicago, Ill.

INSTRUCTIONS FOR CARE AND ADJUSTMENT OF TIMKEN-DETROIT TRUCK AXLES

Care of Truck Wheel Bearings

In ordinary truck service, wheel bearings should be removed, cleaned, and readjusted at least four times a year. If the service is unusually severe, it is advisable to inspect the condition of the lubricant and the adjustment of the bearings every two months.

To Remove, Clean, and Readjust Front Wheel Bearings

First of all, remove the hub cap; then put a jack under the front axle, and raise the wheel clear of the floor. Wipe the grease from the end of the spindle, and with your pliers remove the cotter pin from in front of the outer lock nut. Take off the outer lock nut with a wrench; a thin lock washer comes off next; then take off the inner lock nut.

Now kneel directly in front of the wheel. Grasp the rim with both hands and pull directly toward you, being careful not to let the outer bearing slip from the hub and fall to the floor, as this may bend or damage the cage so that the bearing will not render perfect service when replaced. The oute bearing having been removed, lift the wheel off th spindle, exposing the inner bearing.

Now, with a stiff brush and gasoline or kerosene clean all old grease from both the inner bearing and the inside of the hub. It is not necessary t remove the inner bearing from the spindle in order t do this, although it may be removed if desired. I is a good idea occasionally to remove both bearings placing them in a pan containing a mixture of washing soda and hot water, allowing the water to com to a boil, thus cleaning off any grease from behin the rollers that the brush and gasoline may hav failed to remove.

The bearings having been thoroughly cleaned an dried, replace the largest, or inner, bearing on th spindle, covering it thoroughly with good, clea grease, that is, free from acid, grit, or any soli matter. Care should be taken to have no grit o dirt on the paddle.

The inside of the hub should be thoroughl cleaned, and the space between the two bearin cups should be repacked with clean grease.

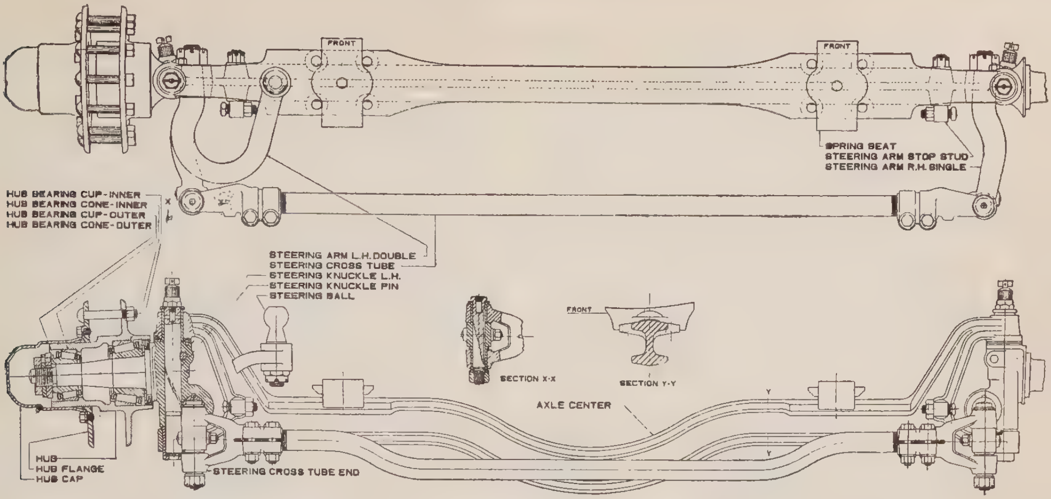

Fig. 90. Timken truck type of front axle with a plain steering knuckle bearing

Now replace the wheel, and, holding it firmly in position, slide the smaller or outer bearing on the spindle, pressing it firmly into the hub. Next screw on the adjusting nut, turning it up tight against the outer bearing so that the wheel binds, at the same time revolving the wheel to be sure that all working surfaces come into contact. Then back off the adjusting nut enough to allow the wheel to rotate freely—but without noticeable end play. Test the adjustment by taking a short bar, placing the end of it between the tire and the floor, at the same time holding one finger on the cage of the outer bearing. Now work the bar up and down so that you can detect any excessive play or looseness. When you can feel a barely perceptible shake and the wheel will oscillate when given a slight spin, your adjustment is right. If there is too much looseness in the bearings, tighten up on the lock nut. If, on the other hand, the lock nut is set too tight to allow the wheel to oscillate, loosen it about a quarter turn.

Now replace the keyed washer which goes between the two lock nuts and which prevents the inner nut from turning. Replace the outer lock nut, and screw it up tight; also replace the cotter pin in the end of the spindle to prevent the outer nut working loose.

Again test the adjustment with a bar as before, because, in using a heavy wrench to tighten the outer lock nut, it is sometimes possible to jam this nut so tightly against the inner nut as to destroy the adjustment. By taking the extra precaution to test the adjustment before replacing the hub cap, you can always be sure that your bearings will render perfect service. Now cover the end of the spindle and the lock nuts with grease, and put on the hub cap, tightening it securely.

To Adjust Bearings in Steering-Knuckle Heads

To adjust the steering-kuckle bearing when a Timken roller bearing is used at this point, simply tighten up on the nut on the bottom of the knuckle pin after the cotter pin has been removed (Fig. 91). This forces the bushing in the lower yoke of the I-beam up against the steering spindle, which in turn forces the bearing up into the cup for a proper seat.

Do not fail to lubricate this bearing thoroughly with good quality cup grease through the cup provided on the top of the knuckle pin.

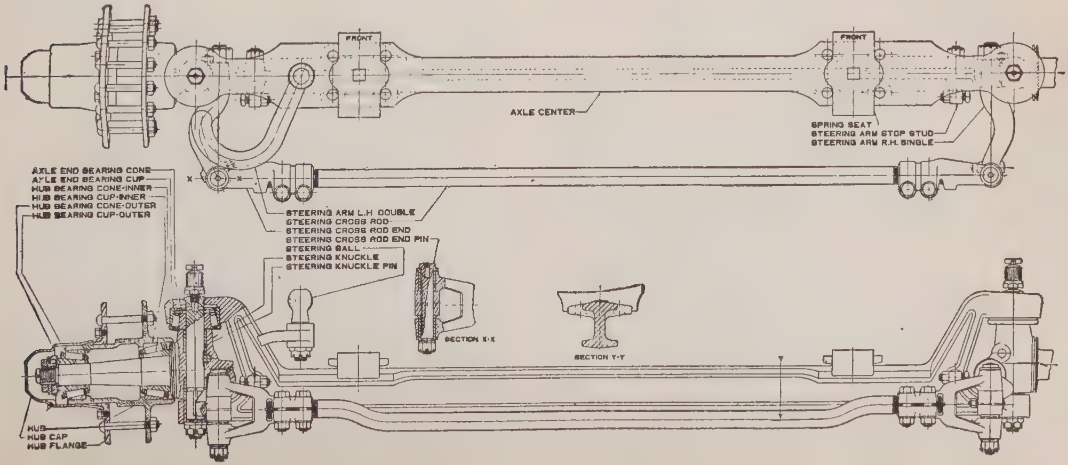

Fig. 91. Timken truck type front axle with a steering knuckle roller bearing.

To Adjust Rear Wheel Bearings—Full Floating Type

Remove the cap screws around the axle-shaft drive plate (Fig. 92), and pull out the axle shaft. Put a jack under the housing, raise the wheel off the floor, and wipe the grease from the end of the housing tube and the lock nuts. Take off the outer lock nut; then remove the thin lock washer and the inner lock nut. As the wheel is too heavy to be easily lifted off the tube, the following method can be used to remove it. Take a short piece of board and cover the upper surface with grease; slide this under the wheel, and then lower the jack several notches until the wheel rests lightly on the board. Remove the outer bearing, being careful not to allow it to fall on the floor which may bend or otherwise damage the cage. The wheel can now be eased off on the greased surface of the board and rolled to one side.

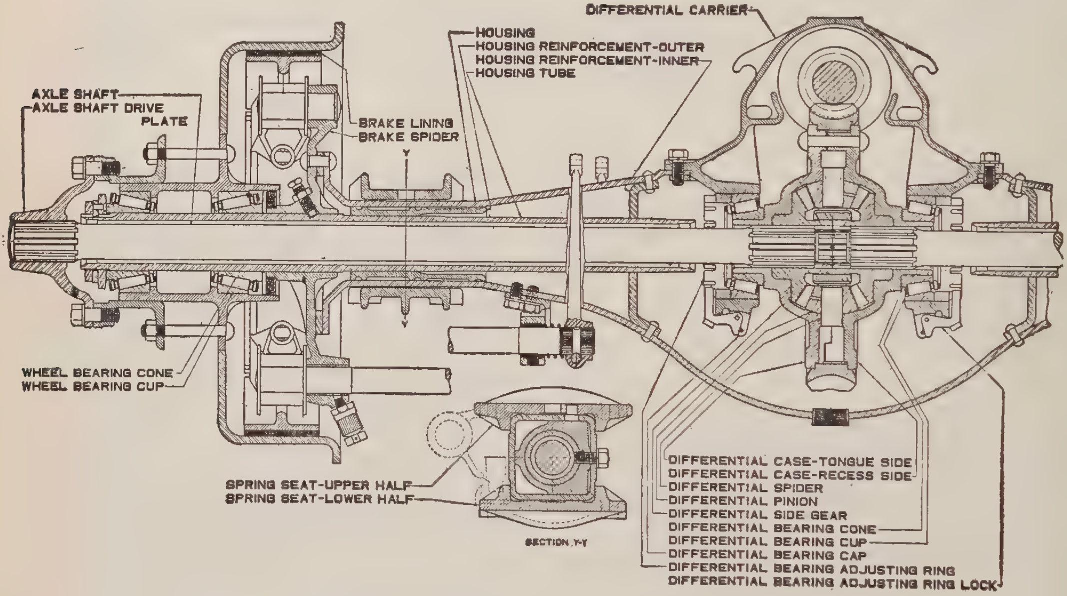

Fig. 92. Timken full-floating type of truck axle.

To clean parts: See page 864.

To lubricate wheel bearings: see page 864.

Replacing the wheel: See page 864.

Bearing adjustment: See page 864.

Test the adjustment by taking a bar, placing the end of it between the tire and the floor, at the same time holding one finger on the cage of the outer bearing. Now work the bar up and down so that you can detect any excessive play or looseness. When you can feel a barely perceptible shake and the wheel will oscillate freely, your adjustment is correct.

Now replace the lock washer and outer lock nut, screwing the nut up tight. Before replacing the drive shaft test the adjustment again with a bar as before, because in using a heavy wrench to tighten the outer lock nut it is sometimes possible to jam the nut so tightly against the inner nut as to destroy the adjustment. By taking the extra precaution to test the adjustment before replacing the drive shaft and plate, you can always be sure that your bearings will render perfect service.

Now cover the end of the axle tube and the lock nuts with grease and replace the drive shaft, being careful to tighten up the cap screws in the plate securely.

To Adjust Rear-Wheel Bearing—Fixed-Hub Semi-Floating Type

On this model of axle the rear wheel is keyed to the axle shaft. The bearing cone is pressed on the shaft, and the cup is mounted in an adjusting ring which is screwed into the axle housing.

Adjustment of bearings is made by turning this ring. These bearings should be cleaned and repacked with grease once a year.

To clean or adjust the wheel bearing, remove the wheel from the shaft, using a wheel puller if necessary. Next release the lock (Fig. 93), which prevents the bearing adjusting ring from turning, and with a flat tool unscrew this ring from the housing.

The axle shaft, carrying with it the bearing cone and rollers, can now be pulled out of the housing.

To clean bearings: See page 863.

To lubricate bearings: See page 863.

Adjusting bearings: See page 864.

To Adjust Differential Bearings

Differential bearings are lubricated by the oil in the axle housing. They require no attention in connection with lubrication beyond keeping the correct amount of the proper lubricant in the housing and seeing that the oil grooves are kept clean.

In adjusting the differential bearing, a combination adjustment is necessary (Fig. 93). First, all play must be taken out of the bearings by screwing up the adjusting rings on both sides of the differential, and second, the worm and worm wheel must be set in proper alignment by adjusting the differential bearings on both sides, end for end, moving the differential and worm wheel to one side or the other, as required for correct alignment.

All ordinary adjustment of these bearings should be made on the left-hand bearing (standing at the rear and facing toward the front of the truck); never disturb the right-hand bearing except when it is necessary to take down the entire differential assembly. By making the adjustments on the left bearing only, the alignment of the worm and wheel will not be destroyed.

To adjust the bearings (Fig. 93), the differential carrier must be removed from the housing; take out both drive shafts, remove the cap screws holding the carrier to the housing, and, having disconnected the propeller shaft, lift out the entire carrier assembly. In most cases it will be necessary to remove the axle from the chassis before the carrier can be pulled out. Now release the lock on the left-hand adjusting ring and tighten up the bearings by screwing in this ring with a flat tool until all end play or shake in the differential housing has been removed. Having obtained a good tight adjustment, unscrew the ring one notch, and lock in this position with the locking finger.

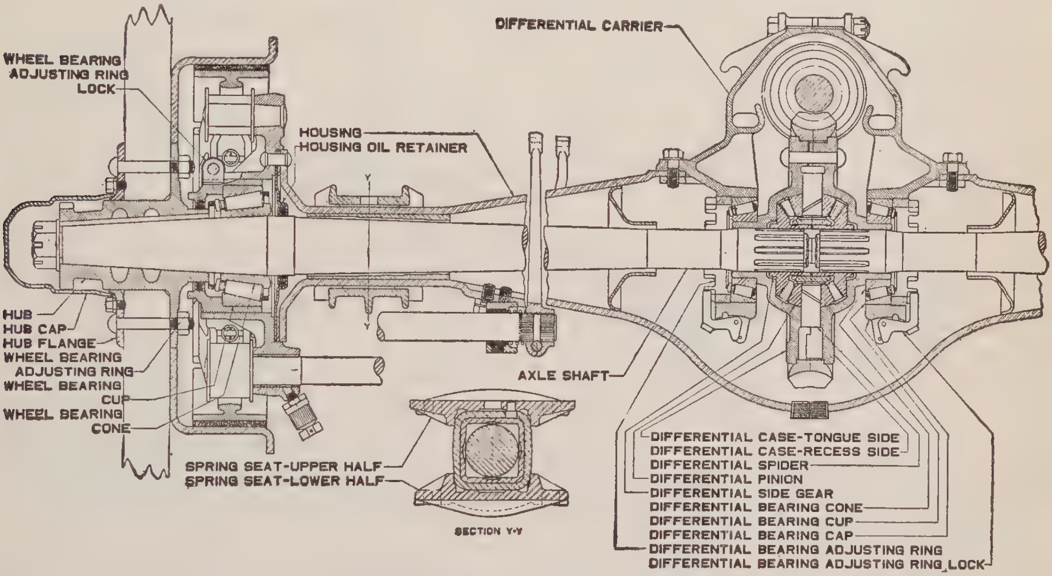

Fig. 93. Timken semi-floating or fixed-hub type of truck axle.

If the alignment of the worm and wheel is not correct, unscrew one ring, at the same time tightening up on the other the same number of notches until the center of the worm wheel is directly under the center of the worm. Check up again for end play, to be sure that the adjustment is all right. The carrier assembly may now be replaced, the drive shafts put in, and the axle reassembled under the truck. In replacing the carrier assembly, be sure to tighten up well on the cap screws holding the carrier to the housing.

To Adjust Worm-Shaft Bearings

To adjust the worm-shaft bearings (Fig. 94), first remove the packing gland from the carrier to avoid binding on the shaft and to allow free movement of the shaft. Next remove the lock from the slot, and, with a flat tool, screw in the forward bearing adjusting ring until the shaft binds. Now unscrew the ring several notches to allow end play, so that the shaft can expand when it becomes heated under running conditions. The exact extent to which the ring should be backed off is shown in the following table:

Size of Axle	Play in Inches	Number of Notches
¾–1½ ton	.011″–.015″	3
2 –3½ ton	.016″–.020″	4
5 ton	.020″	4

Lock the adjusting ring in this position with the locking finger and replace the packing gland on the shaft, tightening up on it sufficiently to prevent oil leaking out at this point.

On the older type of axles (6456—1½-ton, 6552—2½-ton, and 6652—3½-ton), it is necessary, after backing off the cage, to see that the bearing cup is properly seated in the cage. This can be done by driving on the rear end of the worm shaft or by starting the truck up slowly in low gear.

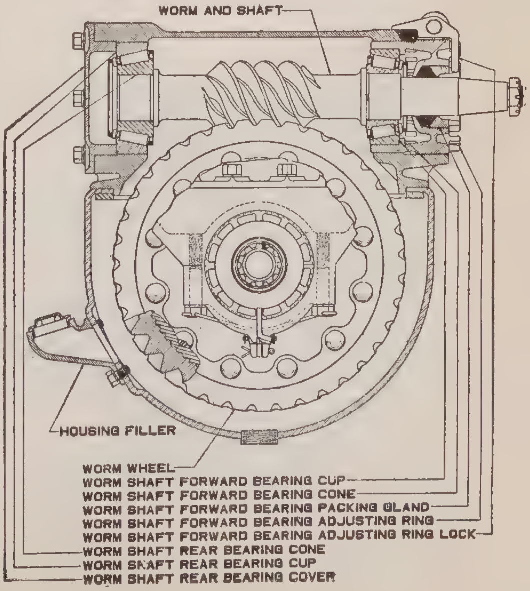
WORM AND SHAFT
HOUSING FILLER
WORM WHEEL
WORM SHAFT FORWARD BEARING CUP
WORM SHAFT FORWARD BEARING CONE
WORM SHAFT FORWARD BEARING PACKING GLAND
WORM SHAFT FORWARD BEARING ADJUSTING RING
WORM SHAFT FORWARD BEARING ADJUSTING RING LOCK
WORM SHAFT REAR BEARING CONE
WORM SHAFT REAR BEARING CUP
WORM SHAFT REAR BEARING COVER

Fig. 94. Worm-shaft bearings.

On the old type of 5-ton axle (6752), where the worm-shaft bearings are set the other way, no end play to take care of expansion is necessary. On this axle the adjustment of bearings is made at the rear of the shaft.

Worm Shaft Bearings and Mounting

The Timken roller bearings, as used on the worm shafts shown in Fig. 94, page 955, are mounted by what is termed a **"direct mounting" of the worm shaft,** meaning that the thrust at the forward operation is taken on the **rear** worm bearing.

Owing to the fact that the worm shaft heats faster than the differential housing during service, the worm shaft will expand, and provision should be made for a certain amount of initial looseness in the adjustment.

The direct mounting is used on trucks up to 3½-ton capacity, and on trucks ranging from 1 to 3½-ton capacity, this looseness should be from .011″ to .020″, according to the size of the worm.

Refer to Fig. 94, and note that a thrust to the rear would be absorbed by the rear roller bearing.

On **"indirect" worm-shaft bearing mounting** the thrust at the forward operation is on the **front** bearing instead of on the rear bearing, meaning that the thrust to the rear is absorbed by the front roller bearing, because the tapers of the rollers are in the opposite direction to that shown in Fig. 94.

The initial looseness in adjustment should be .010″.

TO COMPUTE THE GEAR RATIO OF A WORM DRIVE

The gear ratio of a worm drive is dependent on two factors, namely, the number of **teeth** on the worm gear and the number of **threads** on the worm.

Explanation of One-Thread Worm

Examine the worm shown in Fig. 95.

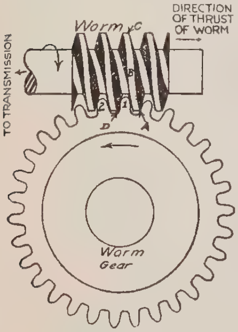

Fig. 95

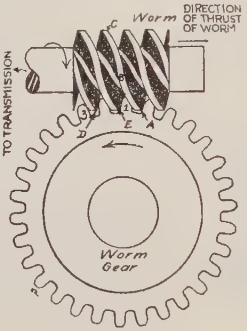

Fig. 96

Fig. 95. A one-thread worm.

Fig. 96. A two-thread worm.

Commencing at the point (**A**), let us trace the thread once around the worm. We will pass from (**A**) to point (**B**), then to point (**C**), then passing around the other side of the worm, we shall come to point (**D**).

It will be noticed that by passing around the worm once, we have advanced the distance of one thread. In other words, there is **one continuous thread** cut on the worm.

This being the case, we see that during one revolution of the worm the gear tooth (1) (Fig. 95) will advance to the position of gear tooth (2). Therefore in a one-thread worm, one revolution of the worm causes the worm gear to advance the distance of one tooth.

If there are 30 teeth in the worm gear, it will require 30 revolutions of the worm to cause one revolution of the worm gear. Consequently the gear ratio would be 30 to 1.

Conclusion: In a one-thread worm, the gear ratio equals the number of teeth on the worm gear.

Explanation of Two-Thread Worm

Examine the worm shown in Fig. 96.

Commencing at the point (**A**) let us trace the thread once around the worm. We will pass from (**A**) to point (**B**), from (**B**) to point (**C**), then passing around the other side of the worm, we shall come to point (**D**).

It will be noticed that by passing around the worm once, we have advanced the distance of **two threads.** Note that in going from (A) to (D), we did not touch point (**E**). This is because the point (**E**) is on a separate thread. So we see that there are **two separate and distinct threads** cut on the worm. This is known as a two-thread worm.

Examination of Fig. 96 will show that during one revolution of the worm, the gear tooth (1) will advance to the position of gear tooth (3). Therefore in a two-thread worm, one revolution of the worm causes the worm gear to advance the distance of two teeth.

If there are 30 teeth in the worm gear, it will require $30 \div 2 = 15$ revolutions of the worm to cause one revolution of the worm gear. Consequently the gear ratio would be 15 to 1.

Conclusion: In a two-thread worm, the gear ratio equals the number of teeth on the worm gear divided by 2.

General Rule for Determining Gear Ratio of Worm Drive

In the same way, a **three-thread worm** causes the worm gear to advance 3 teeth during one revolution of the worm; a **four-thread worm** causes a 4-tooth advance during one revolution, etc.

Therefore we come to the conclusion that **the gear ratio of a worm drive is equal to the number of teeth on the worm gear divided by the number of separate threads cut on the worm.**

Example: In the rear axle of a truck, there are 29 teeth on the worm gear and 4 separate threads cut on the worm. What is the gear ratio?

Ans. $29 \div 4 = 7.25$

Trucks are generally equipped with worms of 4, 5, or 6 separate threads cut upon them. The G.M.C. on the 2-ton truck, uses four separate threads; the Ford standard has four threads also; the Ford special high-speed truck has six threads.

BRAKE ADJUSTMENT AND LUBRICATION OF TIMKEN TRUCK REAR AXLES

Brake Adjustment (Timken Truck Axle)

To tighten up the brakes, first take up on the brake rods. After all the adjustment possible has been made in the brake rods, take off the nut, lock washer, and clamp bolt which clamps the brake levers on the axle to the brake cam shaft. Lengthen out the brake rods again, and move the lever back two or more serrations on the cam shaft and clamp into place with the clamp bolt. Now make a final adjustment of the brakes by means of the adjustment on the brake rods. All possible or necessary adjustment can be made in this way up to the point where the brake shoes require relining.

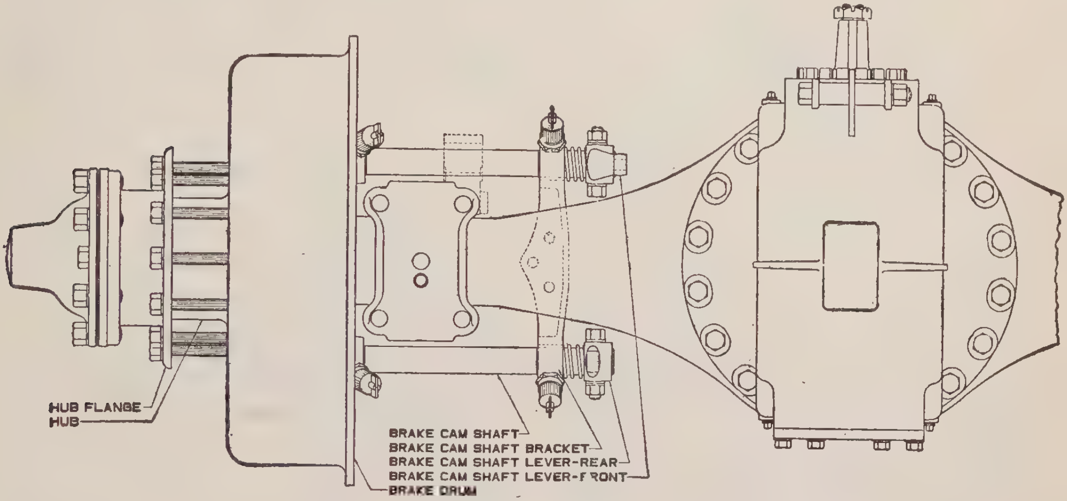

Fig. 97. Showing the location of the brakes on the rear axle and parts of the brake mechanism.

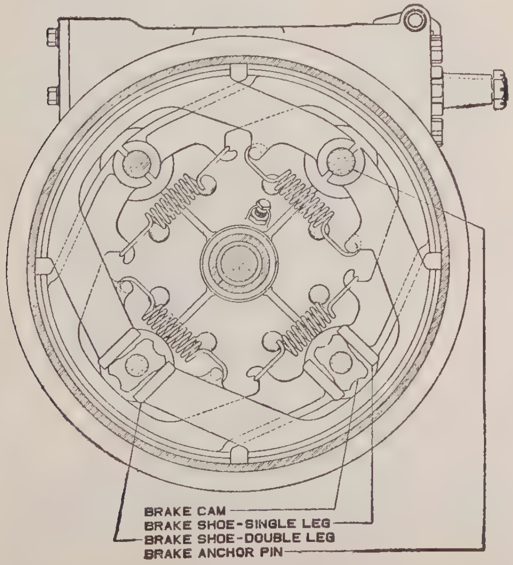

Fig. 98. View of the brake and internal construction of the **Timken duplex internal expanding brakes.** There are four friction fabric lined shoes, so located that the pair of brakes takes up no more room than the ordinary single-shoe type. Note that the internal brake shoes are actuated by a cam.

Lubrication of Timken Rear Axles

Proper lubrication of all points is of the greatest importance. Experience shows that nine-tenths of the troubles of Timken axles can be traced directly to lack of lubrication.

Examine the wheel bearings in the hub about every 5,000 miles and see if they are properly adjusted and lubricated. To lubricate wheel bearings, fill the hub full with a light grease, free from acid and grit.

To lubricate the worm and worm gearing (Fig. 99): Remove the filler cap and pour in oil until level with the opening. Examine the condition and amount of oil weekly. If it contains grit or is so thick that it will not circulate, drain the housing by unscrewing the plug at the bottom. Run kerosene through to cleanse, then refill with oil.

The worm wheel revolving in the oil carries it to the upper part of the housing (Fig. 100). The worm as it revolves throws the oil to the sides, where it is caught by troughs, as shown by arrows in Fig. 100. The oil runs by gravity to the front and rear of the housing, and is drawn through the bearings by their pumping action, and from there flows back to the starting point.

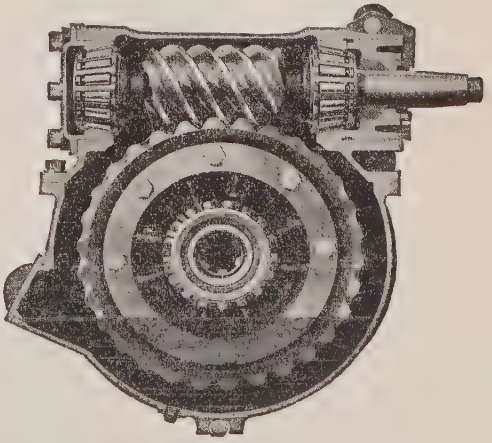

Fig. 99. Showing oil level in Timken worm-drive truck rear axle.

Once every month remove the axle-housing plate and clean out the oil ducts with a wire. Although the housing is dirt proof, the oil may become so thick that it will not circulate.

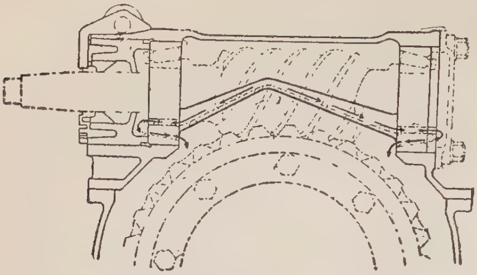

Fig. 100. Showing **oil path**, as explained in text above.

When replacing the housing plate, coat the washer on it with shellac and tighten all bolts.

Occasionally an axle will leak oil at the forward end of the worm shaft. If this happens, draw up on the packing gland (Fig. 94, page 955).

Oil to use: Do not use oil which will clog the oil passages. Use only high-grade oil, free from acid and grit, and that will stand a cold test of zero or below. Light steam cylinder oil is recommended. Do not mix graphite or other solid matter with the oil.

Cautions

The same cautions mentioned on page 865 relative to Timken passenger-car wheel bearings apply to the truck wheel bearings also.

SHELDON HEAVY-DUTY TRUCK AXLES

Front Wheels

To mount front-wheel bearings—taper roller (Fig. 101): (1) insert bearing (**A**) in the hub and press against shoulder (**C**); (2) screw retainer (**G**) in place and lock with screw (**H**); (3) insert bearing (**B**) and press against shoulder (**D**); (4) mount the hub on the spindle (**J**), and tighten nut (**E**) against the shoulder of axle (**K**); (5) there should not be more than 1/1,000″clearance between nut (**E**) and bearing (**B**). To secure this fit, the hub should be so that it cannot slide back and forth. There should be no endwise movement of the spindle, but the bearings should not be bound, and the hub should move freely. The shoulder on nut (**E**) could be filed down if the hub does not fit freely. If the wheel revolves freely, you know that the adjustment is properly made. If not, try another nut, having shoulder (**K**) more full.

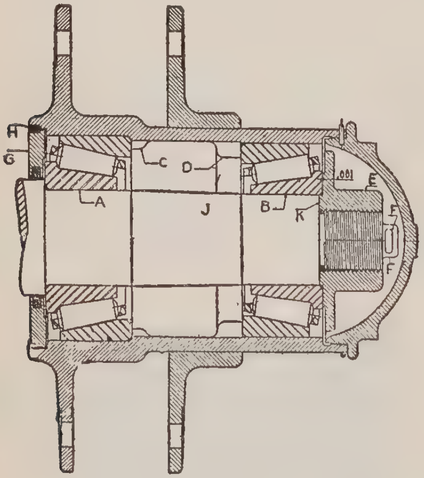

Fig. 101. Sheldon front-wheel bearings.

Care must be taken that the inner bearing seat is tight against the collar on the spindle. Test by moving the wheel from side to side.

Wheel alignment: To test; jack both front wheels up; with a piece of chalk held in a fixed position against the tires, spin the wheels, drawing a line around the tire. The distance between the lines measured at the front of the wheel should be from ⅜″ to ½″ less than in the rear.

To "take in" or "let out" on wheel alignment: Loosen the clevis jam nuts on the end of the cross-rod (Fig. 102). Remove the pins; screw the clevis either in or out, as needed. If the steering knuckle is bent, or if the steering arm is bent, replace it. If the cross-rod is bent, straighten it before realigning the wheels. The front wheels are "cambered," so they are a little closer together at the bottom than at the top.

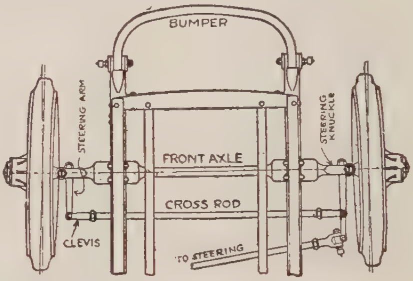

Fig. 102. Sheldon front axle.

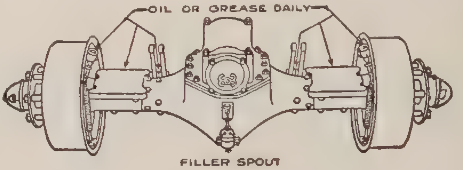

Fig. 103 Sheldon rear axle.

Rear Axle

The rear axle is of the semi-floating type. The axle is mounted throughout on ball bearings except that straight roller bearings on the wheels are sometimes provided. Lubrication of the worm gears is very important. To put oil into the housing (see Figs. 103 and 104), unscrew the filler cap and pour oil in until it overflows. When new, it may be necessary to add oil every two or three weeks, if the

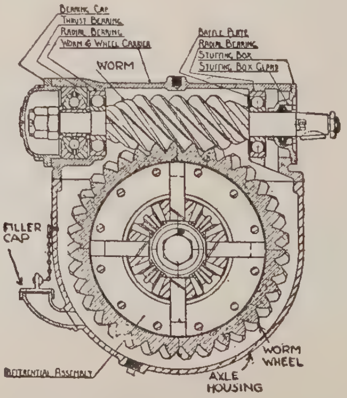

Fig. 104. Sheldon worm drive.

oil level goes down. Drain the old oil out every 5,000 miles, and flush out with gasoline and thoroughly clean. Heavy oil, such as 600W (steam cylinder oil), is best for worm-gear lubrication.

Removing Rear Wheels

To remove the rear wheels, a wheel puller (Fig. 106) is provided. Jack up the axle, unscrew cap screw (**A**), remove hub cap (**B**), remove drive-shaft nut (**C**), press out disk (**D**), replace hub cap (**B**), insert set screw (**E**), and jam it against drive shaft (**F**), tap back of wheel (**G**).

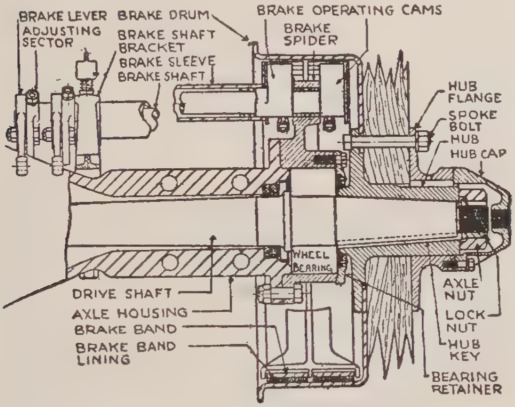

Fig. 105. Rear wheel on Sheldon axle.

Do not attempt to pull the wheel off by simply tightening up on the set screw. Be sure to tap against the rim of the wheel on the inside, after you jam the set screw against the shaft, otherwise you are liable to strip the threads.

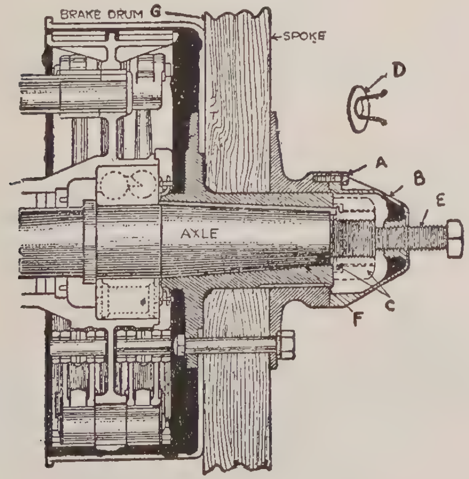

Fig. 106. Rear wheel puller.

Replacing Rear Wheel

In replacing the wheel on the shaft, put the key in position in the key way, then place the hub over the shaft with the key way in the hub in line with the key on the axle shaft. You may not be able to get the nut (which jams the key) screwed in far enough at first, because the hub will not be far enough up on the shaft. Do not attempt to draw the hub up with the key jam-nut alone, but drive the wheel on and take up with the nut as the hub creeps on the shaft. When the hub is well up in position, take off the outer nut, jam the key tight against the bearing with the jam-nut, and then place the outer nut back in position before putting on the hub cap.

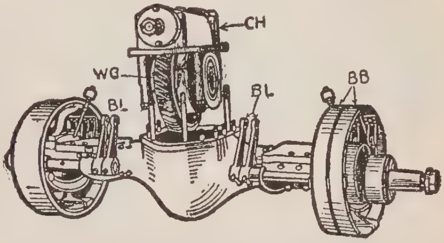

Fig. 107. Removing Sheldon worm and worm-wheel carrier.

Removing Worm and Worm-Wheel Carrier

These come out as a unit complete with the worm gear, differential, etc. (Fig. 107). Before lifting out the carrier, the axle shaft must first be removed and the carrier (**CH**) unbolted from the axle housing.

Procedure: Jack up the wheels and remove; take off the wheel-bearing retainers by unbolting them from the brake spiders (Fig. 108); pull out the axle shafts, remove the nuts which fasten the carrier to the axle housing marked "remove" (Fig. 109). These nuts are all near the outside edge. Do not disturb any of the other nuts, as they have nothing to do with the carrier removal. Fit an eye bolt (any blacksmith can make it) into the hole in the top of the carrier (Fig. 109), and lift out the carrier with a chain hoist by means of this bolt. If the entire axle lifts up with the carrier, bump the housing lightly on each side of the carrier with a heavy bar at the points marked by black squares (Fig. 109), applying force downward. Do not use a small hammer or hit too hard.

A top view of the carrier and housing is shown in Fig. 109.

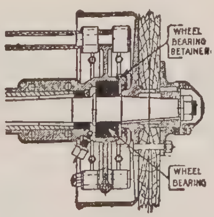

Fig. 108

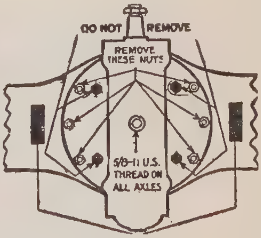

Fig. 109

Do not destroy the gasket by driving a chisel between the carrier and the housing.

On W-30 and W-50 axles, used on 3 and 5-ton trucks, there is a thrust bearing on each side of the differential, as shown in Fig. 110. Be careful that they do not fall into the housing when the carrier is lifted out. They can be held in place by reaching the hand in the axle tubes and smearing them with heavy grease, while the carrier is being lifted out. It is important that the right-hand bearing be reassembled on the right-hand side, and the left-hand bearing on the left-hand side. Do not interchange.

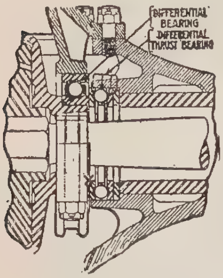

Fig. 110

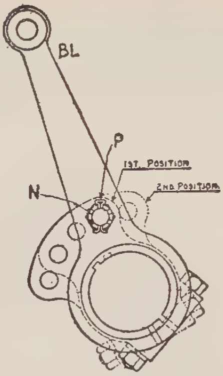

Fig. 111

Fig. 110. Differential bearings on Sheldon rear axle.
Fig. 111. Brake adjusting sector on Sheldon rear axle.

Reassembling Worm and Worm-Wheel Carrier

Reassembling: Remove the drain plug and wash out the carrier and housing with gasoline, and clean thoroughly. See that all parts are clean. See that the gasket between the carrier and housing is in perfect condition. Set the carrier back in place.

On W-30 and W-50 axles put the thrust bearings on the same side from which they were removed. On these axles they must be put in place before the carrier is dropped in, and must be held until the carrier gets down far enough to keep them in their proper position. This can be done by smearing with heavy grease, as before mentioned. Bend a short hook of ¼″ iron, insert the hand holding the hook in the axle tube, and hook it over the bearings at the bottom, at point (X) (Fig. 110), applying sufficient pressure, pulling towards you, to keep the bearings from falling out.

Bolt the carrier in place. Put the axle shafts in place, making sure that the "hex" part of the shaft is shoved well back in the hex part of the differential case.

Replace the wheel bearings, first washing them with gasoline. Pack the bearings, and also the brake spider, with grease. The grease will then work into and through the bearings when shoved back in place.

Put on the wheel-bearing retainers, and draw up tight.

Replace the wheels, being sure that the key that fastens the hub to the axle shaft is driven up well.

Refill the housing with oil, and then run the axle by hand by twisting on the front end of the worm shaft, to make sure that it is in good condition, before attaching the universal joint.

Sheldon Brakes

The **foot brake** is the regular service brake. The **hand brake** is the emergency and for use when it is desired to set brakes while the car is standing still. Both brakes on Sheldon axles are of the internal type. On the small axles they are of the cam type, and on the larger sizes of the "wrap-up" type. In this latter type the brake action gradually increases automatically.

Adjustment: Equal adjustment is essential. There is no adjustment in the brakes themselves (it being all in the parts which pull the brake levers).

On the late type of axles the adjustment is made by a sector attached to the brake pull lever, as shown in Fig. 111.

To tighten up on the brake levers, simply take out the bolt which fastens the sector to the lever, and move the hole in the lever one hole (towards the rear) on the sector.

On older type of axles the adjustments were made by simply tightening up the pull rods.

In braking the truck with the engine, with the switch off and on low gear, care must be taken. If you intend using the engine and low gear on a hill, engage your low speed before you reach the incline, because changing gears while a truck is rapidly descending is likely to strip the gears. The engine used in this way makes a powerful brake and saves the brakes. The spark should be given just before reaching the bottom of the incline, in order to start the engine before the bottom is actually reached.

THE INTERNAL-GEAR DRIVE AXLE

There are several makes of internal-gear-driven truck axles, one example being shown below. See also the internal-gear drive on the White truck (page 933), and the International truck (page 929). The ring gear (B) is driven by a bevel-driving pinion (N), which is driven by the drive shaft (S) from transmission. Note that the differential housing is fastened to the rear axle.

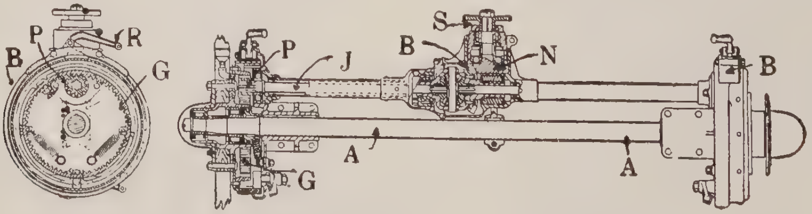

Fig. 112. Internal-gear drive axle.

This rear axle differs from the other types in that the rear axle (A) is solid. An **internal gear** (G) is on the inside of the wheel hub. A **spur-gear pinion** (P) drives this gear (G), which revolves the wheel. The spur-gear drive-pinion (P) is driven by a **jack shaft** (J) enclosed in a tube. The jack shaft (J) is driven in the same manner as a regular split axle, through differential gears and a ring gear (B).

The brake band (B) is of the external contracting type, and is controlled by lever (R), which is connected with the foot-brake pedal.

The adjustments on this axle are similar to a "live" split axle, in that the parts necessary to adjust, are the ring gear (B) on the differential and the bevel-drive pinion (N).

The adjustment of the differential ring gear (B) is to provide the proper center distance for gears (B) and (N), which can be done by shifting the ring gear with the adjustments provided. **The adjustment of the drive pinion** (N) is to provide the proper mesh between the gears (B) and (N). Manufacturers of this type of axle are: Russell Mfg. Co., Middletown, Conn.; Torbensen Co., Cleveland, Ohio, also manufacture an internal gear-drive axle, which is used on a number of different makes of trucks.

GAS-ELECTRIC TRUCK

A very unique and satisfactory combination gas-electric power truck is called the Couple-Gear.

The drive system is by means of an electric motor in each wheel, as shown in the illustration (Fig. 113). This would be termed the transmission.

This gives a four-wheel drive and a four-wheel steer without complications. No universal joints are used on the drive. All chains, sprockets, clutches, sliding and reverse gears are dispensed with.

"Couple-gear" transmission consists of an electric motor in each wheel, the motor armature having a pinion on either end, one pinion pulling up on one side of the wheel, the other pulling down at the opposite side, and both working at the periphery (Fig. 114). Each pinion meshes with a separate gear mounted on the rear wheel drum, as shown by the two illustrations (Fig. 114). Each illustration represents a separate part.

The gear reduction is 25 to 1 direct, and is supposed to deliver 97 per cent of the motor energy to the rim of the wheel. Tires are solid, 3½″ x 36″.

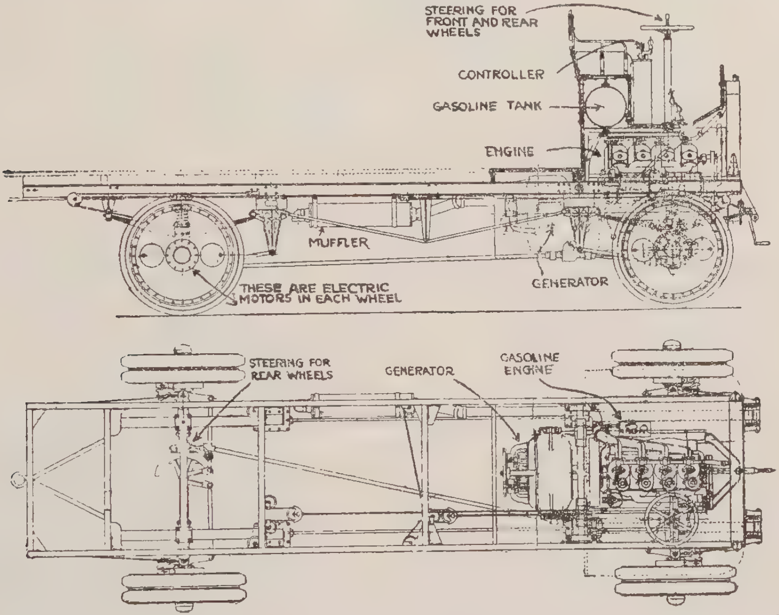

Fig. 113. A couple-gear four-wheel drive and four-wheel steer **gas-electric motive-power truck.** Especially designed for suburban and other long-distance work. Made in 3½, 4, 5, and 6-ton capacity.

The power plant is self-contained, and consists of a gasoline engine connected to an electric generator. The speed of the generator, controlled by the speed of the engine, governs the speed of the electric motors in the four wheels. The engine is equipped with Bosch ignition, a Stromberg carburetor, and a 2⅛″ five-bearing crank.

The generator is designed especially for this class of work. It is rated at 12½ k.w. at 100 volts, 680 r.p.m., and will run completely sparkless with an ampere load 200 per cent in excess of its normal rating, and with a 100 per cent rise in speed. The voltage at the maximum speed can be held down as low as 40. It is a six-pole machine, with the same number of commutating poles, compound wound, with a dropping characteristic, which automatically assists the engine to hold or increase speed at approximately the same rate as the increase in power is demanded for the vehicle propulsion. It is equipped with a rheostat connected to the fields by means of which the operator may raise or lower the gear ratio at will. The voltage can be held down to 40. The voltage drops when the amperage exceeds 70. Weight 765 lbs.

The engine is 4-cylinder, 5″ bore, with a 5½″ stroke.

Control

The throttle is operated by foot lever. **Ignition** is fixed. The **motors** are operated either in series, series parallel, or parallel, which is governed by a controller of street-railway type. There is also a reverse lever on the controller, giving the same range of speed backward as foward, and it also operates an electric brake. **Speed** is from 7 to 15 miles per hour (12 miles, loaded; 15 miles, without load).

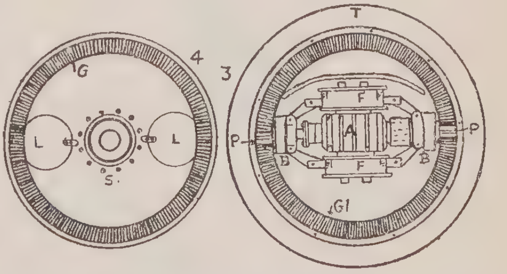

Fig. 114. Front disk and side of motor removed, giving access to the armature, field coils, and bearings. It will be noted that the electric motors are mounted in the wheels, which is the **method of transmitting the drive power.** 33-ampere 80-volt motors are used in each wheel.

(T) rubber tire; (F) field winding; (A) armature; (B) armature bearing; (P) pinion (gears which drive G1); (G) (G1) gear in wheel; (4) steel band for tire; (L) wheel inspection door; (S) roller bearing.

The motor is suspended by half of the motor casting, which is a heavy stub passing through the knuckle shaft, making the motor frame itself a component part of the axle. The armature is carried rigidly within the motor frame. The wheel shell then revolves about the motor frame, on roller bearings, one of which is on the rear of frame (3), and the other in frame (4). A cover which fits over armature (A) carries this bearing for (3), but is not shown. (Couple-Gear Freight Wheel Co., Grand Rapids, Mich.)

FOUR-WHEEL DRIVE TRUCKS

Nash Quad Truck

Drive method: All four wheels are driven by means of two drive shafts leading from the transmission (Fig. 115) to a differential housing (Fig. 117) mounted on "dead" rear and front axles.

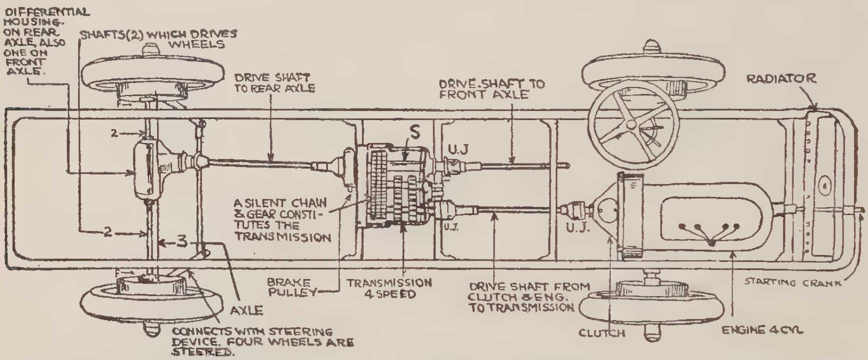
DIFFERENTIAL HOUSING ON REAR AXLE, ALSO ONE ON FRONT AXLE.
SHAFTS(2) WHICH DRIVES WHEELS
DRIVE SHAFT TO REAR AXLE
DRIVE SHAFT TO FRONT AXLE
RADIATOR
S
U.J
2
2
3
A SILENT CHAIN & GEAR CONSTITUTES THE TRANSMISSION
U.J.
U.J.
BRAKE PULLEY
TRANSMISSION 4 SPEED
DRIVE SHAFT FROM CLUTCH & ENG. TO TRANSMISSION
STARTING CRANK
AXLE
CONNECTS WITH STEERING DEVICE. FOUR WHEELS ARE STEERED.
CLUTCH
ENGINE 4 CYL

Fig. 115. Top view of Nash Quad truck chassis.

In order that the front wheels may be turned for steering, universal joints (B) (Fig. 118) are connected to shaft flanges (F) (Fig. 117). There are internal gears in all wheels by which they are driven. All four wheels are steered (see Fig. 118).

Specifications of the Nash Quad[1]

The engine is 4-cylinder (Buda); L-type cylinder 4¼" x 5½"; 28.9 h.p.; **ignition** is type "G4" Eisemann magneto (page 269); **carburetor,** the model "L" Stromberg (see Index); **governor** is the Simplex (see Index); this governor cuts off at a speed of 14 m.p.h., or an engine speed of 1,500 revolutions; the **clutch** is the Borg & Beck (page 23); the **brakes** are internal, expanding in each wheel, and one external, contracting on the drive shaft; the **tires** are solid rubber, 36"x5"; the **wheel base** is 142" and 124"; **tread,** 56"; the **capacity** of truck is 4,000 lbs., maximum is 5,200 lbs.; the **fuel tank,** 26.7 gallons, with reserve tank of 5 gallons; the **water capacity,** 11 gallons.

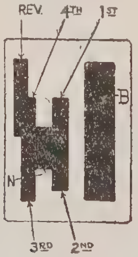

Fig. 116. Gear shift is a 4-speed shift (not a standard S. A. E. truck-gear shift).

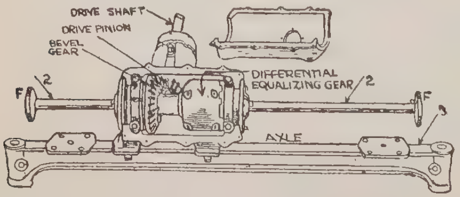

Fig. 117. Illustrates the **method of placing the differential housing** on the "dead" front and rear axle with drive shafts (2), which drive the universal joint (B) (Fig. 118), by flange connection (F).

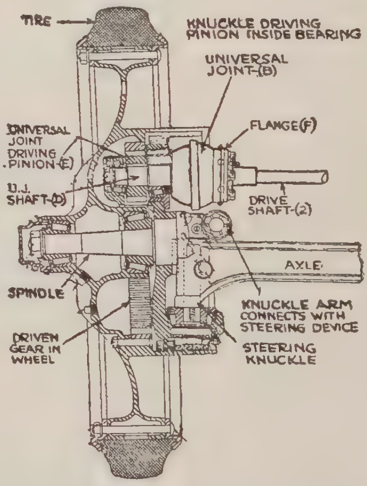
TIRE
KNUCKLE DRIVING PINION INSIDE BEARING
UNIVERSAL JOINT-(B)
UNIVERSAL JOINT DRIVING PINION-(E)
FLANGE(F)
U.J. SHAFT-(D)
DRIVE SHAFT-(2)
AXLE
SPINDLE
KNUCKLE ARM CONNECTS WITH STEERING DEVICE
DRIVEN GEAR IN WHEEL
STEERING KNUCKLE

Fig. 118. One of the four wheels, illustrating how the shaft (D) of universal joint (B), on which is a pinion (E), drives the internal gear in the wheel. Steering is by connection, in the usual way, of the knuckle arm with the steering device.

F. W. D. Four-Wheel Drive Truck

Drive: Power from the engine (Fig. 119) is transmitted through a Hele-Shaw clutch (see Fig. 6, page 22), to the main transmission, thence through a silent chain to a sub-transmission, thence to the front and rear "live" axles through drive shafts (P). The front and rear axles are similar to other automobile "live" rear axles, except that it is necessary to have universal joints connected with the spindle of the front wheels so that the front wheels can be turned for steering. The steering device connects with the front wheels, not the rear.

The locking center differential: A feature of this truck is a center "locking differential" in the sub-transmission. Normally this differential is in action to compensate for the difference in speed between the front and rear axles when turning corners. Thus, by the center differential action, tire economy is assured. Should the truck be in a position where

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[1] Nash Motors Co., Kenosha, Wis.

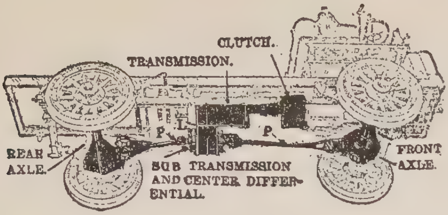

Fig. 119. View underneath the F. W. D. truck, showing how the front and rear wheels are driven.

the rear or front wheels are slipping, the center differential can be locked by means of a lever (L), operating a clutch connecting with each drive shaft, so that the differential action is thrown out of use and all four wheels are driven at the same speed. When the truck has been extricated from the soft spot, the locking lever (L) is released, and the differential is again in action. If one of the axles is permanently damaged or disabled, the propeller shaft (P) can be disengaged and the other axle used. There are also differentials in the front and rear live axles.

Specifications of F. W. D. Truck

Model B: 3-ton; **engine,** Wisconsin T-head, 4-cylinder bore, 4¾″ x 5½″stroke, with cylinders offset ¾″, and rating of 36.1 h.p.; **ignition,** Eisemann high-tension magneto with impulse starter; **carburetion,** Stromberg model "G"; **governor,** Pierce (page 947), adjusted for maximum speed of 14 m.p.h. on high speed; **tires,** 36″ x 6″; **gasoline tank,** gravity feed, 30 gallons; **gearshift,** same as shown in Fig. 19, page 29; **load distribution,** designed so that 45 per cent of the total load is carried on the front wheels and 55 per cent on the rear wheels; **transmission gear ratio,** 1:1 on high, 2:1 on second, 4:1 on low, and 4.13:1 on reverse; **total gear reduction,** 8.9:1 on high, 17.80:1 on second, 35.60:1 on low, 36.07:1 on reverse. (Four wheel drive Auto Co., Clintonville, Wis.)

THE G. V. ELECTRIC TRUCK (2-TON CAPACITY)

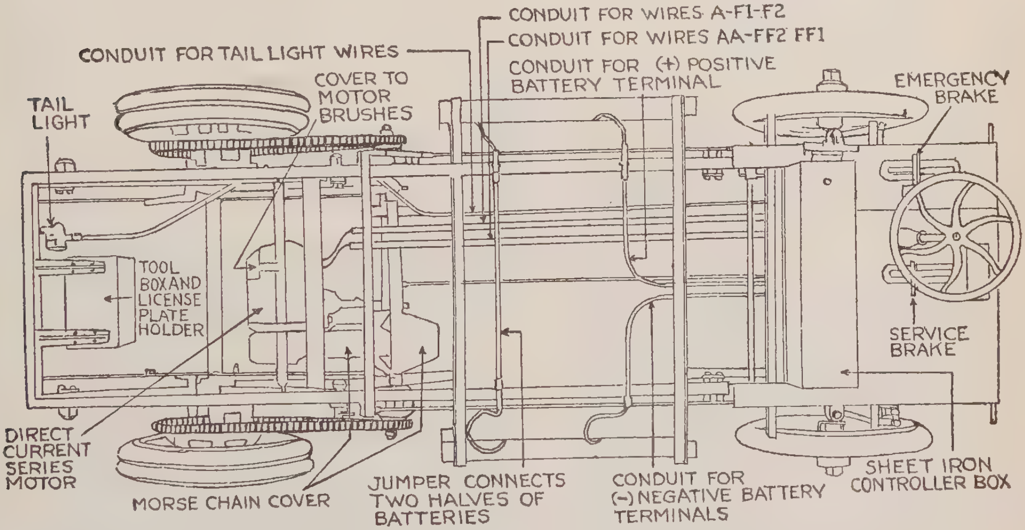
CONDUIT FOR WIRES A-F1-F2
CONDUIT FOR WIRES AA-FF2 FF1
CONDUIT FOR TAIL LIGHT WIRES
CONDUIT FOR (+) POSITIVE BATTERY TERMINAL
EMERGENCY BRAKE
TAIL LIGHT
COVER TO MOTOR BRUSHES
TOOL BOX AND LICENSE PLATE HOLDER
SERVICE BRAKE
DIRECT CURRENT SERIES MOTOR
MORSE CHAIN COVER
JUMPER CONNECTS TWO HALVES OF BATTERIES
CONDUIT FOR (−) NEGATIVE BATTERY TERMINALS
SHEET IRON CONTROLLER BOX

Fig. 120. **Top view of G. V. 2-ton electric truck.** The G. V. truck is made in 6 sizes: the 1,000 lb. wagon is made with worm or chain drive; the 2,000 lb. is chain driven; the 2 and 3½ and 5-ton trucks are chain driven.

Specifications

Carrying capacity 2 tons; speed, 9 m.p.h.; mileage travel (approximately) on one charge, 45; number of batteries, 42; amperage (approximately) in starting, 75 to 80; amperage when running, 35; weight of truck, including batteries, 6,395 lbs.; weight without batteries, 4,050 lbs.; price (chassis), $3,000; wheel base, 112½″; track or tread, 61″; overall lentgh, 167″; tires (solid), front, 36″x 4″, rear, 36″ x 3″ dual.

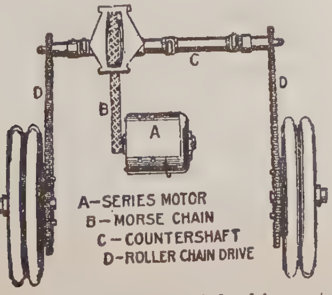

Fig. 122. **Note the simplicity of the drive system, which is a double-chain drive.**

The horsepower of the motor at 84 volts and 40 amperes is approximately 4 h.p. Starting cold, this motor will run 100 per cent overload for one half-hour and 200 per cent overload for 10 min.

The wiring diagram (Fig. 121) shows the connections to be used for either a differential shunted "three-wire" ampere-hour meter, or a "two-wire" ampere-hour meter equipped with variable resistor element.

Explanation of Parts

The controller box is placed in front, convenient to the driver. It contains the controller, resistance unit, fuse block switches, etc. The current is disconnected by the switch (Fig. 123) which is a 3-way running switch and is thrown to the left when the battery is being charged, to the center when current is off, and to the right when running.

When charging the battery, connection is made with the "charging receptacle" (Fig. 121) from an outside source of electric supply. In case the current charging the battery should fail for any reason, the circuit breaker (Fig. 121) will disconnect, so that the current from the battery would not flow back.

The ampere-hour meter (Fig. 121) shows the amount of current taken from the battery when running.

When charging, a compensating shunt is used, so that the meter runs approximately 15 per cent slow. The Sangamo Electric Co., Springfield, Ill., manufactures the meter used on this truck.

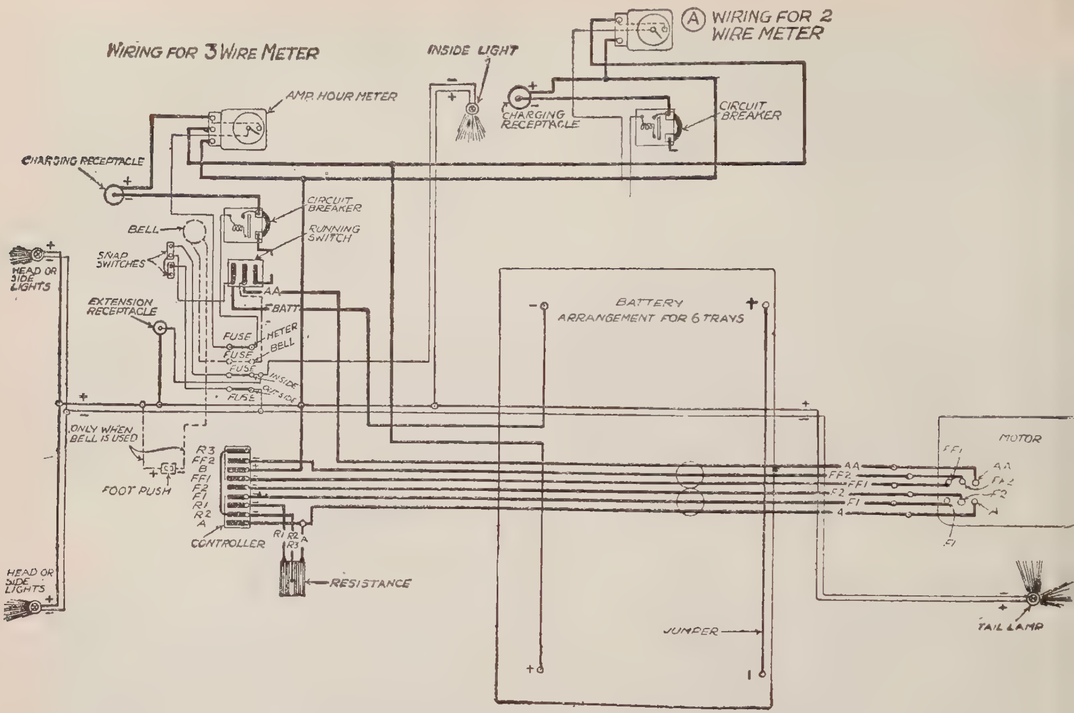

Fig. 121. Wiring diagram of G. V. 2-ton electric truck.

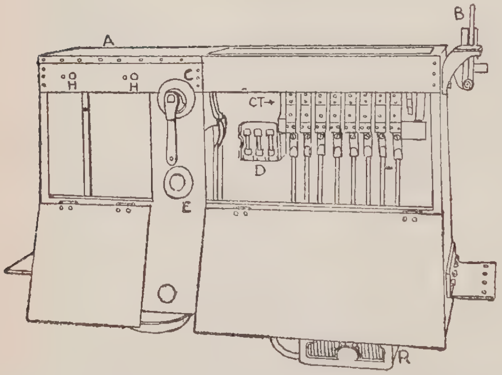

Fig. 123. **Controller box:** (A) sheet-steel controller box; (B) controller handle; (C) three-way switch; (D) lamp-circuit fuses; (E) plug for portable lamp; (R) resistance.

The Controller of G. V. Electric Truck

The controller is used to make connections for the different speeds. Refer to Fig. 124, and note the movement of the lever for the five speeds forward and the two speeds reverse.

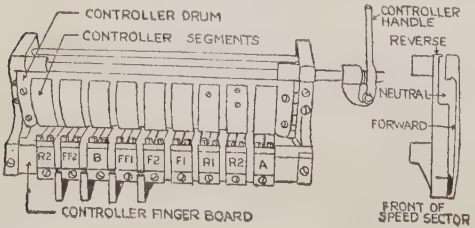

Fig. 124. **Controller.** Note the connections of the fingers, which refers to diagram (Fig. 125).

The controller is of the "constant torque" type, and the batteries are connected in series at all times. The various speeds are obtained by cutting out or in resistance (cast iron), and also by making "field" connections of the motor, as explained below.

Controller Connections

By referring to Figs. 124, 125, 126, and 127, the connections from the controller to the resistance and field circuits can be traced.

(R1) (R2) (R3) mean resistance; at (R1) all resistance is in the circuit; at (R3) about one-half is in; at (R2) about one-third is in (see Figs. 126, 127).

(F1) and (FF1) constitute one set of three field windings; (F2) and (FF2) are the second set, and are connected in series. The two windings are connected in series on speeds 1, 2, 3, 4, and in parallel on fifth speed.

(A1) and (AA) are two armature brushes; there are two brush holders with three brushes each, on the motor.

In Fig. 125, **the letter (O) is the neutral or "off" position of** the controller, and the black dots denote the controller fingers.

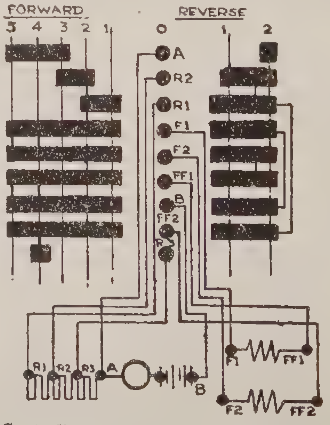

Fig. 125. **Controller connections:** (O) is off or neutral position. Black dots denote the controller fingers; black squares denote the controller copper segments. The five speeds forward and two speeds reverse are shown.

Forward Speeds

First speed: see Fig. 126 (1 forward); both fields are in series, and all resistance (R1) is in the circuit. This is the slowest speed.

Second speed: see Fig. 126 (2 forward); both fields are in series, and part of the resistance is cut out (R2).

Third speed: see Fig. 126 (3 forward); both fields are in series, and all resistance is cut out.

Fourth speed: see Fig. 126 (4 forward); resistance (R3) is shunted across the series field.

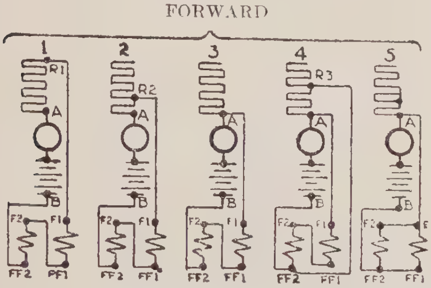

Fig. 126. Illustrating the resistance connections (**R1**) (**R2**) (**R3**) and field connections (**F1**) and (**F2**) and (**FF1**) and (**FF2**). (**A**) shows the armature brush connections; (**B**) battery connections.

Fifth speed: see Fig. 126 (5 forward); fields are in parallel; all resistance is cut out.

The forward speeds are divided approximately equally, each notch of the controller being an increase of approximately 20 per cent in speed.

Reverse Speeds

Reverse speeds (Figs. 127 and 125) are the same connections as second and third forward (Fig. 126), but passing through first speed to prevent a heavy rush of current. The direction of flow of the current is changed through the field, which reverses the rotation of the armature.

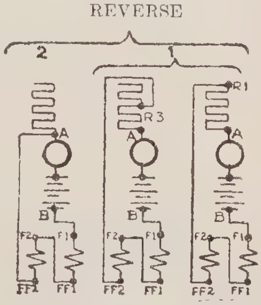

Fig. 127. Reverse connections.

Resistance: For resistance, cast iron is used.

STEINMETZ ELECTRIC TRUCK

The present model has a capacity of 1,500 lbs., and is rather remarkable for its simplicity, freedom from freak design, and its abundance of power. The feature which is expected to do so much to bring the electric to the fore ground is in the motor and rear axle. Other parts of the car are of a conventional design.

The high speed at which the electric motor operates efficiently makes it necessary to have a high gear reduction, which is objectionable in this kind of a vehicle. Steinmetz's first designs called for a revolving field rotating in an opposite direction to the armature. This was found to be impractical from a service standpoint, and the gear reduction is accomplished in this latest design in a **double-reduction spur-gear axle** of which the motor is a unit part.

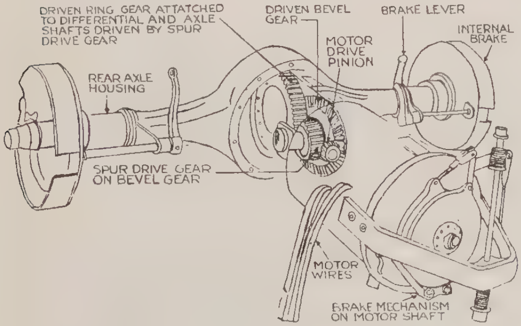
DRIVEN RING GEAR ATTATCHED TO DIFFERENTIAL AND AXLE SHAFTS DRIVEN BY SPUR DRIVE GEAR
DRIVEN BEVEL GEAR
BRAKE LEVER
INTERNAL BRAKE
MOTOR DRIVE PINION
REAR AXLE HOUSING
SPUR DRIVE GEAR ON BEVEL GEAR
MOTOR WIRES
BRAKE MECHANISM ON MOTOR SHAFT

Fig. 128. The motor and axle using a double reduction drive.

A standard battery is supplied.

The truck is fitted with pneumatic tires, 33″ x 5″. There is a hood in front of the driver's seat, resembling very much the hood on a gasoline truck. A portion of the battery is contained under this hood and another portion is under the driver's seat. Both sections of the battery are contained in trays, and can be rolled out of the car in a very few minutes by simply disconnecting the leads and loosening the clamp bolts.

Drive: Power unit of the Steinmetz truck, made up of the electric motor gearing of the rear axle is a self-contained or integral unit, the motor being readily bolted to the one-piece gear case casting, in which are mounted all of the driving gears. This gear is in turn readily bolted to the rear axle, thus insuring perfect alignment of all important parts, which means not only high efficiency when the truck is new, but high efficiency over a continued period of years.

Bearings: All important bearings throughout the car are ball bearings. The parts containing ball bearings are front wheels, rear wheels, motor shaft, gear-case counter shaft, and the differential bearings. All other bearings throughout the car subject to wear are bronze bushed, and the majority of them are of the oilless type. Ample lubrication is provided for all bearings.

Wheels: Schwarz wood wheels, standard S. A. E. dimensions, 12 spokes for 33″ x 5″ pneumatic tires or 34″ x 4″ solid tires (special wheels for the latter).

Steering gear: Irreversible nut and trunion type, easily adjustable for wear.

Controller: Continuous torque, drum type; all contacts and connections in plain view and very accessible. Controller segment mounted on metallic segment bases. Segment bases are properly insulated from each other and from the controller shaft, thus insuring against short circuits and possible burning of the controller segment bases.

Main switch: Double pole, double throw, rigidly constructed, and of large capacity; three positions—running, off and charging; locks in any position. When in charging position, this switch isolates the battery from the controller so that adjustment or repairs may be made to the controller with perfect safety to the mechanic.

Wiring: All power wire used through the truck is of flexible copper conductor, heavily insulated with 30 per cent Para rubber insulation.

Ward Electric Truck

A popular make of electric truck using a worm-driven rear axle is the Ward, made by the Ward Motor Vehicle Co., Mt. Vernon, N.Y.

Although the worm drive is used on 68 per cent of the gasoline-driven trucks the worm drive has not heretofore been adopted for electric trucks.

MECHANICAL SPECIFICATIONS OF 1922 MOTOR TRUCKS

From *Motor Age.*

MAKE AND MODEL	CHASSIS			TIRES		ENGINE							ELECTRICAL EQUIPMENT				TRANSMISSION SYSTEM						STEERING GEAR	WHEELS
				SIZE							CARBURETER		IGNITION		STARTING	LIGHTING	CLUTCH	GEARSET		REAR AXLE				
	Tons Capacity	Price	Standard Wheelbase, Inches	Front	Rear	Make	Number of Cylinders	Bore and Stroke	S. A. E. Hp.	Water Circulation	Make	Truck M. P. H.	Current Source	Make	Make	Make	Make	Make	Forward Speeds	Make	Gear Reduction	Final Drive	Make	Make
½-Ton																								
Dodge Bro.	½	$885	114	32x4p	32x4p	own	4	3⅞x4½	24.0	pu	Stw		bat	N.E.	N.E.	N.E.	own	own	3	own	4	sb	own	Kel.
Dort.....103-109	½	685	105½	31x4p	31x4p	Lyc	4	3½x5	19.6	t	Car	45.0	bat	Con	Bos	Bos	own	own	3	Flint	4	sb	Jac	Imp.
Seneca.....M	½	1,020	108	30x3½p	30x3½p	LeR	4	3½x4½	19.6	t	Stm	42.0		Con			B&B	War	3			sb	Gem	Day
Vim.....29	½	1,050	108	31x4p	31x4p	own	4	3⅛x4½	15.6	t	Zen	33.0	bat	Will	West	Wes	B&B		3		5	w		
Vim.....30	½	1,175	127	32x4½p	32x4½p	own	4	3⅛x4½	15.6	t	Zen	33.0	bat	Will	West	Wes	B&B		3		5	w		
¾-Ton																								
Acme.....G	¾		130	35x5p	35x5p	Cont	4	3¾x5	22.5	t	Ray	28.0	mag	Eis		Eis	B&B	Cotta	3	Tim	6	w	Ros	Bim
Chevrolet.....G	¾		120	31x4p	34x4½p	own	4	3¹¹⁄₁₆x4	24.0	pu	Zen		bat	Rem	Au-L	Au-L	own	own	3	Cen	5	sb	own	Hay
Commerce.....T	¾	1,450	127	34x4½p	34x4½p	Cont	4	3¾x5	22.5	t	Zen	40.0	mag	Eis	Bijur	Bijur	Det	Det	3	Sal	5	sb	Jac	
Clydesdale.....18	¾	1,890	136	34x5p	34x5p	Cont	4	3¾x5	22.5	t	Zen	33.0	mag	Eis	Bijur	Eis	B-L	B-L		Tim	5	w	Ros	Smi
Denby.....31	¾	1,625	130	35x5p	35x5p	Cont	4	3½x5	19.6	t	Stm	35.0	mag	Eis	Remy	Rem	Full	Full	3	Col	5	sb	Ros	MWC
International.....S	¾	1,500	124⅛	34x5p	34x5p	Lyc	4	3½x5	19.6	t	Ens	35.0	bat	Con	Au-L	Au-L	Mun	Mun	3	Tor	6	i	CAS	own
Ranier.....R-21	¾	1,990	125	35x5p	35x5p	Cont	4	3½x5	19.6	t	Zen		mag	Opt	Opt	Opt	B-L	B-L	3	Tim	6	w	Lav	Jon
Republic.....75	¾	1,250	124	32x4½p	32x4½p	Lyc	4	3½x5	19.6	t	Stm	35.0	bat	Aul	Aul	Aul	own	own	3	Tor	5	i	Jac	MWC
Stoughton.....C	¾	1,240	131	34x4½p	34x4½p		4	3½x5	19.6	t	Stm		bat	Wes	Wes	Wes			3	Col	5	sb		
White.....15	¾	2,400	133½	34x5p	34x5p	own	4	3¾5⅛	22.5	pu	own		mag				own	own	4	own		sb	own	own
White.....15-45	¾	3,200	143½	34x5p	34x5p	own	4	4¼x5¾	28.9	pu	own		mag				own	own		own		sb	own	own

[continued on next page

continued from page 966]

1-Ton

Acme B	1		130	34x3½	34x5	Cont.	4	3¾x5	22.5	t.	Ray	23.0	mag.	Eis	G&D.	Eis	B&B	Cot.	3	Tim	7	w	Ros	Bim
Armleder 20	1		148	**34x3½	**34x5	Bud	4	3¾x5¼	22.5	pu	Zen	19.0	mag.	Bos	Wes	Wes	Ful	Ful	3	Tim	7	w	Ros	StM
Atlas MD	1	1,185	130	32x4½p	32x4½p	Lyc	4	3½x5	19.6		Mar		mag.	A-K	Bij		B&B	own	3	own		w	CAS	E&O
Avery	1		129	34x5p	34x5p	own	4	3x4	14.4	t.	Stm.	20.0		KW	Wes		own			Tor		i	Ros	own
Bessemer G	1	1,395	124	*34x3	*34x4	Cont.	4	3½x5	19.6	t.	Stm.		mag.	Bos	Bij	Bij	Ful	Ful	3	Tor	7	i	Ros	Sch
Brockway E	1		135	35x5p	35x5p	Bud	4	3¾x5⅛	22.5	t.	Stm.		mag.	Rem	Rem	Rem	War	War	3	Col	5	sb	Lav	
Clydesdale 20	1	2,385	136	34x5p	34x5p	Cont.	4	3¾x5	22.5	t.	Zen.	40.0	mag.	Eis.	Bij	Eis	B-L	B-L		Tim	6	w	Ros	
Corbitt H-22	1	1,480	130	34x3½	34x4	Cont.	4	3¾x5	22.5	t.	Stm.	18.0	mag.	Eis	Bij	Bij	B-L	B-L	3	Shl	5	w	Ros	Bim
Dearborn E	1	1,600	132	35x5p	35x5p	Bud	4	3⅝x5⅛	21.0	pu	Str	45.0	bat	Con	Wes	Wes	Ful	Ful	3	Wis	6	w	Dit	own
Day Elder A	1	1,600	128	35x5p	35x5p	Cont.	4	3¾x5	22.5	t.	Zen.	30.0	mag.	Eis.	Wes	Eis	Cvt	Mu	3	Shl	6	w	Gem	Jon
Defiance G	1	1,695	128	35x5p	35x5p	High	4	3¾x5	22.5	pu	Stm.		mag.	Eis	Au-L.	Au-L.	B&B	GL	3	Eat	5	sb	own	StM
Ford TT	1	445	123	30x3½p	32x4½p	own	4	3¾x4	22.5	t.	own		mag.	own	own	own	own	own	2	own	7	w	own	own
G.M.C. K-16	1	1,495	132	34x5p	34x5p	own	4	3½x5½	19.6	pu&t.	Mar	25.0	mag.	Eis	Rem	Rem	own	own	3	own	6	stb	own	Kel
Gary F	1	2,800	130	36x3½	36x4	Bud	4	3¾x5	22.5	t.	Mas.	20.0	mag.	Eis		Opt.	Ful	Ful		Tim	7	w	Ros	
Graham Bros	1	1,370	140	33x4½p	34x5p	Dod	4	3⅞x4½	24.0	pu	Stw		bat	N.E.	N.E.	N.E.	Dod	Dod	3	own	6	sb	Dod	Kel,Stn
Gramm Bern. 10	1	1,365	129	33x5p	33x5p	Lyc	4	3½x5	19.6	t.	Stm	50.0	bat	Con	Au-L.	Au-L.	B&B	War	3	Sal		sb	Jac-Ros.	
Hahn J-4	1		132	34x3½	34x5	Cont.	4	3¾x5	22.5	pu	Z&Str			Del		Del	B-L	B-L		Shl		w	Ros	Bm&Sch
International 21	1	1,750	115	36x3½	36x3½	own	4	3½x5¼	19.6	pu	Ens	22.0	mag.	Bos		N.E.	own	own	3	own	7	i	own	own
Kissel Express	1		140	34x5p	34x5p	own	4	3⅞x5½	24.0	pu	Stm		bat	Rem	Rem	Rem	War	War	3	Tim	5	w	Jac	StM
Kleiber	1	2,600	140	34x3½	34x5	Cont.	4	4⅛x5¼	27.2	pu	Stm		mag.				B-L	B-L	4	Tim	7	w	Ros	San
Larrabee X-2	1	1,925	138	34x5p	34x5p	Cont.	6	3¼x4½	25.3	pu	Zen		bat	Bos	Bos	Bos	B-L	B-L	3	Sal	5	w	Gem	Ind
Menominee HT	1	2,080	130	34x3½	36x5	Wis	4	3¾x5	22.5	pu	Stm	18.0	mag.	Eis	Bos	Bos	Dtl	Cotta	3	Wis	7	w	Ros	
Napoleon 9	1	1,535	133	35x5p	35x5p	Gray-B.	4	3½x5	19.6	t.	Shb	31.2	bat	G&D	G&D	G&D	Ful	Ful	3		6	i	Lav	Roy
Nash 2018	1	1,895	130	34x3	34x4	own	4	3¾x5¼	22.5		Stm	22.0		Eis	Au-L.	Au-L.	B&B	Det		Cla	6	i	Lav	

ABBREVIATIONS

Types of Construction

*—Tires optional
**—Pneumatics extra
***—Pneumatics and cushions extra
†—Price includes body
bat—storage battery
bs—bevel spur
cu—cushion
i—internal gear
mag—magneto
opt—optional
p—pneumatic
pu—pump
sb—Spiral bevel
stb—straight bevel
t—thermo-syphon
w—worm

MAKERS OF PARTS

A-K—Atwater-Kent
Apo—Apollo
Arc—Archibald
Au-L—Auto-Lite
AuW—Auto Wheel
B&B—Borg & Beck
Bij—Bijur
Bim—Bimel
Ben—Bendix
Ber—Berling
B-L—Brown-Lipe
Bos—Bosch
Bud—Buda
Car—Carter
CAS—CAS Products
Cen—Central
Cla—Clark
Col—Columbia
Con—Connecticut
Cont—Continental
Cot—Cotta
Cvt—Covert
Day—Dayton
Del—Delco
Dela—Delaney
Det—Detroit
Dit—Ditwiler
Dix—Dixie
Dod—Dodge
Dtl—Detlaff
Dun—Dundore
Dur—Durston
Dyn—Dyneto
Eat—Eaton
Eis—Eismann
Ens—Ensign
E&O—Eberly & Oris
Ful—Fuller
GBS—Golden, Belknap & Swartz
G&D—Gray & Davis
Gem—Gemmer
G-L—Grant-Lees
Hay—Haynes
Hels—Hele Shaw
Her—Hercules
Hin—Hinkley
Hoo—Hoopes Bros.
Hrt—Hartford
HS—Herschell-Spillman
Ind—Indestructible
IrM—Iron Mountain
Jac—Jacox
John—Johnson
Jon—Jones
Kel—Kelsey
Kng—Kingston
KW—KW Ignition Co.
Lav—Lavine
LeR—LeRoi
Lib—Liberty
L-N—Leece-Neville
Lyc—Lycoming
Mar—Marvel
Mas—Master
McC—McCanna
M&E—Merchant & Evans
Mid—Midwest
Mon—Monarch
Mun—Muncie
MWC—Motor Wheel Corp.
N.E.—North East
N.—Northern
Pru—Prudden
Ray—Rayfield
Rem—Remy
Ros—Ross
Roy—Royer
Rus—Russel
Sag—Saginaw Products Co.
Sal—Salisbury
Sav—Savage
Sch—Schwartz
Shb—Shebler
Shl—Sheldon
Sim—Simplex
Smi—Smith
Spl—Splitdorf
Stan—Standard Parts C
StM—St. Mary
Stm—Stromberg
Stw—Stewart
Tea—Teagle
Til—Tillotson
Tim—Timken
Tor—Torbensen
Uni—Universal
Ves—Vesta
Wal—Walker
Wan—Wayne
War—Warner Corp.
Wau—Waukesha
Weid—Weidely
Wes—Westinghouse
Wis—Wisconsin
Woh—Wohlrab
Zen—Zenith

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MAKE AND MODEL	CHASSIS			TIRES		ENGINE							ELECTRICAL EQUIPMENT				TRANSMISSION SYSTEM						STEERING GEAR	WHEELS
				SIZE							CARBURETER		IGNITION		STARTING	LIGHTING	CLUTCH	GEARSET		REAR AXLE				
	Tons Capacity	Price	Standard Wheelbase, Inches	Front	Rear	Make	Number of Cylinders	Bore and Stroke	S. A. E. Hp.	Water Circulation	Make	Truck M. P. H.	Current Source	Make	Make	Make	Make	Make	Forward Speeds	Make	Gear Reduction	Final Drive	Make	Make
1-Ton CONTINUED																								
Patriot....Revere	1	1,500	128	35x5p	35x5p	Cont...	4	3¾x5	22.5	t.....	Stm....	....	bat....	A-K...	Bij....	Bij....	B&B....	Cvt....	3	Emp...	6	w.....	CAS ...	Bim.....
Rainier.....R-19	1	2,150	133	34x3½	34x4d	Cont...	4	3½x5	19.6	t.....	Zen.....	20.0	mag...	Opt....	Opt....	Opt....	B-L.....	B-L....	3	Shl....	7	w....	Lav.....	Jon.....
Republic......10	1	1,395	124	34x3	34x4	Cont...	4	3¾x5	22.5	t.....	Stm....	17.0	mag...	Bos....	....	....	Ful.....	Ful....	3	Tor....	6	i......	Jac.....	MWC.*
Republic....10-E	1	1,695	124	35x5p	35x5p	Cont...	4	3¾x5	22.5	t.....	Stm....	25.0	mag...	Bos....	....	Del....	Ful.....	Ful....	3	Tor....	6	i.....	Jac.....	MWC....
Signal ......NF	1	2,227½	132	34x5p	36x6p	Cont...	4	3¾x5	22.5	pu....	Stm....	25.0	mag...	Eis....	....	....	B-L.....	B-L....	3	Tim...	7	w.....	Ros.....	StM.....
Stoughton.....A	1	1,995	130	35x5p	35x5p	Wau...	4	3¾x5¼	22.5	pu....	Stm....	....	mag...	....	....	Dyn...	B-L.....	B-L....	3	Shl....	6	w.....	....	....
Triangle......AA	1	1,385	115	34x4½p	34x4½p	H.S....	4	3¼x5	16.9	t.....	Stm....	40.0	bat....	N.E...	N.E...	N.E...	Ful.....	Ful....	3	Cla....	6	i.....	Gem....	Nor......
Vim.......... 31	1	1,975	125	35x5*	35x5*	Her....	4	3¾x5⅛	22.5	pu....	Zen.....	30.0	mag...	Spl....	Wes...	Wes...	Covt....	Covt...	3	....	6	w.....	....	....
Watson......	1	......	128	34x5p	34x5p	Bud...	4	3⅝x5⅛	21.0	pu....	Zen.....	35.0	bat....	....	Dyn...	Dyn...	B-L.....	B-L....	....	....	....	sb....	Ros.....	....
Wichita........K	1	2,300	144	36x3	36x4	Wau...	4	3¾x5¼	22.5	pu....	Stm....	13.5	mag...	Eis....	N.E...	N.E...	own.....	B-L....	4	Shl....	7	w.....	Ros.....	Bim.....
Wilcox Trux...AA	1	......	130	36x4	36x4	Bud...	4	3¾x5¼	22.5	pu....	Stm.....	....	mag...	Bos....	....	....	B-L.....	B-L....	....	Shl....	....	w.....	Gem....	....
Winther......751	¾-1	1,795	135	34x4½p	35x5p	H.S....	4	3½x5	19.6	t.....	Stm....	30.0	bat....	Wes...	Wes...	Wes...	War.....	War....	3	Tor....	6	i.....	Lav.....	MWC....
Wolverine....J-1	1	......	140	34x3½*	34x5*	Cont...	4	3¾x5	22.5	pu....	Stm.....	18.0	mag...	Eis....	Bos....	Bos....	Ful.....	Ful....	....	Russ...	8	i.....	Gem....	own.....
1½-Ton																								
Ace............	1½	2,295	144	34x3½	34x5	Bud...	4	3¾x5⅛	22.5	t.....	Zen.....	18.0	....	A-K...	Wes...	Wes...	Ful	Ful....	3	Tim...	7	w.....	Ros.....	Sch......
Acme.........F	1½	......	141	34x3½	34x5	Cont...	4	3¾x5...	22.5	pu....	Zen.....	18.5	mag...	Eis....	Day...	Day...	B&B....	Cot....	3	Tim...	8	w.....	Ros.....	Bim.....
Akron Multi...20	1¼	1,695	133½	34x5p	34x5p	Hin....	4	4x5¼	25.6	pu....	Stm.....	35.0	bat....	Wes...	Wes...	Wes...	War.....	War....	3	Eat....	5	sb....	Jac.....	Bim.....
Atterbury....20R	1½	2,475	144	34x3½	34x5	Cont...	4	3¾x5...	22.5	pu....	Zen.....	20.0	mag...	Ber....	....	Bel....	Ful.....	Ful....	3	Tim...	7	w.....	Ros.....	Arc .....
Available...H1½	1½	2,450	147	36x3½	36x5	Her....	4	4x5⅛...	25.6	pu....	Stm.....	18.0	mag ..	Bos....	Bos....	Bos....	B-L.....	B-L....	3	Tim...	7	w.....	Ros.....	StM.....
Bessemer ...H-2	1½	1,995	144	36x3½	36x5	Cont...	4	3¾x5	22.5	t.....	Stm....	....	mg&bt.	Bos....	Bij....	Bij....	B&B....	B-L....	3	Tor....	8	i.....	Ros.....	Sch.....
Clydesdale....42	1½	2,475	146	36x3½	36x6	Cont...	4	3¾x5	22.5	t.....	Zen.....	18.0	mag...	Bos....	Bij....	Eis....	B-L.....	B-L ...	3	Tim...	7	w.....	Ros.....	....
Commerce.....12	1½	1,800	130	35x5*	35x5*	Cont...	4	3¾x5	22.5	t.....	Zen.....	40.0	mag...	Eis....	Bij....	Bij ...	B-L	B-L....	4	Tor....	8	i.....	Jac	....
Corbitt......E-22	1½	2,200	144	34x3½	34x5	Cont...	4	3¾x5	22.5	t.....	Stm....	18.0	mag...	Eis....	Bij....	Bij....	B-L.....	B-L....	3	Shl....	6	w	Ros.....	Bim.....
Dearborn.......F	1½	2,180	......	34x4	34x5	Bud...	4	3¾x5⅛	22.5	t.....	Stm....	28.0	mag...	....	....	V&W...	Ful.....	Ful....	....	Wis....	7	w.....	Dit.....	own......
Defiance.......D	1½	2,095	140	35x5p	36x6p	High...	4	3¾x5...	22.5	pu....	Stm....	....	mag...	Eis....	Au-L...	Au-L...	B&B....	GL....	3	Tor....	7	i.....	own....	StM.....
Denby........33	1½	2,300	136	35x5p	38x7p	Cont...	4	3¾x5	22.5	t.....	Stm....	26.5	mag...	Eis....	Opt....	Opt....	Ful.....	Ful....	3	Cla....	6	i.....	Gem....	MWC....
Dependable....C	1½	2,350	150	34x4	34x6	Bud...	4	3¾x5¼	22.5	pu....	Zen.....	18.0	mag...	Spl....	....	....	Ful.....	Ful....	3	Wis....	8	w....	Ros.....	Bim.....
Diamond T.....03	1-1¼	1,975	132	36x3½	36x4	Hin....	4	3¾x5¼	22.5	pu....	Stm....	28.0	mag...	Bos....	Opt....	Bos....	Cvt.....	Cvt....	3	own....	6	w....	Gem....	Sch.....
Diamond T....FS	1½	2,525	144	36x3½	36x5	Hin....	4	2¾x5¼	22.5	pu....	Stm....	18.0	mag...	Bos....	Opt....	Bos....	Cvt.....	Cvt....	4	Wis....	8	w....	Gem....	Sch.....
Diamond T.....T	1½	2,250	154	36x3½	36x5	Hin....	4	3¾x5¼	22.5	pu....	Stm....	20.0	mag...	Bos....	Opt....	Bos	Cvt.....	Cvt....	3	Tim...	7	w....	Gem....	Sch......
Federal.......SD	1-1½	1,800	132	35x5p	36x6p	Cont..	4	3¾x5	22.5	pu....	Zen.....	25.0	mag...	Eis....	Au-L.	Au-L...	B&B....	own....	3	Tim...	7	w....	Gem....	Det.....
G. W. W........	1-1½	1,950	142	35x5p	35x5p	Weid...	4	3¾x5½	22.5	pu....	Shb.....	38.0	bat....	Opt....	Opt..	Opt ...	Ful.....	Ful....	4	Cla....	7	i.....	Woh....	opt.....

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Gary I	1½	3,250	144	36x3½	36x5	Bud	4	4x5½	25.6		Mas	18.0					Ful	Ful	3	Tim	7	w	Ros	
Giant 15A	1½	2,250	138	34x3½	34x5	Cont	4	3¾x5	22.5	t	Shb	15.8	mag				B-L	B-L	3	Shl	7	w	Jac	Wan
Graham Bros.	1½	1,430	140	33x4½p	36x6p	Dodge	4	3⅞x4½	24.0	pu	Stw		bat	N.E	N.E	N.E	Dod	Dod	3	own	6	sb	Dod	Kel-St
Gramm-B'stein 15	1½	1,900	138	36x3½	36x5	Cont	4	3¾x5	22.5	t	Stm	25.0	bat	N.E.	N.E.	N.E.	Ful	Ful	3	Cla	7	i	Ros	Bim
Indiana 12	1½		134	34x3½	34x5	Wau	4	3¾x5¼	22.5	pu	Stm	20.0	mag	Eis	Wes	Wes	B&B	B-L	3	Shl	7	w	Woh	Bim
International 31	1½	1,850	129	36x3½	36x4	own	4	3½x5¼	19.6	pu	Ens	19.4	mag	Bos		N.E.	own	own	3	own	8	i	own	own
Kalamazoo G1	1½		144	34x4	34x5	Cont	4	3¾x5	22.5	t	Stm	20.0	bat	Con	Dyn	Dyn	Ful	Ful	4	Wis	8	w	Ros	Bim
Kalamazoo G2	1½	2,800	144	36x4	36x6	Cont	4	3¾x5	22.5	pu	Stm	20.0	mag	Bos	Dyn	Dyn	Ful	Ful	4		8	w	Ros	Bim
Kelly-S K-34	1½	2,900	144	36x3½	36x6	own	4	3¾x5¼	22.5	pu	Zen	20.0				Eis			3	Shl	8	w	Gem	
Kissel, Gen. Util.	1½		152	36x3½	36x5	own	4	3⅞x5½	24.0	pu	Stm	12.0	mag				War	War	3	Shl	7	w	Pru	Smi
Kleiber	1½	3,100	147	36x3½	36x6	Cont	4	4⅛x5¼	27.2	pu	Stm		mag				B-L	B-L	4	Tim	7	w	Ros	Smi
Koehler D	1½	1,985	137	34x3½	34x5	H.S.	4	3½x5	19.6	t	Zen	18.0	mag	Spl		Wes	Mech	Mech	3	own	7	w	Lav	Jon
Larrabee J-4	1½	2,400	138	34x3½	34x5	Cont	4	3¾x5	22.5	pu	Zen	18.2	mag	Bos	Bos	Bos	B-L	B-L	3	Shl	7	w	Gem	Hoo
Maccar L-2	1½	2,700	150	36x4	36x6	Cont	4	4⅛x5¼	27.2	pu	Zen	19.0	mag	Eis		Bos	B-L	B-L	4	Tim	8	w	Ros	Dav
Mack AB Chain	1½	3,000	144	36x4	36x3½d	own	4	4x5	25.6	pu	shb	19.5	mag	Tea	L-N	L-N	own	own	4	own	6	ch	own	opt
Mack AB	1½	3,450	144	36x4	36x3½d	own	4	4x5	25.6	pu	shb	17.9	mag	Tea	L-N	L-N	own	own	4	own	7	bs	own	opt
Master JW	1½	2,690	142	34x3½	34x5	Bud	4	4⅛x5½	27.2	pu	own	15.3	mag				Ful	Ful	3	Tim	7	w	Ros	Pru
Maxwell	1½	932	124	32x3	32x4	own	4	3⅝x4½	21.0	t		25.0					own	own	3	own	7	w	own	
Moline 10	1½	1,985	130	34x5p	36x6p	own	4	3½x5	19.6	t	Til	24.0	mag	Spl	Au-L.	Au-L.	B&B	own	3	Tor	8	i	Ros	MWC
Napoleon 11	1½	1,835	133	35x5p	36x6p	Gy.-B.	4	3½x5	19.6	t	Shb	25.7	bat	G&D.	G&D.	G&D.	Ful	Ful	3	Mid	7	i	Lav	Roy
Noble B30	1½	2,100	156	36x3½	36x5	Bud	4	3¾x5¼	22.5	pu	Stm	15.8	mag	Eis	Wes	Wes	Ful	Ful	3	Shl	8	w	Lav	Bim
Old Hickory W	1¼	2,175	135	36x3½	36x4	Cont	4	3¾x5	22.5	t	Stm	18.0		Eis	Ves		B&B	GrL	3	Tim	7	w	Lav	Sta
Oneida B	1½	2,825	144	36x3½**	36x6**	Hin	4	4x5¼	25.6	pu	Stm	25.0	mag	Bos	Wes	Wes	Ful	Ful	3	Wis	7	w	Ros	StM
Paige 52-19	1½	2,880	140	34x3½	34x5	Hin	4	4x5¼	25.6	pu	Stm	20.0	mag	Bos	Rem	Rem	B-L	B-L	4	Tim	7	w	Ros	
Rainier R-16	1½	2,490	147	34x3½	34x5	Cont	4	3¾x5	22.5	t	Zen	18.0	mag	Opt	Opt	Opt	B-L	B-L	3	Shl	7	w	Lav	Jon
Reo F	¾-1¼	1,245	128	34x4½p	34x4½p	own	4	4⅛x4½	27.2	pu	Joh		bat		Rem	Rem	own	own	3	own	4	sb	own	Pru
Republic 11-X	1½	1,795	144	34x3½	34x5	Cont	4	3¾x5	22.5	t	Stm	15.0	mag				Ful	Ful	3	Tor	8	i	Jac	MWC
Schwartz A	1¼	1,685	130	34x4½p	34x4½p	Lyc	4	3½x5	19.6	t	Car	30.0	bat	Wes	Wes	Wes	Ful	Ful	3	Eat	6	sb	Ros	Sch
Selden 1½-A	1½	2,360	137	34x3½	34x5	Cont	4	3¾x5	22.5	t	Stm	18.0	mag	Eis	N.E	N.E	B-L	B-L	3	Tim		w	Lav	Arc
Service 15	1-1½	1,840	132	34x4½p	35x5p	Mid	4	3⅝x5	21.0	p	Stm		bat	Rem	Rem	Rem	B-L	B-L	3	Eat		sb	own	Det
Signal H	1½	2,632	144	34x4	36x6	Cont	4	4⅛x5¼	27.2	pu	Stm	15.0	mag	Eis	Del	Del	B-L	B-L	4	Tim	7	w	Ros	StM
Standard IK	1½	1,800	134	34x3½	34x5	Cont	4	3¾x5	22.5	pu	Stm	17.0					B-L	B-L	3	Tim	7	w	Ros	
Sterling 1½	1½	2,885	142	36x3½	36x5	own	4	4x5¾	25.6	pu	Zen	16.0	bat	Eis		G&D.	B-L	B-L	4	Tim	7	w	Ros	Pru
Stoughton B	1½	2,350	140	36x3½	36x5	Wau	4	3¾x5¼	22.5	pu	Stm		mag			Dyn	B-L	B-L	3	Shl	7	w		
Tower J	1½	2,900	142	35x5p	38x7p	Cont	4	4⅛x5¼	27.2	pu	Opt		mag				Ful	Ful		Tim	7	w	Ros	
Traffic Speedboy	1½	1,595	128	35x5p	35x5p	Cont	4	3¾x5	22.5	t	Car	35.0	mag	Bos	G&D.	G&D.	Cvt	Cvt	3	Rus	6	i	Own	Day
Tiffin	1½	2,400	135	36x3½	36x5	Cont	4	4⅛x5¼		pu	Shb	16	mag		Wes	Wes	Ful	Ful	3	Shl	7	w	Ros	Smi
Triangle A	1½	2,350	144	34x3½	34x6	Wau	4	3¾x5¼	22.5	pu	Stm	18.0	mag	Eis	N.E	Eis	Ful	Ful	3	Cia	7	i	Gem	N or Ry.
United AT	1½		145	34x3½	34x5	Bud	4	3¾x5¼	22.5	pu	Stm	18.0	mag	Eis		Rem	Ful	Ful	3	Shl	7	w	Jac	
United States N	1½	1,975	144	36x3½	36x5	Cont	4	3¾x5	22.5	pu	Stm	19.8	mag	Bos	Bos	Bos	Ful	Ful	3	Cla	7	i	Lav	Sch

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MAKE AND MODEL	CHASSIS			TIRES		ENGINE							ELECTRICAL EQUIPMENT				TRANSMISSION SYSTEM						STEERING GEAR	WHEELS
				SIZE							CARBURETER		IGNITION		STARTING	LIGHTING	CLUTCH	GEARSET		REAR AXLE				
	Tons Capacity	Price	Standard Wheelbase, Inches	Front	Rear	Make	Number of Cylinders	Bore and Stroke	S. A. E. Hp.	Water Circulation	Make	Truck M. P. H.	Current Source	Make	Make	Make	Make	Make	Forward Speeds	Make	Gear Reduction	Final Drive	Make	Make
1½-Ton CONTINUED																								
Velie.........46	1½	1,585	133	36x3½	36x5	Cont.	4	3¾x5	22.5	pu	Stm	16.0	mag.bt.	Ber	Bij	Bij	B&B	Dur	....	Tor	8	i	Ros	Mut
Veteran........E	1½	3,500	186	34x5p	34x5p	Bud	4	3¾x5¼	22.5	pu	Zen	20.0	mag	Eis	......	......	B&B	Cot	3	Shl	6	w	Ros	Smi
Wichita........L	1½	2,600	144	36x3½*	36x5*	Wau	4	3¾x5¼	22.5	pu	Stm	12.5	mag	Eis	N.E.	N.E.	own	B-L.	4	Shl	8	w	Ros	Bim
Wilson.........F	1½	2,270	140	36x3½	36x5	own	4	3¾x5		t	Stm	19.6	mag	Eis	Eis	Eis	B&B	Cot	4	Tim	6	w	Ros	......
Wilcox Trux....B	1½	......	135	36x4**	36x5**	own	4	4½x5	32.4	pu	Stm	....	mag	......	......	......	M&E	own	4	Wal	....	w	own	Smi
Winther........39	1½	2,450	140	34x3½	34x5	Wis	4	3¾x5	22.5	pu	Stm	20.0	mag	Eis	Wes	Eis	Ful	Ful	3	Med	7	i	Lav	Med
Winther......430	1½	2,850	132	32x4	32x4	Wis	4	3¾x5	22.5	pu	Stm	15.0	mag	Eis	Wes	Eis	Ful	Ful	3	Med	9	i	Lav	Med
Wolverine......J	1½	......	140	34x3½*	34x5*	Cont.	4	3¾x5	22.5	pu	Stm	18.0	mag	......	Bos	Bos	Ful	Ful	3	Rus	8	i	Gem	......
Autocar....21-F	1½–2	1,950	97	34x4	34x6	own	2	4¾x4½	18.1	pu	Stm	....	mag	......	......	......	own	own	3	own	8	bs	Ros	......
Autocar....21-G	1½–2	......	120	34x4	34x6	own	2	4¾x4½	18.1	pu	Stm	....	mag	......	......	......	own	own	3	own	8	bs	Ros	......
Autocar....27-H	2	2,950	114	34x5	34x7	own	4	4x5½	25.6	pu	Stm	....	......	......	......	......	own	own	4	own	6	bs	Ros	......
Autocar....27-K	2	3,075	138	34x5	34x7	own	4	4x5½	25.6	pu	Stm	....	......	......	......	......	own	own	4	own	6	bs	Ros	......
Brockway.....S4	1½–2	......	140	36x3½	36x5	Cont.	4	3¾x5	22.5	pu	Stm	19.0	mag	Eis	N.E.	N.E.	B-L.	B-L.	3	Tim	7	w	Gem	Hoo
Brockway.....SK	1½–2	......	145	36x4	36x6	Cont.	4	4⅛x5¼	27.2	pu	Stm	22.0	mag	Eis	N.E.	N.E.	B-L.	B-L.	3	Tim	6	w	Gem	Hoo
Commerce.....16	2	......	137	35x5p	36x6p	Cont.	4	3¾x5	22.5	t	Zen	30.0	mag	Eis	Bij	Bij	B-L.	B-L.	4	Tor	9	......	Jac	......
Corbitt......C22	2	2,600	148	36x3½	36x7	Cont.	4	4⅛x5¼	27.2	pu	Stm	16.0	mag	Eis	......	Eis	B-L.	B-L.	3	Shl	8	w	Ros	Bim
Day-Elder......B	1½–2	2,000	144	34x3½	34x5	Cont.	4	3¾x5	22.5	t	Zen	15.0	mag	Eis	Wes	Eis	Cvt	Cvt	3	Shl	8	w	Gem	Jon
2-Ton																								
Defiance.......E	2	2,275	140	35x5p	38x7p	High	4	3¾x5	22.5	pu	Stm	....	mag	Eis	Au-L.	Au-L.	BB	Gr.L.	3	Tor	8	i	own	StM
Denby.......134	2	2,600	144	36x3½	36x6	Cont.	4	3¾x5	22.5	t	Stm	22.5	mag	Eis	......	......	Ful	Ful	4	Rus	10	i	Gem	MWC
Diamond T.....U	2	2,650	160	36x4	36x7	Hin	4	4x5¼	25.6	pu	Stm	16.0	mag	Bos	BijorW.	Bos	Cvt	Cvt	4	Tim	7.75	w	Gem	Sch
Duplex.........A	1½–2	2,775	145	35x5p	38x7p	Hin	4	4x5¼	25.6	pu	Stm	35.0	bat	Wes	Wes	Wes	Cvt	Cvt	3	Shl	6	w	Ros	MWC
Duty...........	2	......	134	*	*	Gray-B	4	3½x5	19.6	t	Zen	34.6	......	......	......	......	Cvt	......	....	......	....	......	......	......
Federal.......TE	1½–2	2,175	144	36x3½	36x5	Cont.	4	4⅛x5¼	27.2	pu	Zen	15.0	mag	Eis	Au-L.	Au-L.	BB	Det	4	Tim	8	w	Gem	Sch
G. M. C....K-41A	2	2,775	......	36x4	36x7	own	4	4x5½	25.6	t&pu	Mar	18.0	mag	Eis	Rem	Rem	own	own	7	Tim	7	w	own	own
Giant.........18	2	3,050	144	36x4	36x7	Cont.	4	4⅛x5¼	27.2	pu	Shb	13.8	mag	......	......	......	B-L.	B-L.	3	Tim	9	w	Ros	Wan
Hahn........DE	2	......	158	36x4	36x7	Cont.	4	4⅛x5¼	27.2	pu	Zn&Str.	....	......	Del	Del	Del	B-L.	B-L.	3	Tim	9	w	Ros	Sh Bim

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Indiana	20	2	....	150	36x4	36x7	own	4	4⅛x5½	27.2	pu	Stm	15.0	mag	Eis	Wes	Wes	BB	B-L	4	Shl	7	w	Woh	Day
International	41	2	2,100	129	36x3½	36x5	own	4	3½x5¼	19.6	pu	Ens	17.2	mag	B s	....	N.E.	own	B-L	4	own	9	i	own	own
Kimball	AB	2	3,675	136	36x4	36x7	Wis	4	4x6	25.6	pu	Mas	17.0	mag	Eis	Wes	Wes	B-L	B-L	4	Shl	6	w	Woh	Smi
Kimball	AC	2	3,975	158	36x4	36x8	Wis	4	4¼x6	28.9	pu	Mas	17.0	mag	Eis	Wes	Wes	B-L	B-L	4	Shl	7	w	Woh	Smi
Kleiber		2	3,600	156	36x4	36x7	Cont	4	4⅛x5¼	27.2	pu	Stm	....	mag	....	....	....	B-L	B-L	4	Tim	8	w	Ros	Smi
Maccar	H-A	2	3,100	162	36x4	36x4d	Cont	4	4⅛x5¼	27.2	pu	Zen	19.5	mag	Eis	Bos	Bos	B-L	B-L	4	Tim	8	w	Ros	Day
Mack	AB	2	3,300	144	36x4	36x4d	own	4	4x5	25.6	pu	Shb	19.5	mag	Tea	L-N	L-N	own	own	4	own	6	ch	own	opt
Mack	AB	2	3,750	144	36x4	36x4d	own	4	4x5	25.6	pu	Shb	17.9	mag	Tea	L-N	L-N	own	own	4	own	7	bs	own	opt
Mapleleaf	AA	2	4,150	144	36x4	36x7	Hin	4	4x5¼	25.6	pu	Stm	18.0	mag	Eis	Wes	Wes	Ful	Ful	4	Shl	8	w	Ros	Dom
Menominee	D	2	3,245	144	36x4	36x8	Wis	4	4x6	25.6	pu	Stm	16.5	mag	Eis	Bos	Bos	Dtl	Cot	3	Wis	8	w	Bos	....
Nash	2018	2	2,550	144	34x4	34x6	own	4	3¾x5¼	22.5	....	Stm	17.0	mag	Eis	Au-L.	Au-L.	BB	Det	4	Cla	....	i	Lav	....
Noble	C-40	2	2,675	160	36x4	36x7	Bud	4	4x5½	25.6	pu	Stm	15.0	mag	Eis	Wes	Wes	Ful	Ful	3	Shl	8	w	Lav	Bim
Oshkosh	A	2	....	136	36x6p	36x6p	HS	4	3½x5	19.6	t	Zen	21.0	bat	N.E.	N.E.	N.E.	Bli	Bli	4	own	8	stb	Ros	Roy
Packard	EC	2	3,500	144	36x3½	36x6	own	4	4³⁄₁₆x5½	28.0	pu	own	15.0	mag	Dix	Bij	Bij	own	own	4	own	7	w	own	own
Packard	EX	2	3,575	144	36x6p	40x8p	own	4	4³⁄₁₆x5½	28.0	....	own	27.0	mag	Dix	Bij	Bij	own	own	4	own	8	w	own	own
Patriot	Lincoln	2	2,050	140	34x3½	34x5	Hin	4	4x5¼	25.6	pu	Stm	....	mag	Spl	....	....	Cvt	Ful	4	Emp	7	w	Ros	Bim
Pierce Arrow	X-5	2	3,200	150	36x4	36x4d	own	4	4x5½	25.6	pu	Stm	18.0	bat	Del	Del	Del	Cvt	Cvt	4	Eat	9	w	Ros	Day
Power	F	2	....	140	36x6p	40x8p	Hin	4	4¼x5	28.9	pu	Zen	22.0	mag	Eis	Wes	Wes	Ful	Ful	4	Vul	7	w	Ros	StM
Rainier	R-18	2	2,890	147	34x4	34x6	Cont	4	4⅛x5¼	27.2	pu	Zen	16.0	mag	....	....	....	B-L	B-L	4	Shl	8	w	Ros	Jon
Schacht	F	2	3,200	156	36x4	36x7	Bud	4	4¼x5½	28.9	pu	Shb	15.0	mag	Bos	....	Wes	BB	own	4	own	8	w	own	StM
Schwartz	B2W	2	2,600	140	34x3½	34x6	Bud	4	3¾x5¼	22.5	pu	Stm	18.0	bat.mg.	Bos	....	G&D	Ful	Ful	4	Shl	8	w	Ros	Sch
Service	31	2	....	150	36x3½	36x6	Bud	4	4x5½	25.6	pu	Stm	....	mag	Eis	Wes	Wes	BB	B-L	4	Tim	....	w	Ros	....
Service	36	1½–2	....	158	36x6p	38x7p	Bud	4	4½x5½	32.4	pu	Stm	....	mag	Eis	Wes	Wes	BB	B-L	4	Tim	....	w	Ros	Bim
Sterling		2	3,085	142	36x4	36x6	own	4	4x5¾	25.6	pu	Zen	16.0	bat	Eis	....	G&D	B-L	B-L	4	Tim	7	w	Ros	Pru
Stoughton	D	2	2,800	140½	36x4	36x7	Her	4	4x5⅛	25.6	pu	Stm	....	mag	....	....	Wes	B-L	B-L	4	Shl	8	w	Ros	....
Sullivan	E	2	....	150	36x4	36x7	Bud	4	4¼x5½	28.9	pu	Stm	....	mag	Bos	....	....	B-L	B-L	4	Tim	7	w	Ros	Wan
Super Truck	40	2	....	156	36x6p	40x8p	Wau	4	3¾x5½	22.5	pu	Zen	13.4	mag	Bos	....	....	Ful	Ful	3	Wis	8	w	Lav	Pru
Triangle	C	2	2,700	147	36x4	36x6	Wau	4	3¾x5¼	22.5	pu	Stm	16.0	mag	Eis	N.E.	Eis	Ful	Ful	3	Cla	9	i	Gem	Nr. Roy.
Velie	46	1½–2	1,585	133	36x3½**	36x5**	Cont	4	3¾x5	22.5	....	Stm	18.0	....	Ber	....	....	BB	Dur	3	Tor	8	i	Ros	Bim
White	20	2	3,250	145½	36x4	36x4d	own	4	3¾x5⅛	22.5	pu	own	....	mag	....	....	....	own	own	4	own	....	bs	own	own
White	20-45	2	4,050	168	36x4*	36x7*	own	4	4¼x5¾	28.9	pu	own	....	mag	....	....	....	own	own	4	own	....	bs	own	own
Wichita	M	2	2,800	144	36x3½*	36x6*	Wau	4	3¾x5¼	22.5	pu	Stm	12.5	mag	Eis	N.E.	N.E.	own	B-L	4	Shl	8	w	Ros	Bim
Winther	49	2	3,250	147	34x4	34x4d	Wis	4	4x5	25.6	pu	Stm	17.0	mag	Eis	Wes	Eis	BB	B-L	4	Cla	8	i	Ros	Med

2½-Ton

Ace		2½	2,795	156	36x4	36x4d	Bud	4	4¼x5½	28.9	pu	Zen	16.0	mag	Eis	Wes	Wes	Ful	Ful	4	Tim	7	w	Ros	Sch
Acme	A	2–2½	....	148	36x4	36x7	Cont	4	4⅛x5¼	27.2	pu	Ray	17.5	mag	Eis	Day	Day	BB	Cot	4	Tim	9	w	Ros	Bim
Acme	AC	2½	....	156	36x4	36x7	Cont	4	4½x5½	32.4	pu	Zen	30.0	mag	Eis	Day	Day	BB	Cot	4	Tim	6	w	Ros	Bim
American	25	2½	3,350	158	36x4	36x4d	Wis	4	4x6	25.6	pu	Stm	18.0	mag	Apo	....	Wes	Dtl	Cot	4	Tho	8.66	w	Ros	Ind
Armleder	HW	2½	....	148	36x4*	36x7*	Bud*	4	4⅛x5½	27.2	pu	Zen	15.0	mag	Bos	Wes	Wes	B-L	B-L	4	Tim	9	w	Ros	StM
Atterbury	7CX	2½	3,175	153½	34x4	36x4d	Cont	4	4⅛x5¼	27.2	pu	Zen	15.0	....	Eis	....	....	B-L	B-L	4	Tim	9	w	Gem	Arc
Available	H2½	2½	3,160	152	36x4	36x8	Her	4	4x5⅛	25.6	pu	Stm	16.0	mag	Bos	Bos	Bos	B-L	B-L	4	Tim	8	w	Ros	StM
Bessemer	J-2	2½	2,595	158	36x4	36x4d	Cont	4	4⅛x5¼	27.2	pu	Stm	....	mag	Eis	....	Eis	BB	B-L	4	Tor	8	i	Ros	Sch
Clydesdale	65X	2½	3,450	....	36x4*	36x4d*	Cont	4	4⅛x5¼	27.2	pu	Zen	17.0	mag	Bos	Bos	Eis	B-L	B-L	4	Tim	8.50	w	Ros	Smi

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MAKE AND MODEL	CHASSIS			TIRES		ENGINE							ELECTRICAL EQUIPMENT				TRANSMISSION SYSTEM						STEERING GEAR	WHEELS
				SIZE							CARBURETER		IGNITION		STARTING	LIGHTING	CLUTCH	GEARSET		REAR AXLE				
	Tons Capacity	Price	Standard Wheelbase, Inches	Front	Rear	Make	Number of Cylinders	Bore and Stroke	S. A. E. Hp.	Water Circulation	Make	Truck M. P. H.	Current Source	Make	Make	Make	Make	Make	Forward Speeds	Make	Gear Reduction	Final Drive	Make	Make
2½-Ton CONTINUED																								
Clydesdale 65EX	2½	3,475		36x4*	36x4d*	Cont	4	4½x5½	32.4	pu	Zen	17.0	mag	Bos	Bos	Eis	B-L	B-L	4	Tim	8.50	w	Ros	Smi
Columbia G	2½		148	36x4	36x7	Hin	4	4x5¼	25.6	pu	Stm	14.0	mag	Dix	Wes	Wes	M&E	Cot	4	Rus	9	i	own	Det
Commerce 18	2½		149	36x6p	38x7p	Cont	4	4⅛x5¼	27.2	pu	Zen	30.0	mag	Eis	Bij	Eis	B-L	B-L	4	Tor	9	i	Jac	
Corbitt B22	2½	3,000	152	36x4	36x7	Cont	4	4⅛x5¼	27.2	pu	Stm	16.0	mag	Eis		Eis	B-L	B-L	4	Shl	8	w	Ros	Bim
Day-Elder D	2-2½	2,400	144	36x4	36x7	Cont	4	4⅛x5¼	27.2	pu	Zen	14.0		Eis	Wes	Eis	Cvt	Cvt	4	Shl	8	w	Gem	Jon
Dependable E	2½	2,950	165	36x4	36x7	Bud	4	4¼x5½	28.9	pu	Zen	16.0	mag	Spl			Ful	Ful	4	Wis	8	w	Ros	Bim
Federal UE	2-2½	2,425	156	36x4	36x4d	Cont	4	4⅛x5¼	27.2	pu	Zen	13.0	mag	Eis	Au-L	Au-L	BB	Det	4	Tim	9	w	Gem	Sch
Gary J	2½	4,250	148	36x4	36x7	Bud	4	4½x5½	32.4	pu	Mas	15.0	mag	Eis			Ful	Ful	4	Tim	8	w	Ros	
Hahn EE	2½		162	36x4	36x8	Cont	4	4½x5½	32.4	pu	St.-Zn			Del		Del	B-L	B-L	4	Tim	7	w	Ros	Sh,Bim
Hall	2½	3,275	156	36x4	36x4d	Cont	4	4⅛x5¼	27.2	pu	Zen	22.0	mag	Bs,Eis		Eis	B-L	B-L	4	Tim	7	w	Gem	Smi
Indiana 25	2½		156	36x4	36x8	own	4	4⅛x5½	27.2	pu	Stm	15.0	mag	Eis	Wes	Wes	B-L	B-L	4	Shl	8	w	Woh	Day
Kalamazoo H	2½	3,275	160	36x4	36x8	Wis	4	4x6	25.6	pu	Stm	15.0	mag	Bos	Dyn	Dyn	Ful	Ful	4	Shl	8	w	Ros	Smi
Kelly-S K-38	2½	3,250	150	36x4	36x4d	own	4	3¾x5¼	22.5	pu	Zen	16.0				Eis			3	Shl	8	w	Gem	
Kissel Freighter	2½		168	36x4	36x7	own	4	4½x5½	32.4	pu	Stm	12.0	mag				War	War	4	Tim	8	w	Ros	BL
Kleiber 2½	2½	3,950	160	36x5	36x8	Cont	4	4½x5½	32.4	pu	Stm		mag				B-L	B-L	4	Tim	8	w	Ros	BM
Koehler M	2½	3,175	165	36x4	36x7	Her	4	4x5⅛	25.6	pu	Zen	16.0	mag	Spl		Wes	B-L	B-L	4	Tim	9	w	Lav	
Larrabee K-4	2½	3,200	158	36x4	36x8	Cont	4	4⅛x5¼	27.2	pu	Zen	15.0	mag	Bos	Bos	Bos	B-L	B-L	4	Shl	8	w	Ros	BL
Mack A B Chain	2½	3,400	144	36x4	36x4d	own	4	4x5	25.6	pu	Shb	19.5	mag	Tea	L-N	L-N	own	own	4	own	6	ch	own	AB
Mack AB	2½	3,850	144	36x4	36x4d	own	4	4x5	25.6	pu	Shb	14.7	mag	Tea	L-N	L-N	own	own	4	own	9	BS	own	AB
Master W	2½	3,290	144	34x4	36x7	Bud	4	4¼x5½	28.9	pu	own	13.8	mag				Ful	Ful	4	Tim	8	w	Ros	BL
Master D	2½	3,540	144	34x4	36x7	Bud	4	4¼x5½	28.9	pu	own	13.8	mag				Ful	Ful	4	Wal	8	i	Ros	BL
Moreland 22C	2½	3,500	168	36x4	36x8	Cont	4	4½x5½	32.4		Mas	21.0		Spl			own	own	4	Tim		w	Ros	
Noble D50	2½	2,950	162	36x4	36x8	Bud	4	4¼x5½	28.9	pu	Stm	15.0	mag	Eis	Wes	Wes	Ful	Ful	4	Shl	8	w	Lav	B
Oneida C	2½	3,200	160	36x4**	36x8**	Hin	4	4x5¼	25.6	pu	Stm	22.0	mag	Bos*	Wes	Wes	Ful	Ful	4	Wis	8	w	Ros	BL
Oshkosh B	2½		146	38x7p	38x7p	Her	4	4x5⅛	25.6	pu	Stm	21.0	bat	N.E.	N.E.	N.E.	Bli	Bli	4	own	8	stb	Ros	Roy
Paige 54-20	2½	3,400	150	34x4	34x8	Hin	4	4¼x5½	28.9	pu	Stm	17.0	mag	Bos	Rem	Rem	B-L	B-L	4	Shl	8	w	Ros	Day
Rainier R-20	2½	3,550	165	34x4	34x7	Cont	4	4⅛x5¼	27.2	pu	Zen	16.0	mag				B-L	B-L	4	Tim	8	w	Ros	Jon.
Sanford W125	2½	3,350	174	36x4	36x4d	Cont	4	4⅛x5¼	27.2	pu	Stm	15.0	mag	Eis			BB	B-L	4	Shl	8	w	Ros	Hoo
Selden 2½-A	2½	†3.425	145	36x4	36x7	Cont	4	4⅛x5¼	27.2	pu	Stm	16.0	mag	Eis	N.E.	N.E.	B-L	B.L	4	Tim		w	Gem	Stan
Service 51	2½		160	36x4	36x7	Bud	4	4¼x5½	28.9	pu	Stm		mag	Eis	Wes	Wes	BB	B-L	4	Tim		w	Ros	Bim

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Standard 76	2½	2,800	140	36x4	36x7	Cont.	4	4⅛x5¼	27.2	pu	Stm	15.0					B-L	B-L	4	Tim	8	w	Ros	
Sterling 2½	2½	3,290	156	36x4	36x4d	own	4	4⅜x5¾	30.6	pu	Zen	15.0	bat	Eis		G&D	B-L	B-L	4	Tim	7	w	Ros	Pru
Super Truck 50	2½	3,300	156	36x4	36x8	Wis	4	4x6	25.6	pu	Zen	12.2	mag			Ves	Ful	Ful	4	Shl	8	w	Lav	Pru
Tiffin MW	2½	3,100	148	36x4	36x3½	Cont.	4	4⅛x5¼		pu	Shb	14	mag		Wes	Wes	Ful	Ful	4	Shl	8	w	Ros	Smi
Tower H	2½	3,200	146	36x4	36x8	Cont.	4	4⅛x5¼	27.2	pu	Stm	15.0		Eis			Ful	Ful		Tim		w	Ros	
Triangle B	2½	2,950	150	36x4	36x7	Wau	4	4x5¾	25.6	pu	Stm	16.0	mag	Eis		Spl	Ful	Ful	4	Cla	9	i	Gem	Nr, Roy
Union FW	2½		155	36x5	36x8	Wis	4	4x6	25.6	pu	Shb	15.0	mag	Eis	L-N	L-N	Ful	Ful	4	Wal	7	BS	Ros	Wal, Pr.
United BT	2½		171	36x4	36x7	Bud	4	4¼x5½	28.9	pu	Stm	15.0	mag	Eis		Rem	Ful	Ful	4	Shl	8	w	Lav	
Veteran A	2½	4,000	156	36x4	36x7	Bud	4	4¼x5½	28.9	pu	Zen	18.0	mag	Eis			BB	Cot	4	Shl	6	w	Ros	Smi
Veteran D	2–2½	4,400	156	36x4	36x7	Bud	4	4¼x5½	28.9	pu	Zen	18.0	mag	Eis			BB	Cot	4	Shl	7	w	Ros	Smi
Wichita R	2½	3,000	144	36x4**	36x7**	Wau	4	3¾x5¼	22.5	pu	Stm	12.0	mag	Eis	N.E.	N.E.	own	B-L	4	Shl	10	w	Ros	Day
Wichita RX	2½	3,600	160	36x4**	36x8**	Wau	4	4⅜x5¾	30.6	pu	Stm	12.0	mag	Eis	N.E.	N.E.	Hrt	B-L	4	Shl	8	w	Ros	Day
Wilcox Trux C	2½		150	36x4**	36x3½d*	own	4	4¼x5	28.9	pu	Stm						M&E	own		Wal		w	own	Smi
Wilson EA	2½	2,825	152	36x4	36x7	own	4	4⅛x5½		pu	Stm	15	mag		Eis	Eis	BB	Cot	4	Tim	7	w	Ros	
Winther 50	2½	3,995	110	36x6p	42x9p	Wis	4	4x6	25.6	pu	Mas	18.0	mag	Eis	Wes	Wes	Ful	B-L	4	Cla	8	i	Ros	own
Winther 450	2½	3,690	150	34x5	36x6	Wis	4	4x5	25.6	pu	Stm	13.0	mag	Eis	Wes	Eis	Ful	Ful	3	Cla	12	i	Lav	Med
3½-Ton																								
Acme C	3½		168	36x5	40x5d	Cont.	4	4½x5½	32.4	pu	Zen	13.5	mag	Eis	Day	Day	BB	Cot	4	Tim	10	w	Ros	Bim
American 40	4	4,275	158	36x5	36x5d	Wis	4	4½x6	32.4	pu	Stm	15.0	mag	Apo		Wes	Dtl	Cot	4	Wis	10	w	Lav	Ind
Armleder KW	3½		156	36x5***	36x5d***	Bud*	4	4½x6	32.4	pu	Zen	12.0	mag	Bos	Wes	Wes	B-L	B-L	4	Tim	10	w	Ros	St M
Atterbury 7DX	3½	3,975	167½	36x5	40x5d	Cont.	4	4½x5½	32.4	pu	Zen	14.0		Eis			B-L	B-L	4	Tim	10	w	Gem	Arc
Available H3½	3½	4,175	176	36x5	40x5d	Her	4	4½x5½	32.4	pu	Stm	14.0	mag	Bos	Bos	Bos	B-L	B-L	4	Tim	10	w	Ros	StM
Bessemer K-2	4	3,495	175	36x5	36x5d	Cont.	4	4½x5½	32.4	pu	Stm						BB	B-L	4	Tor	10	i	Ros	Smi
Brockway RT2	3½–4		175	36x5	36x10	Cont.	4	4½x5½	32.4	pu	Stm	20.0	mag	Eis	N.E	N.E	B-L	B-L	4	Tim	6	w	Gem	Smi
Brockway R4	3½		164	36x5	36x10	Cont.	4	4½x5½	32.4	pu	Stm	14.5	mag	Eis	N.E.	N.E.	B-L	B-L	4	Tim	7	w	Gem	Smi
Brockway KR2	3		160	36x4	36x8	Cont.	4	4⅛x5½	27.2	pu	Stm	21.0	mag	Eis	N.E	N.E	B-L	B-L	4	Tim	6	w	Gem	Hoo
Brockway K5	2½–3		153	36x4	36x8	Cont.	4	4⅛x5¼	27.2	pu	Stm	18 0	mag	Eis	N.E.	N.E.	B-L	B-L	4	Tim	7	w	Gem	Hoo
Clydesdale 90	3½	4,125	170	36x5	40x5d	Cont.	4	4½x5½	32.4	pu	Zen	16.0	mag	Bos	Bos.	Eis	B-L	B-L	4	Tim	10–	w	Ros	Smi
Corbitt R-22	3	3,200	158	36x4	36x8	Cont.	4	4½x5½	32.4	pu	Stm	15.0	mag	Eis		Eis	B-L	B-L	4	Shl	8	w	Ros	Bim
Corbitt A-22	3½–4	3,800	178	36x5	36x10	Cont.	4	4½x5½	32.4	pu	Stm	14.0	mag	Eis		Eis	B-L	B-L	4	Shl	11	w	Ros	Smi
Day-Elder C	2½–3	2,750	150	36x4	36x7	Bud	4	4¼x5½	28.9	pu	Zen	14.0	mag	Eis	Wes	Eis	Cvt	Cvt	4	Shl	8	w	Gem	Jon
Day-Elder F	3½–4	3,150	165	36x5	36x5d	Cont.	4	4½x5½	32.4	pu	Zen	12.0	mag	Eis		Eis	B-L	B-L	4	Shl	10	w	Gem	Jon
Denby 25	3	3,300	150	36x4	36x7	Cont.	4	4⅛x5¼	27.2		Stm	27.3	mag	Eis			Ful	Ful	4	Rus	9	i	Gem	Smi
Denby 27	4	4,200	170	36x5	36x10	Cont.	4	4½x5½	32.4	pu	Stm	32.4	mag	Eis			own	War	4	Cla	10	i	Ros	Smi
Diamond T K	3½	3,750	170	36x5	36x5d	Hin	4	4¼x5½	28.9	pu	Stm	13.0	mag	Bos	Wes	Bos	Cvt	Cvt	4	Tim	8	w	Gem	Smi
Duplex E	3½	4,250	130	36x8	36x8	Bud	4	4¼x5½	28.9	pu	Shb	15.0	mag				B-L	B-L	4	own	8	i	Woh	MWC
F. W. D B	3	4,200	124	36x6	36x6	Wis	4	4¾x5½	36.1	pu	Stm	16.0	mag	Ben	N.E	N.E	H-S	Cot	3	own	8	stb	Ros	Sch
Federal WE	3½–4	3,150	154	36x5	36x5d	Cont.	4	4½x5½	32.4	pu	Zen	12.0	mag	Eis			BB	War	4	Tim	10	w	Gem	Smi
G. M. C K-71	3½	3,950	163	36x5	40x5d	own	4	4½x6	32.4	pu, t.	Mar		mag	Eis	Rem	Rem	own	own	7	Tim	8	w	own	own
Gary K	3½	5,250	162	36x5	40x5d	Bud	4	4½x6	32.4	pu	Mas	12.0	mag				B-L	B-L	4	Tim	10	w	Ros	Smi
Giant 17	3½		176	36x5	36x5d	Cont.	4	4½x5½	32.4	pu	Stm	12.0	mag				B-L	B-L	4	Tim	10	w	Ros	Wan
Hahn F	3½		191	36x5	36x10	Cont.	4	4½x5½	32.4	pu	Stm		mg, bt.	Del	Del	Del	B-L	B-L	4	Tim	10	w	Ros	Sh, Bm
Hall	3½		144	36x5	36x5d	Cont.	4	4½x5½	32.4	pu	Zeni	18.0	mag	Eis, Bs			B-L	B-L	4	Tim	10	w	Gem	Smi
Indiana 35	3½		160	36x5	36x5d	own	4	4⅜x5½	30.6	pu	Stm	12.0	mag	Eis	Wes	Wes	BB	B-L	4	Shl		w	Woh	Day

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MAKE AND MODEL	CHASSIS			TIRES		ENGINE						Truck M. P. H.	ELECTRICAL EQUIPMENT				TRANSMISSION SYSTEM						STEERING GEAR	WHEELS
				SIZE							CARBURETER		IGNITION		STARTING	LIGHTING	CLUTCH	GEARSET		REAR AXLE				
	Tons Capacity	Price	Standard Wheelbase, Inches	Front	Rear	Make	Number of Cylinders	Bore and Stroke	S. A. E. Hp.	Water Circulation	Make		Current Source	Make	Make	Make	Make	Make	Forward Speeds	Make	Gear Reduction	Final Drive	Make	Make
3½-Ton CONTINUED																								
International...61	3	2,400	138½	34x4	36x6	own	4	4¼x5	28.9	t	Ens	15.1	mag	Dix	......	N.E.	own	B-L	4	own	9	i	own	own
Kalamazoo...K	3½	4,000	160	36x5	36x10	Wis	4	4¼x6	28.9	pu	Stm	12.0	mag	Bos	Dyn	Dyn	Ful	Ful	4	Shl	10	w	Ros	Smi
Kelly-Sp'gf'd K-41	3½	4,200	156	36x5	40x5d	own	4	4½x6½	32.4	pu	Zen	15.4	mag	......	......	Eis	......	......	....	Cla	10	i	......	......
Kimball...AK	3	4,500	172	36x5	36x10	Wis	4	4½x6	32.4	pu	Mas	16.0	mag	Spl	Wes	Wes	B-L	B-L	4	Shl	7	w	Woh	Smi
Kimball...AE	4	5,000	164	36x5	40x6d	Wis	4	4¾x6	36.1	pu	Zen	....	mag	Spl	Wes	Wes	B-L	B-L	4	Shl	8	w	Woh	Smi
Kissel H'vy Duty	3½	......	168	36x5	36x5d	own	4	4¼x5½	28.9	pu	Stm	12.0	mag	......	......	......	War	War	4	Shl	11	w	Ros	Smi
Kleiber...3½	3½	4,600	167	36x5	36x10	Cont	4	4½x5½	32.4	pu	Stm	....	mag	......	......	......	B-L	B-L	4	Tim	10	w	Ros	Smi
Koehler...F	3½	4,150	162	36x5	36x5d	Her	4	4½x5½	32.4	pu	Zen	14.0	mag	Spl	......	Wes	B-L	B-L	4	Tim	10	w	Lav	Dav
Larrabee...L-4	3½	4,000	160	36x5	36x5d	Cont	4	4½x5½	32.4	pu	Zen	13.0	mag	Bos	Bos	Bos	B-L	B-L	4	Shl	10	w	Ros	Smi
Maccar...M-A	4	4,200	186	36x5	36x5d	Cont	4	4¾x6	36.1	pu	Zen	16.5	mag	Eis	Bos	Bos	B-L	B-L	4	Tim	8	w	Ros	Day
Maccar...H-2	3	3,400	162	36x4	36x4d	Cont	4	4½x5½	32.4	pu	Zen	20.5	mag	Eis	Bos	Bos	B-L	B-L	4	Tim	7	w	Ros	Day
Mack...AC	3½	4,950	168	36x5	40x5d	own	4	5x6	40.0	pu	Shb	14.0	mag	Tea	L-N	L-N	own	own	3	own	8	ch	own	opt
Mapleleaf...BB	3	4,775	150	36x4	36x4d	Hin	4	4½x5½	32.4	pu	Stm	16.0	mag	Eis	Wes	Wes	Ful	Ful	4	Shl	8	w	Ros	Dom
Mapleleaf...CC	4	5,570	162	36x5	36x5d	Hin	4	4½x5½	32.4	pp	Stm	12.5	mag	Eis	Wes	Wes	Ful	Ful	4	Shl	10	w	Ros	Dom
Master...A	3½	4,190	158	36x5	40x5d	Bud	4	4½x6	32.4	pu	Mas	11.5	mag	......	......	......	B-L	B-L	4	Tim	10	w	Ros	Smi
Master...E	3½	4,640	158	36x5	40x5d	Bud	4	4½x6	32.4	pu	Mas	11.3	mag	......	......	......	B-L	B-L	4	Wal	10	i	Ros	Cla, Wal
Menominee...G	3½	4,270	160	36x5	36x10	Wis	4	4½x6	32.4	pu	Stm	12.8	mag	Eis	Bos	Bos	Det	Cot	4	Tim	10	w	Ros	Smi
Moreland...22H	3½	4,600	186	36x5	40x5d	Cont	4	4¾x6	36.1	......	Mas	21.0	......	Spl	......	......	own	own	4	Tim	....	w	Ros	Smi
Noble...E70	3½	3,800	182	36x5	36x10	Bud	4	4½x6	32.4	pu	Stm	12.0	mag	Eis	Wes	Wes	Ful	War	4	Shl	8	w	Lav	Bim
Oneida...D	3½	4,050	170	36x5	36x10	Hin	4	4½x5½	32.4	pu	Stm	18.0	mag	Wes	Wes	Wes	Ful	Ful	4	Tim	10	w	Ros	Smi
Packard...ED	3	4,100	156	36x5	36x5	own	4	4½x5½	32.4	pu	own	12.0	mag	Dix	Bij	Bij	own	own	4	own	9	w	own	own
Paige...51-18	3½	......	160	36x5	36x5d	Hin	4	4½x5½	32.4	pu	Stm	15.0	mag	Bos	Rem	Rem	B-L	B-L	4	Tim	10	w	Ros	own
Patriot Wash...	3	2,900	156	36x4**	36x7**	Hin	4	4½x5½	32.4	pu	Stm	....	mag	Spl	......	......	Cvt	Cvt	4	Wis	9	w	Ros	Bim
Pierce Arrow W-2	3½	4,350	162	36x5	36x5d	own	4	4½x6¾	32.4	pu	Stm	16.0	bat	Del	Del	Del	Cvt	own	4	own	8	w	Ros	Day
Power...C	3½	......	160	36x5cu	36x10cu	Hin	4	4½x5½	32.4	pu	Zen	14.5	mag	Eis	Wes	Wes	Ful	Ful	4	Wis	10	w	Ros	St.M
Rainier...R-15	3½	4,400	170	36x5	36x5d	Cont	4	4½x5½	32.4	pu	Zen	15.0	mag	Eis	......	......	B-L	B-L	4	Tim	10	w	Ros	Jon
Republic...20	3½	3,095	165	36x5	36x10	Cont	4	4½x5½	32.4	pu	Stm	12.0	mag	......	......	......	Ful	Ful	....	Tor	10	i	Jac	Smi
Sanford...135	3½	4,200	174	36x5	36x5d	Cont	4	4½x5½	32.4	pu	Stm	13.0	mag	Eis	......	......	BB	B-L	4	Shl	3	w	Ros	Hoo
Schacht...F	3	3,800	168	36x5	36x5d	Bud	4	4¼x5½	28.9	pu	Shb	15.0	mag	Bos	......	Wes	BB	own	4	own	9	w	own	StM
Schacht...E	4	4,200	168	36x5	40x6d	Bud	4	4½x6	32.4	pu	Shb	20.0	mag	Bos	......	Wes	BB	own	8	own	10	w	own	StM
Schwartz...C2W	3	3,200	150	36x4	36x8	Bud	4	4¼x5½	28.9	pu	Stm	16.0	mag	Bos	......	G&D	Ful	Ful	4	Shl	8	w	Ros	own
Selden...3½A	3½	4,175	162	36x5	36x10	Cont	4	4½x5½	32.4	pu	Stm	14.0	mag	Eis	......	N.E.	B-L	B-L	4	Tim	....	w	Gem	Stan
Service...71	3½	......	171	36x5	36x5d	Bud	4	4¼x5½	28.9	pu	Stm	....	mag	Eis	Wes	Wes	B-B	B-L	4	Tim	8	w	Ros	Stan

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Service........76	3½	......	171	36x5	36x5d	Bud	4	4½x6	32.4	pu	Stm	....	mag	Eis	Wes	Wes	B-B	B-L	4	Tim	7	w	Ros	Stan
Signal........M	3½	3,847	168	36x5	40x10	Cont	4	4½x5½	32.4	pu	Stm	12.0	mag	Eis	......	......	B-L	B-L	4	Tim	12	w	Ros	StM
Standard......66	4	3,600	160	36x5	36x10	Cont	4	4½x5½	32.4	pu	Stm	12.0	......	......	......	......	B-L	B-L	4	Tim	10	w	Gem	......
Sterling........	3½	4,325	162	36x5**	40x5d**	own	4	4½x6¼	32.4	pu	Zen	14.0	bat	Eis	......	Wes	Hel-S	own	3	Tim	8	w	Ros	Pru
Stoughton......F	3	3,600	158	36x5	36x5d	Her	4	4¼x5½	28.9	pu	Stm	....	mag	......	......	Wes	B-L	B-L	4	Shl	8	w	Ros	......
Sullivan.......H	3½	......	156	36x5	36x5d	Bud	4	4½x6	32.4	pu	Stm	14.0	mag	......	......	......	B-L	B-L	4	Tim	10	w	Ros	Wan
Super Truck...70	3½	4,300	164	36x5	40x5d	Wis		4¼x6	28.9	pu	Zen	11.6	mag	Bos	......	Ves	Ful	Ful	4	Shl	10	w	Ros	Smi
Tower........G	3½	4,100	165	36x5	36x10	Cont	4	4½x5½	32.4	pu	Stm	12.0	......	......	......	......	Ful	Ful	....	Tim	....	w	Ros	......
Union.......HW	4	4,650	174	36x6	40x12	Wis	4	4½x6	32.4	pu	Shb	15.0	mag	Eis	L-N	L-N	Ful	Ful	4	Wal	11	bs	Ros	Wal,Smi
							4																	
Tiffin........F35	3½	4,100	160	36x5	40x5	Cont.	4	4½x5½		pu	Stm	14	mag	......	Wes	Wes	Det	Cot	4	Shl	8	w	Ros	Smi
United.......CT	3½	......	157	36x5	36x5d	Bud	4	4¼x5½	28.9	pu	Stm	13.0	mag	Eis	......	Rem	Ful	Ful	4	Shl	10	w	Lav	......
United States...R	3	3,075	156	36x4	36x4d	Hin	4	4x5¼	25.6	pu	Stm	17.3	mag	Eis	Bos	Bos	B-L	B-L	4	Shl	8	w	Lav	Sch
United States...S	4	3,875	168	36x5	36x5d	Hin	4	4½x5½	32.4	pu	Stm	12.5	mag	Eis	Bos	Bos	B-L	B-L	4	Shl	10	w	Lav	Sch
Veteran.......H	3½-4	5,600	156	36x5	36x10	Bud	4	4½x6	32.4	pu	Zen	14.0	mag	Eis	......	......	BB	Cot	4	Shl	8	w	Ros	Smi
Vim..........23	3	3,950	175	36x5	36x5d	Her	4	4¼x5½	28.9	pu	Zen	14.0	mag	Spl	......	......	B-L	B-L	4	......	7	w	......	......
							4																	
White.........40	3½	4,200	174	36x5	40x5d	own		3¾x5¾	22.5	pu	own	....	mag	......	......	......	own	own	4	own	....	i	own	own
Wichita........O	3½	4,000	165	36x5	36x5d	Wau	4	4½x6¼	32.4	pu	Stm	9.0	mag	Eis	N.E.	N.E.	Har	B-L	4	Shl	11	w	Ros	Smi
Wilcox Trux....E	3½	......	162	36x5**	36x5d**	Bud	4	4½x6	32.4	pu	Stm	....	......	......	......	Wes	M&E	own	....	Wal	....	w	own	Smi
							4																	
Winther........70	3½	4,200	150	36x5	36x5d	Wis		4x6	25.6	pu	Mas	15.0	mag	Eis	Wes	Wes	BB	B-L	4	Cla	9	i	Ros	Cla
Wilson.........G	3½	3,615	160	36x5	36x5d	own	4	4½x5½	....	pu	Stm	15.0	mag	......	Eis	Eis	B&B	Cot	4	Tim	9	W	Rcs	......
Wolverine.......I	3½	......	186	36x5	36x10	Cont	4	4½x5½	32.4	pu	Stm	12.0	mag	Eis	Bos	Bos	Ful	Ful	4	Cla	10	i	Ros	Cla

5-Ton

Acme..........E	5	......	180	36x6	40x6d	Cont	4	4¾x6	36.1	pu	Ray	12.5	mag	Eis	......	Day	B&B	Cot	4	Tim	11	w	Ros	Smi
American.......50	5	4,500	174	36x5	36x5d	Wis	4	4½x6	32.4	pu	Stm	15.0	mag	Apo	......	West	Dtl	Cot	4	Thom	10	w	Ros	Ind
Atterbury.....8E	5	4,975	167½	36x5	40x6	Cont	4	4¾x6	36.1	pu	Zen	11.0	mag	Eis	......	Del	B-Li	B-L	4	Tim	11	w	Gem	Sta.
Autocar.....26-B	5	4,100	156	34x6	36x12	own	4	4¼x5½	28.9	pu	Stm	....	mag	......	......	......	own	own	4	own	8	bs	Ros	......
Autocar.....26-Y	5	......	120	34x6	36x12	own	4	4¼x5½	28.9	pu	Stm	....	mag	......	......	......	own	own	4	own	8	bs	Ros	......
Available.....H5	5	5,375	190	36x6	40x12	Her	4	5x6	40.0	pu	Stm	12.0	mag	Bos	Bos	Bos	B-L	B-L	4	Tim	11	w	Ros	Smi
Brockway.....T4	5-6	......	174	36x6	40x6d	Cont	4	4¾x6	36.1	pu	Stm	13.0	mag	Eis	N.E.	N.E.	B-L	B-L	4	Tim	10	w	Gem	Smi
Clydesdale..120B	5	4,500	176	36x6	40x6d	Cont	4	4¾x6	36.1	pu	Stm	14.0	mag	Bos	Wes	Wes	B-L	B-L	4	Tim	11	w	Ros	Smi
Corbitt.....AA-22	5	4,500	178	36x6	40x6d	Cont	4	4¾x6	36.1	pu	Stm	12.0	mag	Eis	......	Eis	DTI	B-L	4	Shl	10	w	Ros	Smi
Day Elder......E	5-6	4,250	162	36x5	40x6d	Bud	4	4½x6	32.4	pu	Zen	10.0	mag	Eis	......	Eis	B-L	B-L	4	Shl	10	w	Gem	Jon
Denby.........210	5	4,500	170	36x6	40x12	Cont	4	4½x5½	32.4	pu	Stm	32.4	mag	Eis	......	......	own	War	4	Cla	12	i	Ros	Cla
Diamond-T...EL	5	4,325	180	36x6	40x6d	Hin	4	4½x5½	32.4	pu	Stm	12.0	mag	Bos	Wes	Bos	Cvt	Cvt	4	Tim	11	w	Gem	Smi
Diamond-T.....S	5	4,500	180	36x6	40x6d	Lib	4	4¾x6	36.1	pu	Stm	12.0	mag	Bos	Wes	Wes	B-L	B-L	4	Tim	11	w	Gem	Smi
Federal......X-2	5-6	4,500	163	36x6	40x6d	Cont	4	4¾x6	36.1	pu	Zen	12.0	mag	Eis	......	Au-L	B&B	War	4	Tim	10	w	Gem	Smi
G. M. C....K-101	5	4,350	167	36x5	40x6d	own	4	4½x6	32.4	pu	Mar	15.0	mag	Eis	Rem	Rem	own	own	7	Tim	10	w	own	own
Gary..........M	5	6,200	182	36x5	40x6d	own	4	5½x6½	48.4	pu	Mas	10.0	......	......	......	......	B-L	B-L	4	Tim	11	w	Ros	Smi
Hall............	5	5,100	144	36x5	40x6d	Cont	4	4½x5½	32.4	pu	Zen	15.0	mag	Es,Bs	......	Eis	B-L	B-L	4	Tim	15	w	Gem	Smi
Hall............	5-7	5,100	144	36x5	40x6d	Cont	4	4½x5½	32.4	pu	Zen	15.0	mag	Es,Bs	......	Eis	B-L	B-L	4	Tim	14	ch	Gem	Smi

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MAKE AND MODEL	CHASSIS			TIRES		ENGINE							ELECTRICAL EQUIPMENT				TRANSMISSION SYSTEM						STEERING GEAR	WHEELS
				SIZE							CARBURETER		IGNITION		STARTING	LIGHTING	CLUTCH	GEARSET		REAR AXLE				
	Tons Capacity	Price	Standard Wheelbase, Inches	Front	Rear	Make	Number of Cylinders	Bore and Stroke	S. A. E. Hp.	Water Circulation	Make	Truck M. P. H.	Current Source	Make	Make	Make	Make	Make	Forward Speeds	Make	Gear Reduction	Final Drive	Make	Make
5-Ton CONTINUED																								
Indiana 51	5		170	36x5	40x6d	Wau	4	5x6¼	40.0	pu	Stm	12.0	mag	Eis	Wes	Wes	B&B	B-L	4	Shl	10	w	Woh	Smi
International 101	5	3,600	160	36x5	40x10	own	4	4¼x5	28.9	t	Ens	14.0	mag	Dix		N.E.	own	B-L	4	own	11	i	own	own
Kalamazoo K-5	5	4,500	160	36x6	36x6d	Wis	4	4½x6	32.4	pu	Stm	12.0	mag	Bos	Dyn	Dyn	Ful	Ful	4	Shl	13	w	Ros	Smi
Kelly-S K-50	5	4,900	158	36x6	40x6d	own	4	4½x6½	32.4	pu	Zen	13.6	mag			Eis			4		12	ch		
Kelly-S K-60	6	5,100	158	36x6	40x7d	own	4	4½x6½	32.4	pu	Zen	13.6	mag			Eis			4		12	ch		
Kimball AF	5		164	36x6	40x7d	Wis	4	5x6	40.0	pu	Zen	12.0	mag	Spl	Wes	Wes	B-L	B-L	4	Shl	8	w	Woh	Smi
Kleiber	5	5,300	180	36x6	40x12	Bud	4	5x6½	40.0	pu	Stm		mag				B-L	B-L	4	Tim	11	w	Ros	Smi
Larrabee W	5	4,800	185	36x6	40x6d	Cont	4	4¾x6	36.1	pu	Zen	10.0	mag	Bos		Bos	B-L	B-L	4	Shl	10	w	Ros	Smi
Maccar G	5	4,950	186	36x5	40x6d	Cont	4	4¾x6	36.1	pu	Zen	13.5	mag	Eis	Bos	Bos	B-L	B-L	4	Tim	10	w	Ros	Smi
MacDonald A	7	5,750	180	40x7	40x14	Bud	4	4½x6	32.4	pu	Stm	10.0	mag				B-L	B-L	4	own	17	opt	own	own
Mack A B Trac	5	3,400	120	36x4	36x4d	own	4	4x5	25.6	pu	Shb	12.9	mag	Tea	L-N	L-N	own	own	4	own	10	ch	own	opt
Mack AC	5	5,500	168	36x6	40x6d	own	4	5x6	40.0	pu	Shb	13.2	mag	Tea	L-N	L-N	own	own	3	own	9	ch	own	opt
Mack AC	6½	5,750	168	36x6	40x12	own	4	5x6	40.0	pu	shb	11.3	mag	L-N	L-N	L-N	own	own	3	own	10	ch	own	opt
Mack AC Trac	7	4,950	119	36x5	40x5d	own	4	5x6	40.0	pu	Shb	11.1	mag	Tea	L-N	L-N	own	own	3	own	10	ch	own	opt
Mack AC	7½	6,000	168	36x7	40x7d	own	4	5x6	40.0	pu	Shb	10.3	mag	L-N	L-N	L-N	own	own	3	own	11	ch	own	opt
Mack AC Trac	10	5,500	119	36x7	40x6d	own	4	5x6	40.0	pu	Shb	10.3	mag	Tea	L-N	L-N	own	own	3	own	11	ch	own	opt
Mack AC Trac	13	5,750	119	36x6	40x12	own	4	5x6	40.0	pu	Shb	9.2	mag	L-N	L-N	L-N	own	own	3	own	12	ch	own	opt
Mack AC Trac	15	6,000	119	36x7	40x7d	own	4	5x6	40.0	pu	Shb	8.4	mag	L-N	L-N	L-N	own	own	3	own	14	ch	own	opt
Mapleleaf DD	5	6,490	160	36x6	40x6d	Hin	4	4½x5½	32.4	pu	Stm	11.0	mag	Eis	Wes	Wes	Ful	Ful	4	Shl	13	w	Ros	Smi
Master B	5	5,290	170	36x6	40x6d	Bud	4	4¾x6½	36.1	pu	own	9.4	mag				B-L	B-L	4	Tim	11	w	Ros	Smi
Master F	5	5,440	170	36x6	40x6d	Bud	4	4¾x6½	36.1	pu	own	9.5	mag				B-L	B-L	4	Wal	11	i	Ros	Wal, Cla.
Menominee J-3	5	5,450	160	36x6	40x12	Wis	4	4¾x6	36.1	pu	Stm	12.6	mag	Eis	Bos	Bos	Dtl	Cotta	4	Tim	11	w	Ros	Smi
Oneida E	5	4,725	180	36x5	40x12	Hin	4	4½x5½	32.4	pu	Stm	11.0	mag	Bos	Wes	Wes	Ful	Ful	4	Tim	11	w	Ros	Smi
Packard EF	5	4,500	156	36x6	40x6d	own	4	5x5½	40.0	pu	own	11.0	mag	Dix	Bij	Bij	own	own	4	own	10	w	Ros	own
Pierce A. R-10	5	4,850	168	36x5	40x6d	own	4	4½x6¾	32.4	pu	Stm	14.0	bat	Del	Del	Del	Cvt	own	4	own	10	w	Ros	Day
Rainier R-17	5	5,100	172$\frac{7}{16}$	36x6	40x6d	Cont	4	4¾x6	36.1	pu	Zen	15.0	mag	Eis			B-L	B-L	4	Tim	13	w	Ros	Smi
Sanford 150	5	5,100	174	36x5	36x6d	Cont	4	4½x5½	32.4	pu	Stm	11.0	mag	Eis			B&B	B-L	4	Shl	4	w	Ros	Smi
Schacht E	5	4,400	168	36x6	4x12	Bud	4	4½x6	32.4	pu	Shb	15.0	mag	Bos		Wes	B&B	own	8	own	14	w	own	StM
Schwartz DW	5		170	36x6	36x12	Bud	4	4½x6	32.4	pu	Stm	14.0	mag	Bos		G&D	Ful	Ful	4	Shl	10	w	Ros	Smi
Selden 5-A	5	5,600	164	36x5	40x12	Cont	4	4¾x6	36.1	pu	Stm	13.0	mag	Eis	N.E	N.E.	Dtl	B-L	4	Tim		w	Gem	Sta
Service 101	5		171½	36x6	40x6d	Bud	4	4½x6	32.4	pu	Stm		mag	Eis	Wes	Wes	B&B	B-L	4	Tim	10	w	Ros	Sta
Signal R	5	4,770	180	36x6	40x12	Cont	4	4¾x6	36.1	pu	Stm	12.0	mag	Eis			B-L	B-L	4	Tim	11	w	Ros	Smi
Standard 5K	5–6	4,400	164	36x6	40x12	Cont	4	4¾x6	36.1	pu	Stm	10.0					B-L	B-L	4	Tim	11	w	Gem	

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Sterling	5	4,950	168	36x6	40x6d	own.	4	5x6¼	40.0	pu	Zen	14.0	mag	Eis	....	Wes	Hels	own	3	Tim	8	w	Ros	Pru
Sterling	5	5,500	174	36x6	40x5d	own	4	5x6¼	40.0	pu	....	18.0	bat	Eis	....	Wes	Hels	own	6	own	7	ch	Ros	Smi
Sterling	7½	6,000	174	36x5	40x7d	own	4	5x6¼	40 0	pu	Zen	16½	bat	Eis	....	Wes	Hels	own	6	own	7	ch	Ros	Smi
Tiffin TU	5	4,800	168	36x6	40x6d	Cont	4	4¾x6		pu	Shb	12	mag		Wes	Wes	B&B	Cot		Shl	10	w	Ros	Smi
Super Truck 100	5	5,300	164	36x5	40x12	Wis	4	4¾x6	36.1	pu	Zen	11.6	mag	....	....	Ves	Ful	Ful	4	Shl	10	w	Ros	Smi
Union JW	6	5,800	167	36x6	40x14	Wis	4	5x6	40.0	pu	Kng	12.5	mag	Eis	L-N	L-N	Ful	Ful	4	Wal	10	bs	Ros	Smi
United States T	6	5,000	172	36x6	40x6d	Bud	4	4¾x6½	36.1	pu	Stm	11.0	mg,bt	Eis	Bos	Bos	B-L	B-L	4	Shl	10	w	Lav	Smi
Tiffin UN	6	5,000	168	36x6	40x12	Cont	4	4¾x6		pu	Shb	12	mag	....	Wes	Wes	B&B	Cct	4	Shl	10	w	Ros	Smi
White 45	5	4,500	174	36x6	40x6d	own	4	4¼x5¾	28 9	pu	own	....	mag	....	....	....	own	own	4	own	....	bs	own	own
Wichita S	5	5,000	165	36x6	40x6d	Wau	4	4½x6¼	32.4	pu	Stm	8.5	mag	Eis	N.E.	N.E.	Hrt	Sav	4	Sav	14	bs	Ros	own
Wilcox F	5	....	162	36x5	40x12	Bud	4	4¾x6½	36.1	pu	Stm	....	mag	....	....	....	M&E	own	....	Wal		w	own	Smi
Wilson H	5	4,520	160	36x6	40x6d	own	4	3¾x6	....	pu	Stm	....	mag	....	Eis	Eis	B&B	Cot	....	Tim	10	W	Ros	....
Winther 109	5	5,250	162	36x6	40x6d	Wis	4	4½x6	32.4	pu	Mas	12.0	mag	Eis	Wes	Wes	B&B	B-L	4	Cla	12	i	Ros	Cla
Winther 140	7	5,900	162	36x6	40x7d	Wis	4	5x6	40 0	pu	Mas	10 0	mag	Eis	Wes	Wes	B&B	B-L	4	Cla	12.0	i	Ros	Cla

ABBREVIATIONS

Types of Construction

- ***—Tires optional**
- ****—Pneumatics extra**
- *****—Pneumatics and cushions extra**
- **†—Price includes body**
- **bat**—storage battery
- **bs**—bevel spur
- **cu**—cushion
- **i**—internal gear
- **mag**—magneto
- **opt**—optional
- **p**—pneumatic
- **pu**—pump
- **sb**—Spiral bevel
- **stb**—straight bevel
- **t**—thermo-syphon
- **w**—worm

MAKERS OF PARTS

A-K—Atwater-Kent
Apo—Apollo

Arc—Archibald
Au-L—Auto-Lite
AuW—Auto Wheel

B&B—Borg & Beck
Bij—Bijur
Bim—Bimel
Ben—Bendix
Ber—Berling
B-L—Brown-Lipe
Bos—Bosch
Bud—Buda

Car—Carter
CAS—CAS Products
Cen—Central
Cla—Clark
Col—Columbia
Con—Connecticut
Cont—Continental
Cot—Cotta
Cvt—Covert

Day—Dayton
Del—Delco
Dela—Delaney
Det—Detroit
Dit—Ditwiler
Dix—Dixie
Dod—Dodge
Dtl—Detlaff
Dun—Dundore
Dur—Durston
Dyn—Dyneto

Eat—Eaton
Eis—Eismann
Ens—Ensign
E&O—Eberly & Oris
Ful—Fuller

GBS—Golden, Belknap & Swartz
G&D—Gray & Davis
Gem—Gemmer
G-L—Grant-Lees

Hay—Haynes
Hels—Hele Shaw
Her—Hercules
Hin—Hinkley
Hoo—Hoopes Bros.
Hrt—Hartford
HS—Herschell-Spillman

Ind—Indestructible
IrM—Iron Mountain

Jac—Jacox
John—Johnson
Jon—Jones

Kel—Kelsey
Kng—Kingston
KW—KW Ignition Co.

Lav—Lavine
LeR—LeRoi
Lib—Liberty
L-N—Leece-Neville
Lyc—Lycoming

Mar—Marvel
Mas—Master
McC—McCanna
M&E—Merchant & Evans
Mid—Midwest
Mon—Monarch
Mun—Muncie
MWC—Motor Wheel Corp.

N.E.—North East
N.—Northern

Pru—Prudden

Ray—Rayfield
Rem—Remy
Ros—Ross
Roy—Royer
Rus—Russel

Sag—Saginaw Products Co.
Sal—Salisbury
Sav—Savage
Sch—Schwartz
Shb—Shebler
Shl—Sheldon
Sim—Simplex
Smi—Smith
Spl—Splitdorf
Stan—Standard Parts Co.
StM—St. Mary
Stm—Stromberg
Stw—Stewart

Tea—Teagle
Til—Tillotson
Tim—Timken
Tor—Torbensen

Uni—Universal

Ves—Vesta

Wal—Walker
Wan—Wayne
War—Warner Corp.
Wau—Waukesha
Weid—Weidely
Wes—Westinghouse
Wis—Wisconsin
Woh—Wohlrab

Zen—Zenith

A TAXICAB

As an example of the construction of a taxicab we will use the Yellow Cab, as manufactured by the Yellow Cab Co. of Chicago, Ill.

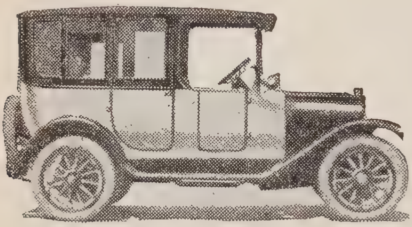


Fig. 129. The Yellow-Cab.

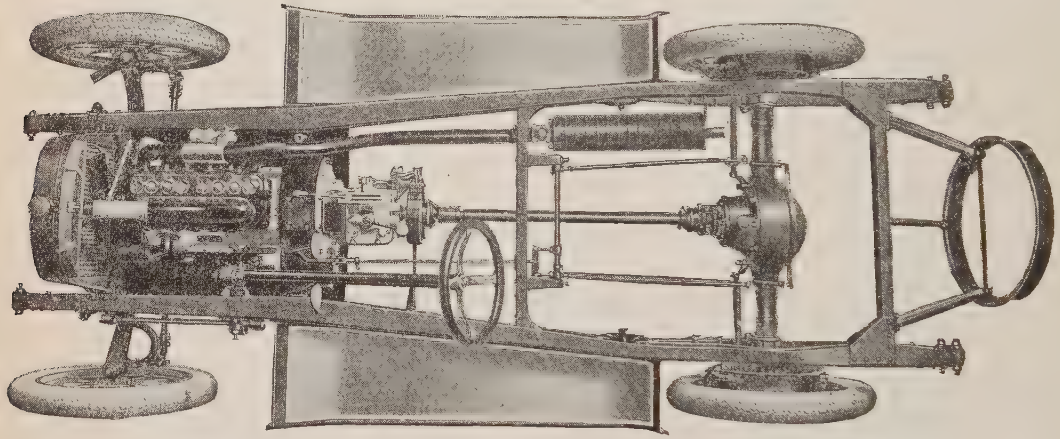


Fig. 130. Top view of chassis of the Yellow Cab, showing the location of parts.

Yellow-Cab Specifications

Engine: Continental Red Seal, similar to the Continental model "N" (see page 94); main-frame unit power plant construction, three-point suspension; four-cylinder, four-cycle, 3¾" bore, 5" stroke cylinders cast en bloc; valves all on one side, easily removed; valve stems, springs, and push rods enclosed, well lubricated, and free from cutting action of sand and dust; accessible by means of removable plate; spiral timing gears, under spring tension to overcome backlash; drop-forged connecting rods with bronze-backed bearings; crank shaft of special alloy, drop forged, and all bearings ground; self-contained constant-level oiling system, has oil-level indicator; average speed of the engine is 1,060 r.p.m.; average speed of car, 20 m.p.h., and will operate from 5 to 35 m.p.h.

Gasoline capacity: 10 gallons, gravity feed, tank under front seat.

Clutch: Brown-Lipe; multiple disk; Raybestos against steel plates; special radial-thrust ball bearing for clutch release; clutch housing integral with transmission case, and bolts to special flange on crank case, making unit power plant.

Transmission: Brown-Lipe; three-speed and reverse, nickel steel gears and shafts mounted on Timken roller bearings and annular ball bearings.

Universal joints: Spicer; double universal between transmission and rear axle, with slip joint to allow for spring action; each universal joint is enclosed in a steel case which is grease tight; drive is obtained through rear springs with spring saddles solid on rear axle, no torque arm or radius rods being used.

Front axle: Timken-Detroit, drop-forged I-beam section; extra heavy wheels mounted on Timken roller bearings.

Rear-axle: Timken-Detroit; semi-floating type, Timken roller bearings on shafts and differential; differential and main drive adjustable and easily removable; driving gears are of the helical bevel type; rear-axle ratio is 4 9/10 and 4 1/12.

Frame: Pressed steel; vertical section 6¼"; width of flange in front 1¾"; width of flange in widest part 3⅝"; tapering to 2⅛" at rear end.

Springs: Chrome vanadium steel; front, semi-elliptic, 2" wide, 36½" long, 8 leaves; rear, semi-elliptic, 2¼" wide, 53" long, 10 leaves; all springs, pins, or bolts of special steel; springs and spring hangers bronze bushed; Alemite system of lubrication used on spring bolts and all other parts of the car that require grease.

Cooling system: Thermo-syphon circulation; radiator of ample capacity to cool the motor under all weather conditions; radiator is mounted on trunnion supports cast integral with the front motor support.

Ignition: Bosch high-tension magneto; latest D.U.4 type with spark in fixed position.

Wheel base: 109"; 8½" road clearance.

Wheels: 1½" spokes; artillery type; 32" x 4"; rims demountable; straight side type.

Tires: 32" x 4" cord, non-skid all around.

Control: Levers for gear shift and emergency brake directly connected to transmission-case cover, giving center control; left-hand steer, no hand spark or throttle levers; spark is fixed and entire carburetor control by foot accelerator; entrance to front seats from either side.

Steering gear: Gemmer; worm-and-sector type; adjustment for lost motion.

Braking system: Service brakes external on rear wheels; brake bands 2½" wide and 15½" in diameter; emergency brake operates directly on gear set; brake band 2¼" wide and 8¼" in diameter.

Carburetor: Zenith model S-4; steering-post adjustment for starting; hot-air stove connection.

Equipment: Two cowl lights, search light, tail light, dome light, large lighting battery, Stewart-Warner hand horn, tire carrier, jack, jack handle, hub cap wrenches, rim wrench, and port plug wrench.

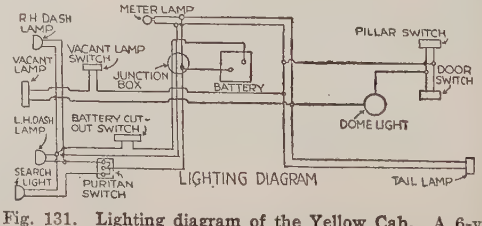


Fig. 131. **Lighting diagram of the Yellow Cab.** A 6-volt storage battery supplies current for lights, and a Bosch high-tension magneto supplies current for ignition. The "Puritan switch" is an ignition switch under the cowl. "Vacant lamp" denotes a lamp placed on the front center of the roof at the top of the wind shield, which shows whether the taxicab is occupied or vacant. "Pillar lights" denote lights placed on the rear door pillar in front of the rear door outside. The "meter lamp" is to light the meter.

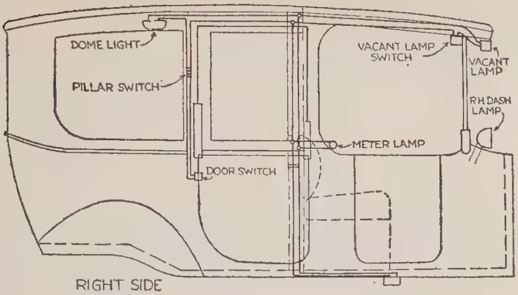


Fig. 132. Right side view of body and lighting connections.

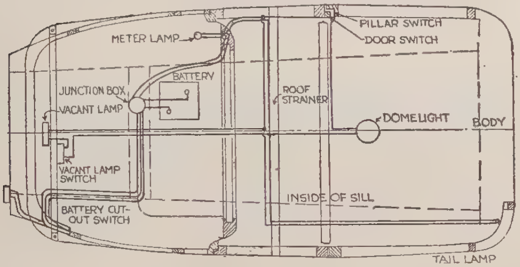


Fig. 133. Top view.

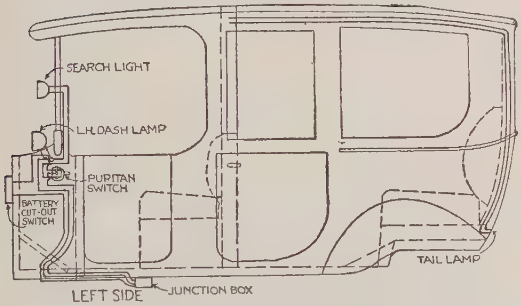


Fig. 134. Left side view of body and lighting connections.

Taxicab Rates

The rates given below are those of the Yellow Cab Co., of Chicago.

For One Passenger

For first one-half mile	$0.25
For each succeeding half-mile	.10
For each four minutes waiting	.10

Additional Passengers

Each additional passenger for entire trip	.20

Cabs by the Hour

Rate per hour	3.00

Time to start when cab is engaged.

Baggage

Hand baggage carried free—trunks, each	.20

"Extras" mean extra passengers.

There is no uniform price regarding the charging of extras, and the rates of fare in use throughout the United States are almost as many as there are cities in the United States.

Chicago has the lowest taxicab rates in the United States.

The most prevalent rates of fare throughout the United States are as follows:

30c. for first one-third mile or fraction thereof,

10c. for each succeeding one-third mile, or fraction thereof,

10c. for each four minutes of waiting time,

Extras, 20c., etc.

In some cities the taxicab companies haul two, three, or four passengers as cheaply as they do one, but the usual price charged is 20c. for each passenger over one.

A few years ago, a great many cities had ordinances requiring taxicabs to haul passengers to practically any place in the city at prices of 50c., 75c., or $1.00.

Today there are only four cities of 50,000 population, or more, that still adhere to this obsolete practice. Practically all the other cities in the United States now have ordinances requiring the use of meters on all taxicabs. The reason for this is obvious. All taxicab operation costs must be figured on a basis of so much per cab per mile.

The selling of transportation should be on the same basis.

In other words, figured on a cab-mile basis, this is equitable both to the passenger and to the taxicab operator.

It would certainly be illogical to do as was done in the past, namely, to charge the same amount whether the passenger rode ten yards or ten miles. It certainly is unfair to ask the short-distance passenger to pay an amount so great that he will be helping to pay for the distance traveled by the long-distance rider, who, in turn, pays too little.

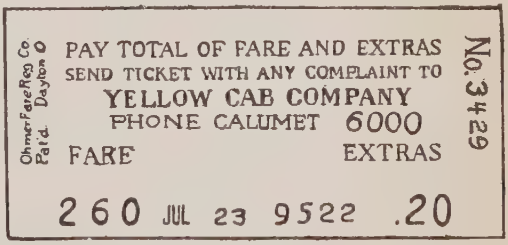
The Ohmer Taximeter as Used on the Yellow Cab

A taximeter is used on taxicabs for the purpose of keeping tab on the distance traversed and the cost per mile to a passenger.

When a car is standing, the meter is shown with the vacant sign standing upright and all dials at zero (Fig. 136).

The Ohmer printing taximeter, as it is termed, not only gives a visual indication of the fare due, but it also has two more **vitally important functions**, as follows:

1. It issues a ticket for the customer or passenger.
2. It keeps a printed record for the operating company's use.



Ohmer Fare Reg. Co.
Pat'd. Dayton O

PAY TOTAL OF FARE AND EXTRAS
SEND TICKET WITH ANY COMPLAINT TO
YELLOW CAB COMPANY
PHONE CALUMET 6000
FARE EXTRAS

No. 3429

260 JUL 23 9522 .20

Fig. 135. **An example of the receipt issued** is shown above The ticket as issued by the machine serves as an invoice to the customer to show him the amount of money that he owes for his ride. It also serves as a receipt in the hands of the customer showing that he has paid for his ride. The fare is shown on the left, and includes the money due for the mileage and also for any waiting time. The amount shown under "extras" includes any charge that is made for hauling baggage, extra passengers, etc.

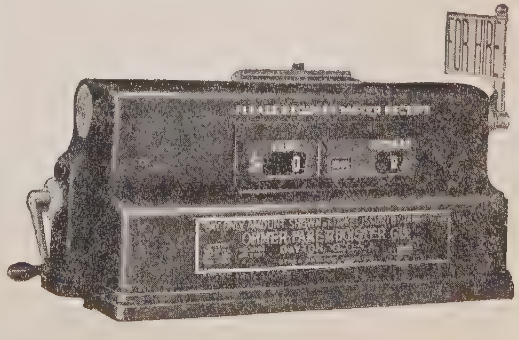


Fig. 136. The Ohmer taximeter with "For Hire" sign up, indicating that the taxicab is not engaged.

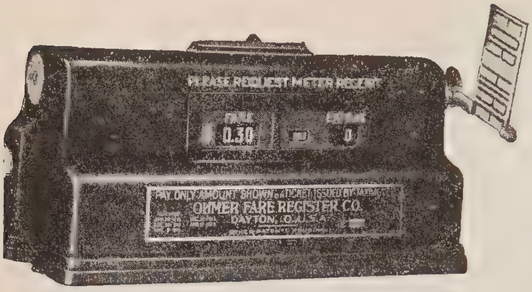


Fig. 137. The Ohmer taximeter flag in "Hired" position.

When the cab is hired, the meter flag is pulled from its "For Hire" position (Fig. 136) to the "Hired" position (Fig. 137), and the machine immediately starts computing. If the cab is running at a speed less than six miles per hour, or stops, the charges are computed on the basis of time consumed, but if a higher rate of speed is maintained, the machine automatically computes on the basis of the established mileage rates.

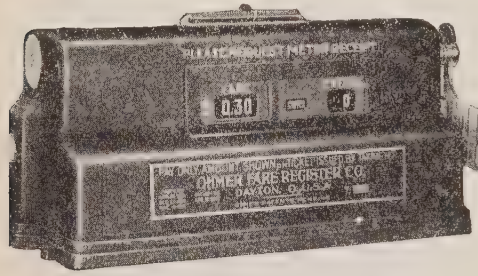


Fig. 138. Flag on "Non-recording" position.

If it is desired to set the meter so that no charge will be computed while the cab is stopped for accidents, tire repairs, engine troubles, etc., the flag is moved another quarter-turn to the non-recording position (Fig. 138). The time lost is recorded by the machine on the company's record, but no charge is made therefor. The flag can then be returned to the "Hired" position, but it can be moved to the "For Hire" position only by printing a ticket, or receipt, and the corresponding record, which is done by turning the crank, after first throwing the flag to the non-recording position.

It is, therefore, mechanically impossible for the driver, after having once put the meter in operation, to avoid making a complete printed record of the job.

Extras are recorded by turning the extras knob through one complete turn for each extra to be recorded.

Each driver is provided with a numbered identification key, which must be inserted in the machine before it can be operated, and which cannot be withdrawn until the flag has been turned to the "For Hire" position. This key prints the driver's number on the record each time a ticket is issued, so that there can be no question at any time as to the responsibility for each charge.

The address of the manufacturers of the Ohmer Taximeter is Ohmer Fare Register Co., Dayton, Ohio.

The Atco Taximeter

This taximeter is not used on the Yellow Cab, but is used on some of the other makes of taxicabs.

By way of illustration, we will explain the function of a taximeter recording as follows:

30 cents for the first half mile;
10 cents for each succeeding ¼ mile;
10 cents for each 4 minutes of waiting time;
20 cents for each extra passenger over one for the trip.

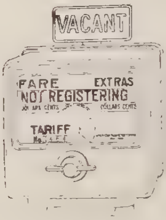


Fig. 139

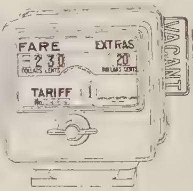


Fig. 140

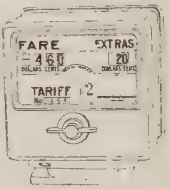


Fig. 141

When the vehicle is hired, the driver releases the flag lock and places the flag in its recording position (Fig. 140) at which time the figure 1 appears on the face of the meter under "tariff." At this time the initial fare, 30 cents, appears on the fare dial. From that minute the fare is accumulated for both distance and waiting time.

When two different rates are charged (such as another rate at 8 cents for each succeeding ¼ mile) a two-tariff meter must be used.

Where a two-tariff meter is used when the vehicle is hired, the driver releases the flag lock and places the flag in second tariff position (Fig. 141). In this position the flag is at the bottom of the meter (flag not shown), and the figure 2 appears on the face of the meter under "tariff." At this time the initial fare of 30 cents appears on the fare dial, and 8 cents will be charged up for each ¼ mile after a ½ mile.

Assuming that there is a second passenger, the driver operates the extra button for a complete turn, thereby recording one extra of 20 cents which appears on the dial under "extras" on the face of the meter.

For the 30 cents initial fare the passenger receives one ½ mile in distance, or 8 minutes of waiting time, or any proportion of either. After this, the fare mechanically changes to 40 cents, entitling the passenger to one ¼ mile of travel or 4 minutes of waiting time, or any proportion of either.

Every minute or fraction of a minute consumed by traffic stops, or when the cab is operating at a speed less than 4 miles per hour, deducts from the distance the passenger would ordinarily receive for the dime previously registered.

At the expiration of the trip, the driver places the flag in its "not recording" position, which stops the time clock. This prevents any additional fare recording while the passenger is paying the fare. Should the driver attempt to operate the cab with the flag in this position, money for distance is registered on both the front and rear of the meter, and all mileage records are recorded.

After the fare recorded on the face under "fare and extras" is collected, the flag is placed in the "vacant" or "upright" position (Fig. 139), by completing the circle through which it travels. When so placed, the flag locks itself and cannot be tampered with to the detriment of the driver, who would be held accountable at the rate of 30 cents for each time the flag is removed from its upright position. (Manufacturer is the American Taximeter Co., 16–24 W. Sixty-first St., New York, N.Y.)

INSTRUCTION No. 77

TRACTORS: Types; Engines; Kerosene as a Fuel; Fordson Tractor

The definition of the word "tractor" is "that which draws, or is used in drawing."

Fuel: The tractor was formerly propelled by a steam engine, but is now usually propelled by a gasoline engine, which uses gasoline or kerosene for fuel. Two methods of using either gasoline or kerosene are explained farther on.

The engine can be either a multiple cylinder, vertical, or of the horizontal opposed type. The **4-cylinder engine** is used quite extensively, and for the same reason as it is used on trucks. The engine varies in but a few details from that used on automobile passenger cars.

The tractor engine must stand continued running at at least three-quarter power for an aggregate of several hours steady work. Therefore the bearings and parts of the engine should be heavier, and capable of withstanding this strain.

The engine ignition is generally by means of a magneto and with an "impulse" starter, as explained farther on.

The governor is used, as the tractor engine does not vary in speed so much as an automobile engine. See Index under "Governors."

The drive systems differ, however; but the same underlying principles, such as clutches, jack shafts with differentials, etc., are employed, but of much heavier and larger design, as explained farther on.

We would advise the reader to send for catalogues of some of the leading tractor manufacturers. These catalogues will give information on the drive methods, and the instructions in this book on engines, ignition, etc., will give sufficient information on the engine. In this way one can gain a good working knowledge of tractors.

A leading concern who has agreed to send descriptive catalogues pertaining to tractors to our readers, is the Minneapolis Steel and Machinery Co., Minneapolis, Minn., manufacturers of the "Twin City" tractors. Some of the other tractor manufacturers are Holt Mfg. Co., Peoria, Ill.; C. L. Best Tractor Co., San Leandro, Cal.; Yuba Mfg. Co., 433 California St., San Francisco, Cal.

The addresses of some of the gas-engine magazines are: *Farm Machinery*, 1827 Prairie Ave., Chicago, Ill.; *Gas Engine*, Cincinnati, Ohio; *Gas Review*, Madison, Wis.; *Gas Power*, St. Joseph, Mich.; *Farm Machinery-Farm Power*, St. Louis, Mo.

What a Medium-Size Tractor Will Do

The medium-size, medium-priced tractor, operating under average conditions, will plow one acre 7 in. deep on 2½ gal. of gasoline and 1/5 gal. of lubricating oil. This, in brief, is the result of an extensive inquiry made by the United States Department of Agriculture, embracing data received from 200 tractor users in the corn belt in Illinois.

The information is given in bulletin No. 719 of the department, entitled "An Economic Study of the Farm Tractor in the Corn Belt," which includes information from the users of tractors of various sizes and on various sized farms.

Best Size of Tractor to Purchase

Belt work represents 50 per cent of the total work of a tractor. For belt work to be thoroughly efficient, the engine needs about the same power as is required for four plows, making the three and four-plow outfits the best sizes for general utility on the farm.

Another important conclusion drawn from the data collected indicates the size of tractor most suitable for a given size farm, and lays particular emphasis on the fact that the medium-size, medium-priced tractor "appears to have proven a profitable investment in a higher percentage of cases than any others." The sizes recommended for various sizes of farms are:

Acreage of Farm	No. Plows Handled
200 or less	3-plow
201-450	4-plow (3-plow second choice)
451-750	4-plow (5- and 8-plow second choice)

It is further noted that the smallest farm upon which the smallest tractor in common use—the 2-plow machine—may be expected to prove profitable, is one of 140 acres.

The bulletin further states that the **chief advantages of the tractor for farm work,** according to the operators, are: (1) its ability to do heavy work rapidly, thus covering the required average in the season; (2) the saving of man labor, and (3) the ability to plow to a good depth, particularly in hot weather. The **chief disadvantages** are put down as difficulty of efficient operation and packing of the soil when wet.

One significant fact brought out is that the purchase of a tractor seldom lowers the actual cost of conducting the farm, and that the purchase of the tractor usually must be justified by increased yield.

With regard to the number of days a tractor is used, the report gives figures which vary from 49 for the 2-plow machine to 70 for the 6-plow machine. Nearly 45 per cent of the tractor users report that they do custom work for others, which would seem to indicate that the tractor is too large to be kept busy on the home farm. The life of tractors, as estimated by their owners, varies from 6 seasons for the 2-plow machine to 10½ seasons for the 6-plow outfits.

Repairs Cost 4 Per Cent of Purchase Price

The longevity of the tractor brings up the question of repair expense, and in this connection the bulletin points out that though no accurate statistics are available on this, it would seem fair to count upon probably less than 4 per cent of the initial cost annually. This represents the average for farm machinery generally.

Under favorable conditions a 14-in. plow drawn by a tractor covers about 3 acres in an ordinary working day. Under unfavorable conditions, large gang plows will cover less ground per day per plow than will the small ones. Plows drawn by tractors do better work on the whole than do plows drawn by horses, the average depth in Illinois with tractors being 1½ in. greater than with horses. It is stated that the tractor displaces about one-fourth of the horses used on the average farm.

Power Required Depends upon the Soil

The resistance that soil offers to the passage of a plow bottom varies from 2 to 20 lbs. per square inch, depending upon the character of the soil.

This being so, a bottom which requires a pull of only about 400 lbs. at the draw bar to turn a furrow 14 in. wide and 6 in. deep, may require as great a pull as 850 lbs. in a soil of different constitution, or a maximum of nearly 1,700 lbs. in the most intractable soil.

Therefore the **power of the tractor** must be determined by the **character of the soil and the number of plows it pulls.** One should secure a soil map of his locality from his State Agricultural College and post himself on the relative condition of the soil in his neighborhood and the power required before purchasing a tractor.

What a Tractor Must Do

1. It must work efficiently after six years.
2. It must reduce horses to the minimum.
3. It must supplant horses.
4. It must cultivate row crops.
5. It must both plow and cultivate.
6. It must handle two plows under bad conditions and three under good conditions.
7. It must operate a 7- or 8-ft. binder at 2½ to 3 m.p.h.
8. It must have power to operate a road grader, a manure spreader, etc.
9. It must have belt power to operate any hay-baler or 24- to 28- in. threshing separator with a self-feeder and wind stacker; it must operate a corn sheller, a feed grinder, a sawmill, etc.
10. It must cost less than $1,000.
11. It must weigh less than 5,000 lbs., and be guaranteed one year.
12. All working parts must be in oil; it must be self-steering; it must have a direct drive for all speeds and a belt pulley, and speed enough for plowing and road work; with a low center of gravity.

Class of Work.	LIGHT WORK.	HEAVY WORK.
BELT WORK	Pumping, Washing, Cream Separating, etc.	Feed Grinding, Ensilage Cutting, Shelling, Shredding, Threshing, etc.
HAULING	Hauling People, Farm Produce, Merchandise, etc.	Hauling Grain, Building Material, etc.
FIELD WORK	Planting, Cultivating, Mowing, Raking, etc.	Plowing, Discing, Harrowing, Drilling, Harvesting, etc.

Tractor Designs

The following matter and illustrations, taken some time ago from *Motor Age*, will give a good general idea as to the variation in the design of tractors. See Fig. 1.

1. Four-wheel tractor design, with two large driving wheels in rear and two smaller steering wheels in front. The front wheels vary in diameter and also in tread. They are generally placed farther apart than shown.

2. Four-wheel tractor design, in which two front wheels are so close together as really to serve as a single wheel.

3. Three-wheel tractor design, with two large driving wheels and one steering wheel located at one side and in front. The diagram shows a two-cylinder engine.

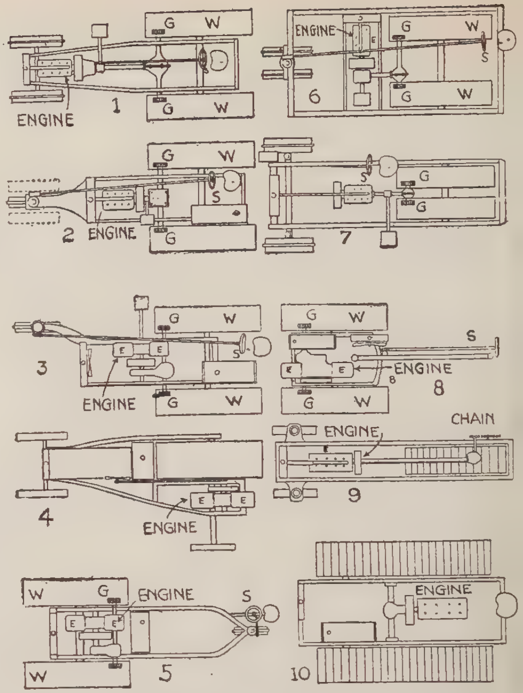


Fig. 1. Tractor designs: (E) is the engine; (G) gears driving internal gears in rim of tractor wheels; (W) tractor drive wheels; (S) steering.

4. Three-wheel tractor design, with a double steering wheel and one very large rear wheel for driving. There is a second rear wheel made quite small for balancing.

5. Three-wheel tractor design, using two large driving wheels and one very small wheel in the rear for steering.

6. Four-wheel tractor design, with large driving wheels in the rear and relatively small front wheels for steering. Note the cross-method of engine mounting.

7. Unusual tractor design, with two large steering wheels mounted very far apart and with two driving wheels placed very close together at the rear.

8. Two-wheel tractor design, to which can be coupled any piece of farm machinery. The entire power plant is mounted between the two driving wheels.

9. The combination wheel and caterpillar tractor, with a single caterpillar for driving in the rear and two steering wheels in front.

10. The short caterpillar using a caterpillar, or flat wheel construction, at each side. This design has been on the market for some time.

Tractor Drive Methods

For a tractor to travel over all kinds of roads, it is necessary that it lay its own track or road in many instances. Therefore some means of presenting a large surafce to the ground must be provided, on which the weight may be supported, to prevent sinking into soft soil. There are several methods employed, the most common being the **"flat-wheel tread,"** the **"chain tread,"** and the **"rail-track tread."**

The "flat-wheel tread" is the type used on the Ford and "Twin City" (page 984) and other light tractors. On some tractor wheels the **projecting treads are detachable** and can be removed, and deep or shallow treads may be applied according to the condition of the soil.

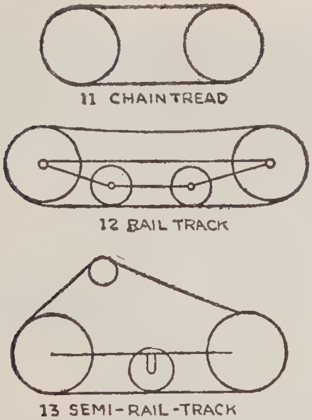


Fig. 2. Illustrations explaining the "chain tread," "rail-track tread" and "semi-rail-track tread."

The "chain tread" is furnished by stretching a movable chain of various constructions over and around two wheels, which has the effect of presenting considerable flat surface to the ground between the two points of support. The tread is made to move or crawl by driving the sprocket support wheels which have cogged teeth to engage cogged teeth on the inner face of the chain. See (11) Fig. 2.

This would be termed the chain tread, because the weight of the tractor is supported on the wheels with direct ground contact with the chain tread and minus the rail track.

The "rail-track tread" is represented by the Caterpillar and Cleveland. It differs widely in principle from that of the "flat wheel tread," and differs also from the chain tread in that a "rail track" is provided.

The point aimed at by the designers is to insure, not merely that the entire weight of the machine shall be evenly supported on the large surface of the chains, but that there shall be no arching of the chains, and that the wheels which do the driving shall carry little or no weight, while the wheels which carry the weight not only do no driving at all, but run on rails and are not affected by the pull of the chain. This result is secured in the following manner:

The weight of the tractor is supported on two axles or trucks, which carry, the one the driving or track sprocket wheel, and the other an idle wheel of similar size. The axles also support a beam or connecting bar beneath which are mounted a series of smaller idle or truck track wheels with smooth faces, formed to run on the rails or track.

The weight of the machine is carried on wheels which run on rails or track.

The chain itself, it will be noted (see Fig. 3), is driven by the track sprocket which is driven by the engine through a counter-shaft and gear transmission. As the chain tread (also called track link shoes) is made to revolve over the drive sprocket and track idler, the tractor, it will be noted, is really running on rails or a track, which are being laid down for the track wheels to revolve upon.

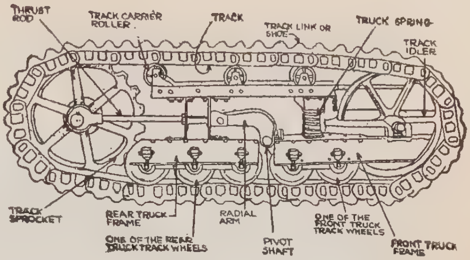


Fig. 3. **The track-laying portion of a Holt caterpillar.** The rear sprocket transmits the drive pulling on the portion of the chain which is lying flat on the ground. The weight of the tractor is carried by the 5-truck track wheels.

Although there are numerous methods of design employed for the construction of this chain or outer shoe, as it is termed, the principle is very much the same in all.

The difference, however, between the "chain tread" and the "rail-track" tread is made quite clear in the illustrations (11) and (12), Fig. 2.

Tractor Steering

When the three-wheel design is used, the third wheel is operated for steering.

Where four wheels are used, as on the Cleveland, for example, the steering-gear arrangement is as follows: a train of gears are operated by the steering wheel, and these in turn apply a brake to one side or the other of the axle. This slows up the crawler belt of one side of the machine, allowing the other to go ahead at a speed ratio corresponding to the resistance placed upon the opposite member by the brake pressure. When the brake is applied altogether, so that one belt or chain crawler is stopped, the reduction is 1½ to ½, or, in other words, 3 to 1, through the differential gears. The actual drive connection between the rear axle and the crawler wheel is by an internal gear. The emergency brake is applied against a band mounted on the outside of the differential drum.

The Transmission of Power

The transmission of power is usually from engine to clutch, thence to a gear transmission, thence to a countershaft, from which the drive sprocket is driven by a chain. On wheel-driven types there is often an internal gear drive in the wheel.

On several machines a regular truck gearset is employed with three ratios, this being coupled to a jackshaft incorporating a constant large reduction through a pair of spur gears. More than one machine is using a worm gear ahead of the last spur train, so that the worm speed is the same as that of the crank shaft on high gear. There are usually two or three speeds plus a reversing gear, which allows the different ratios to be used ahead or astern.

Clutches: Many are still using the old-style expanding or band clutch. The cone or disk clutch is coming into favor.

A clutch lever for throwing out the clutch is used more than a clutch pedal; however, many are now adding the clutch foot pedal.

A typical example of a "flat-wheel tread," light tractor transmission system is shown in Fig. 4, which is the "Twin City 16."

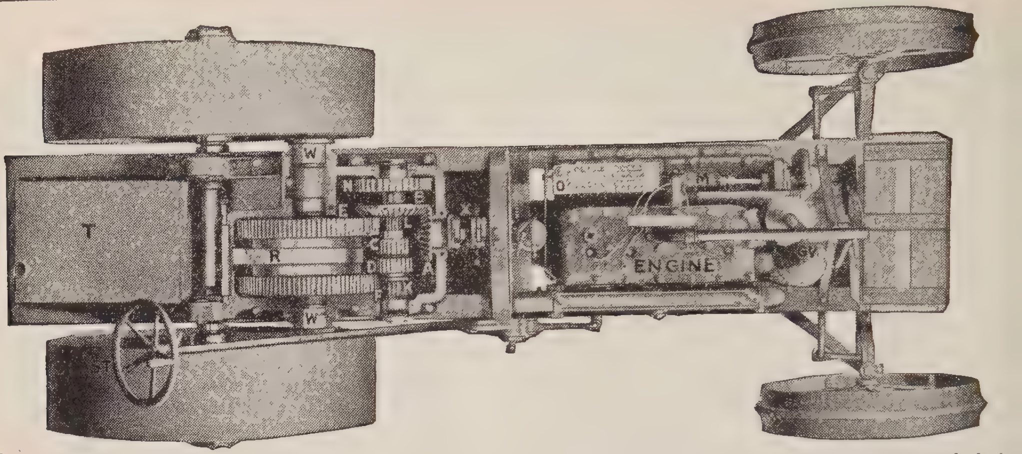


Fig. 4. **(R) is a band brake** around the drum which contains the **differential gears**. **Belt power** is obtained by a shaft (no shown) above and forward, driven from gear **(N)**.

The clutch is the contracting band type which fits over the projecting rim (C) on the flywheel (Fig. 9, page 986). It i operated from the seat by shifting the clutch yoke **(X)** above.

For high speed (2¾ m.p.h.), the power is transmitted through gear **(A)**, then through **(B)**, through sliding gear **(D)** to **(F** thence to the bull pinions on the end of shafts **(W)**, which drives the internal gear in the wheels.

For low speed (2 m.p.h.), sliding pinion **(C)** meshes with **(E)**.

For reverse (2¾ m.p.h.), power is delivered from **(D)** to **(F)** through a floating pinion mounted in the upper half of the trans mission (not shown). The floating pinion is also a sliding pinion, so that when in neutral position it is slid out of mesh wi gear **(F)**, but continues to run idle with pinion **(D)** when in neutral—the position in which **(D)** is now in the illustration.

The Cleveland Tractor

It weighs 2,750 lbs. and is characterized by its small size, being but 52″ long by 50″ wide. It is rated at 12 h.p. at the drawbar and at 20 h.p. at the pulley, and with its crawler or creeping type of tread, 600 sq. in. of traction surface are provided. The overall length of the tractor is 96″.

As may be seen from the illustration (Fig. 5), the powerplant is set well back toward the center of the crawler drive; thus the traction surface carries the weight well toward its center, so that a maximum tractive effort can be secured. The radiator, which is at the front of the tractor, is the only part projecting forward of the driving wheels, and at the rear the driver is seated slightly behind the rear axle.

The frame of the tractor is made up of two side bars mounted on trunnions at the rear axle, and the crank-case transmission and rear axle housings also have their value as structural supports. The effect of the three-point suspension is secured by having the rear connections of the side bars mounted on trunnions, and in front these are connected with the cross-spring by shackles. This gives a flexible drive which allows the tractor to work at an advantage on unequal stretches of ground.

The engine is a Buda model "R," 3½″ by 5¼″. The characteristics of this engine are such that with the gear ratio used on the tractor, an efficient working speed is obtained at 3½ m.p.h., with a maximum working speed of 4 m.p.h. The revolutions per minute of the engine are 1,450 at 4 m.p.h. and 1,272 at 3½ m.p.h.

From the engine the drive is transmitted through a Borg & Beck dry-plate clutch to a transmission unit developed by the Cleveland Tractor Co., provided with one speed forward and one reverse. The reduction is 25 to 1 in either case. From this unit the drive is transmitted through bevel gears to the axle, which transmits the torque to the crawler mechanism. The belt pulley is 8″ in diameter and has a 6″ face. The width of the track is 6″, and the length, 50″, giving 300 sq. in. of tractio surface on each side of the machine.

The carburetor is a Kingston, fitted with a Ben nett air washer, the magneto an Eisemann, an the radiator a built-up cellular type. The gasolin tank is mounted just behind the engine and forwar of the steering wheel, the latter being mounte upon a vertical steering post with the driver seate on a support mounted at the end of a flat stee bracket which acts as a spring.

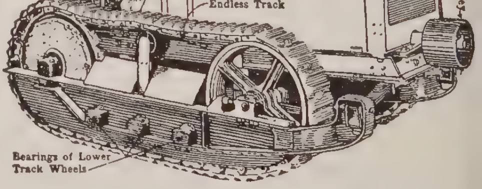


Fig. 5. **The Cleveland light tractor:** Drive, "rail-track also termed the "crawler" principle of drive. Note the pull in front for belt-power use; also note that the driving sprock is in the rear.

The Caterpillar Type of Tractor

Drive: Typical "rail-track." The drive sprock is driven by chains from a countershaft which driven by a gear transmission and clutch.

Engine: Six-cylinder; **vacuum fuel feed** (method employed. Gasoline or kerosene is use the fuel tank is **(T)**. A mechanical oiler **(O)** is use

Ignition by K. W. magneto **(J)**. A throttli type of governor for controlling the speed of t engine through the carburetor is employed. In fact, the principle of operation of the engine is similar to that of an automobile engine. Access to the crank case is through the hand-hole plates (L).

Steering by wheel **(S)** which operates wheel **(W)**.

Radiator is at **(R)**.

Spark and throttle control **(C)**

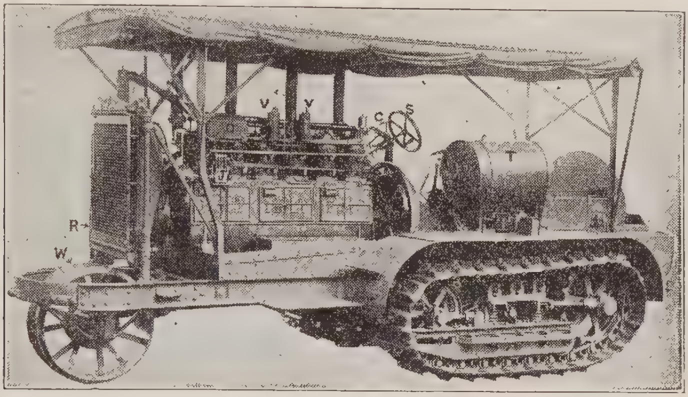


Fig. 6. The Caterpillar type of tractor. The drive is of the "rail-track" type.

TRACTOR ENGINES AND IGNITION

The type of engine used on tractors, as previously stated, differs from the regular automobile engine only in a few details. It is constructed heavier, with larger bearings. It runs at a constant speed most of the time; therefore greater heat is developed, and more cooling surface is necessary. A governor is employed. Engines for tractor use are usually of the four-cylinder or double-cylinder opposed type. The average compression of a truck or tractor engine is 60 to 70 lbs. It has usually a long stroke and slower speed, and operates either on gasoline or kerosene. Many of these engines have cylinders which are fitted with sleeves.

Tractor Engine Ignition

The **magneto** is generally used with an impulse starter. The **spark plugs** on a tractor engine must be the very best, as the tractor engine, unlike an automobile engine, runs for long periods of time at full power, and the use of low grades of fuel means higher temperature, and consequently more carbon.

K. W. Magneto

The K. W. magnetos are used on tractor engines quite extensively, and we shall therefore use this type as an example.

Model H (4 magnets): For engines having normal speed greater than 300 r.p.m., and which have provision for starting or can be cranked at a fair speed by hand.

Model HK (4 magnets): For use on engines the same as model "H," but has the impulse starter for hot starting spark.

Model HT (5 magnets): For use on engines having normal speed of less than 300 r.p.m., and which have provision for starting with air, etc., and will furnish a hot spark as low as 30 r.p.m., and will fire any sort of fuel.

Model HTK (5 magnets): For use on engines the same as model "HT," but the impulse starter allows the engine to be started by hand if the air supply is lost; or for use on large engines which previously had to be started with battery ignition.

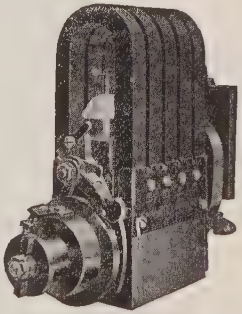


Fig. 7. The K. W. high-tension magneto, model "HTK" with impulse starter.

K. W. Impulse Starter

This attachment allows the engine to be started regardless of cranking speed, as the rotor of the magneto (inductor type) is held stationary while the coupling is moving 80°, then it is tripped and thrown ahead at the rate of 500 r.p.m., assuring a very hot spark for starting. When the engine comes up to speed, the starting device is automatically thrown out of action, and simply revolves with the shaft. See also page 281.

To time with an impulse starter: (1) place the piston 3° to 5° past top center on the power stroke; (2) mount and connect the magneto so that the tripping mechanism will not trip the impulse starting device until the engine is from 3° to 5° past dead center on the firing stroke.

In starting up the engine, place the circuit-breaker in full retard position and press down on the ratchet catch lock (ST-14) (Fig. 8) next page, which releases ratchet catch (ST-13) and allows it to engage with the notch in the ratchet (ST-6).

The ratchet (ST-6) will now be held stationary until the drive shaft has turned about 80°. This will bring the engine from 3° to 5° past the firing center, at which time the trip cam (ST-11) is in such a position as to disengage the ratchet catch

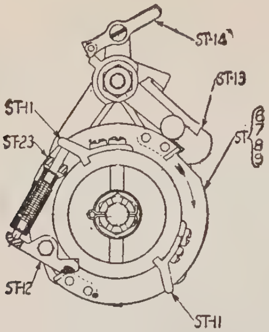


Fig. 8. **The K. W. impulse starter** is located between the magneto drive and the armature. When the engine is cranked, the armature is held stationary, while energy is being stored in the compression spring, which is then tripped.

(ST-13), thus allowing the magneto rotor to fly forward at a high rate of speed, creating a hot spark in the cylinder under compression, thus firing the engine, no matter how slowly the flywheel is turned over.

If these instructions are not clear, then put th ratchet catch (ST-13) out of engagement, and tim the magneto as usual. See Index under "Timin K. W. Magneto."

Example of a Tractor Engine

The engine illustrated in Figs. 9 and 10 is tha of the Twin City tractor engine, as used on the ligh duty tractor (Fig. 4)

Carburetion: Gasoline to start on and kerosen alcohol, distillates of 42° Baume or higher, and flas point of not over 120° F.

Fuel tanks: Kerosene, 33-gallon; gasoline, 3-ga lon. A Stewart vacuum system is used.

Cylinders: 4, L-type, 5″ bore x 7½″ stroke.

Speed of engine, 650 to 750 r.p.m.

Valves, on the side.

Ignition, K. W., magneto model "TK," enclos type.

See also page 938 for the Waukesha engine.

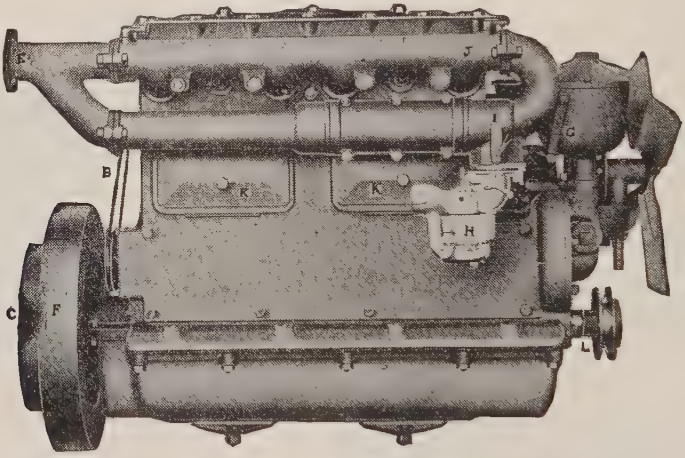


Fig. 9. **Valve, exhaust and inlet side:** (C) clutch member on flywheel (F); (K) valve covers; (H) carburetor; (I) inlet manif around one branch of exhaust manifold which heats mixture; (J-E) exhaust manifold; (G) governor—the lever operates butterfly valve in the carburetor; (L) fan belt pulley.

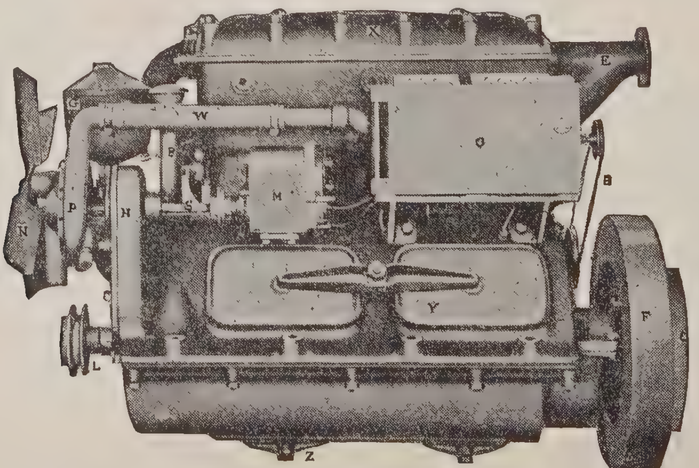


Fig. 10. **Magneto and lubricating side:** (M) magneto, K W. high-tension; (S) shaft driving magneto, which is driven by in gear case (H); (O) force feed lubricator driven by belt (B) (see page 157 for the "mechanical type") (P) water pu (R) breather pipe; (Y) hand-hole plates to reach bearings, and through which pistons and connecting rods can be remo (G) governor, "fly-ball" or "centrifugal" type.

CARBURETION FOR TRACTOR ENGINES

As previously stated, many tractor engines use gasoline to start on and kerosene to run on. Very few tractors operate on kerosene alone with any degree of satisfaction. It is practically impossible to start an electrically ignited engine with kerosene when the engine is cold. Kerosene does not give off vapor until heated nearly to the boiling point of water—it must be heated and kept heated, otherwise it will condense.

Kerosene needs more than a heated carburetor—the mixture itself must be heated to prevent condensation in the manifold.

The consequences attending the use of kerosene and the resulting condensation are described by a manufacturer as follows: "If kerosene is used, it will be absolutely necessary that the oil in the crank case of the engine be changed after every 20 hours of running." This is due to the fact that the kerosene condenses if not properly heated, and mixes with the lubricating oil and thins it down to such an extent that it loses its lubricating qualities.

Experiments conducted by the Holley Co. bear out the fact that once the kerosene has been thoroughly vaporized (heated) and mixed with a sufficient quantity of air to take the vapor by means of heat applied in the proper manner, it is possible to carry the charge several feet without experiencing condensation.

When the engine smokes excessively from the exhaust, and the smoke is black, this indicates that the fuel is not being properly combusted, either as a result of feeding too great a quantity at the carburetor or of not being properly vaporized.

Examples of gasoline-kerosene carburetors are given below.

Schebler Kerosene Carburetor—Single Type

Schebler model "D" (single) carburetor: The successful use of kerosene is not a problem of the carburetor alone, but involves both the carburetor and a proper design of the engine.

It is absolutely necessary, and must be understood, that kerosene can be burned only with the application of the proper amount of heat.

It is also advisable on some sizes of engines to heat the incoming air to the carburetor, and we find that it is rarely the case that too much heat can be applied to the air supply.

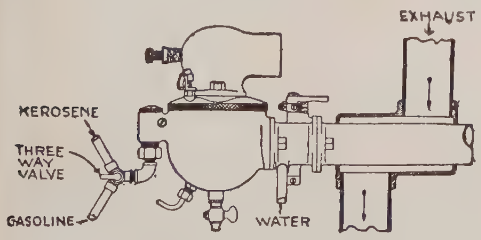


Fig. 11. The Schebler model "D" "single" carburetor, with special water throttle for use with kerosene on tractors and stationary engines.

The intake manifold must be kept as hot as possible, preferably by the exhaust heat, for if heat is not applied, there will be a precipitation on the walls of the manifold.

Heat on the manifold is necessary for two reasons: First, to aid evaporation of the heavier parts of the fuel; second to neutralize the refrigeration produced by the evaporation, so that the incoming charge of gas introduced into the engine is in an intimate mixture and at a uniform temperature.

Note. **Refrigeration** is caused by the fact that as the fuel is drawn through the inner pipe, heat is required to evaporate it; consequently heat is drawn from the pipe, leaving it cold. Evaporation then stops. For this reason extra heating is supplied.

Users of kerosene have always found it advisable to use water to prevent pounding under heavy loads. Moreover, water injection prevents excessive deposits of carbon. In this water or kerosene throttle attachment, there is a small hole in the carburetor side of the throttle, through which may be introduced a stream of water controlled by any suitable type of needle valve. While the engine is pulling a load, this needle valve, which controls the supply of water from any suitable source, should be opened only sufficiently to remove the pound. When the engine is stopped, the water must be shut off. The engine must be started and warmed up on gasoline, and can then be switched over to kerosene.

Kingston Dual Carburetor

The Kingston dual carburetor was designed for handling kerosene and some of the lower grade distillates.

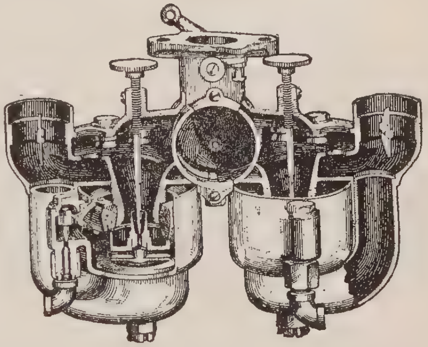


Fig. 12. Kingston dual carburetor for use with two kinds of fuel.

In construction, it is a dual combination of the well-known "Kingston enclosed-type model," one side being adapted for the use of **kerosene** or distillates, the other for **gasoline,** which may be used for starting or continuous running, as the operator may choose, either unit being brought into communication with the manifold and motor through the agency of an integral three-way valve. Both units are subject to individual adjustments, therefore may be operated on either fuel.

Switching from one fuel to the other is accomplished by means of a single lever, which may be connected to a point convenient to the operator.

Should water be required, the small valve shown in Fig. 13 may be used with good results, and is very simple, having but one adjustment which controls the amount of water admitted to the mixture.

It is entirely automatic, admitting water only when needed.

In operation, the engine is started on gasoline and is allowed to warm up sufficiently to permit of kerosene or distillate being used, at which time the fuel switch or three-way valve (31) (Fig. 13) is turned to its corresponding position. Should the engine fail to maintain its cycle (due to lack of sufficient heat having been generated), the switch should be immediately returned to the gasoline side and more time allowed for the warming period. With sufficient heating facilities this should not exceed three or four minutes.

The following installation is recommended:

Pre-heated air to the intake of each carburetor.

The kerosene side requires a much higher temperature than the gasoline side; therefore the collector around the exhaust manifold should be liberal. Care should be taken to provide openings totaling at least one and one-half times the area of the carburetor intake, and should be so located that the greatest amount of air shall pass over the heated surface of the exhaust manifold.

Exhaust jacketing the intake manifold throughout its entire length, if possible, or at least a generous portion leading from the carburetor, including the first bends.

Applying heat directly to the fuel line near the carburetor assists materially.

The temperature of the fuel in the bowl should not, however, exceed 100° F.

Action and Principle of Kingston Dual Carburetor

Fuel is admitted into the cup at fuel connection (**A**) and continues to flow until valve (**B**) is seated, owing to the buoyant action of float (**C**).

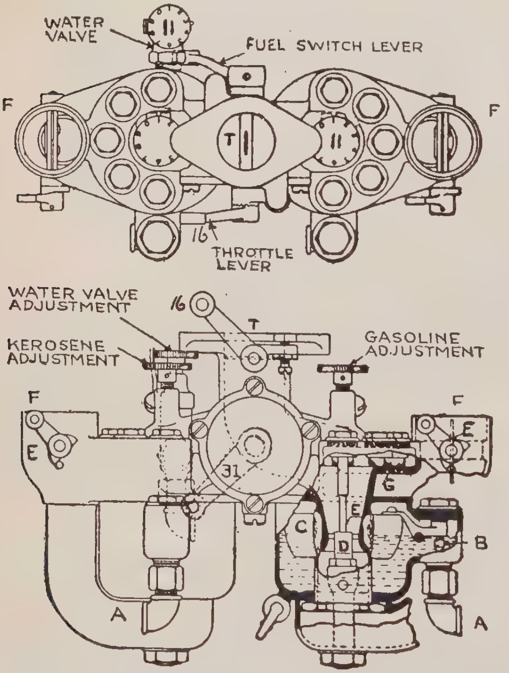


Fig. 13. Top and side sectional views of the Kingston dual carburetor.

Attention is particularly called to the shape of spray nozzle (**D**), which forms a cup around needle valve (**E**) above its seat, the fuel level being 1/16″ below its top.

For starting, this excess of fuel is drawn up with the constant air, and furnishes a very rich charge for starting.

At higher speeds this cup becomes empty; the supply is then drawn from and regulated by the adjustment of needle valve (**E**) at its seat.

Both **constant and auxiliary air** is drawn from a common source, passing by the controller, or (choke) throttle (**F**), located in the air opening, after which it divides, the constant air passing down through the constant air passage and up through the venturi tube, at which point it becomes thoroughly impregnated with the gasoline spray drawn from nozzle (**D**). It then continues upward, combining with the auxiliary air which has been admitted through the bronze ball ports (**G**), these balls lifting automatically in correct proportion as the engine speed varies.

These balls (auxiliary air controllers), after being drawn from their seats, as a result of the vacuum (or suction), remain floating in the air until the engine speed is reduced sufficiently to permit them to return again to their seats. The controller or (choke) throttle (**F**) is so placed that it is possible entirely (or nearly so) to cut off the source of air, thus producing a strong vacuum (or suction) at the venturi tube, and thereby obtaining a very rich mixture for starting purposes in low temperature.

The stop valve at each of the supply tanks should be shut off when the tractor is not being operated. The float valve in the carburetor might stick or fail to keep the supply of fuel to the bowl or float chamber cut off. This would mean that the carburetor would flood and the fuel would run out and be wasted.

For tractor use: Fuel must be connected to both bowls from both tanks when operating the tractor.

Air washer: The Kingston carburetor (Kokomo, Ind.) uses an air washer, called the Bennett, type manufactured by Wilcox-Bennett Co., Minneapolis, Minn.

The Fuel System as Used in the Fordson Tractor

Kerosene as a fuel is desirable on account of its low cost, as compared with gasoline. One of the main difficulties to overcome is the fact that kerosene is less volatile (is harder to evaporate) than gasoline, consequently it is found to be helpful to **preheat** the kerosene before it enters the cylinders. Another essential is the use of **clean air,** and the addition of **moisture** to the air materially aids the operation of the engine by preventing preignition.

Slight alterations in the engine design are necessary for the use of kerosene. This is the result of the experience of the Holley Co., which manufactures the kerosene vaporizer to be described. On the average engine, a compression of about 55 lbs. per square inch is best for kerosene.

Notable Features of Holley Vaporizer

The outstanding features of the Holley vaporizer are:

1. **The amount of heat** (used to preheat the kerosene vapor) **can be regulated.**
2. **The coils in which the kerosene vapor is heated are made of very thin-walled brass tubing, thus effecting quick results.**
3. **Only one float chamber is necessary.**

How the System Works

A diagram sketch of the entire fuel system is shown in Fig. 14.

Air washer (M): Air from the atmosphere enters at the bottom of the air washer (**M**) and passes into guide (**P**) which is closed at the top. Therefore it must come out at the bottom of the guide which is maintained below the water level by float (**J**). The air then bubbles through the water and is washed, and absorbs moisture.

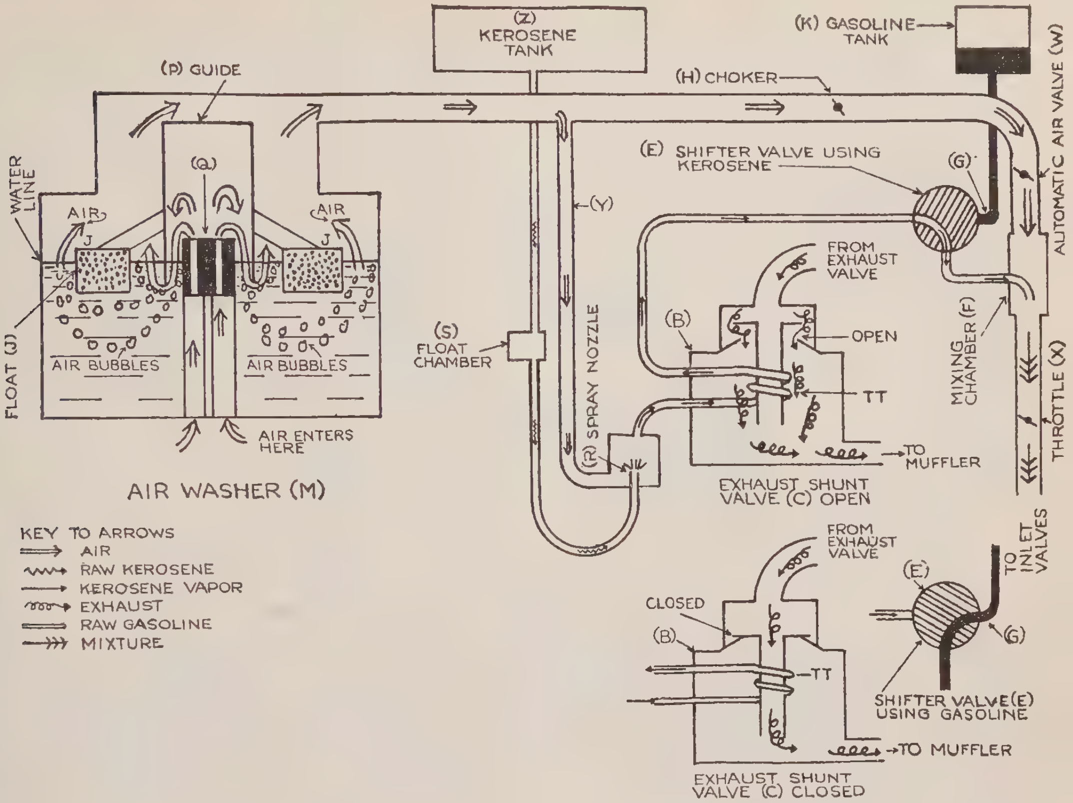


Fig. 14. The fuel system as used on the Fordson tractor.

The absorption of moisture causes the water level to go down, carrying the float and guide with it. When the tank is nearly empty, the top of the guide (P) closes down on surface (Q), thus shutting off the air. The engine stops and the driver knows that he must put more water in the washer.

The flow of air is caused by the suction stroke of the engine cylinder.

When starting the engine, turn shifter valve (E) to the position shown in lower sketch. This will permit the gasoline to flow through a spray nozzle (not shown), then into the mixing chamber (F), where it is mixed with air, the mixture passing through throttle (X) to the engine.

In cold weather, the choker (H) may be closed, thus causing a rich mixture.

After the engine is warmed up, turn the shifter valve to the position shown in main sketch (Fig. 14), thus permitting the kerosene system to operate. Raw kerosene from tank (Z) flows into the float chamber (S), where its speed is regulated, and then through spray nozzle (R), where it is mixed with about 10 per cent of the necessary air, the air coming down the primary tube (Y). The resulting kerosene vapor passes into coils (TT).

The shunt valve being open permits the hot exhaust gases to pass into the heating chamber (B), therefore directly over the coils (TT), thus preheating the kerosene vapor. The warm vapor then passes through the shifter valve (E) and into the mixing chamber (F), where it is mixed with the remaining quantity (about 90 per cent) of air necessary for combustion. The resulting mixture passes through throttle (X) and into the engine.

Exhaust shunt valve (C): During starting, when the engine is running on gasoline, the **exhaust gases must not pass directly over the coils** (TT). To avoid this, the exhaust shunt valve (C) is closed to position shown in the lower sketch. The exhaust gases cannot now enter the heating chamber (B), but will pass through the valve and thence to the muffler. The metal in the valve protects the coils from intense heat.

In very warm weather, it is sometimes advisable to close the exhaust shunt valve partly.

Automatic air valve (W) is for the purpose of regulating the quantity of air according to the speed of the motor. As the speed increases, the valve opens farther, allowing more air to flow to the mixing chamber (F). It is entirely automatic, and is not controlled by the operator.

The actual shape of the Holley kerosene vaporizer is shown in Fig. 15 (page 990).

The figure is lettered to correspond to the lettering of the diagram (Fig. 14).

The exhaust shunt valve is controlled by lever (D).

The heating chamber (B) has an extension (A).

The quantity of kerosene entering the spray nozzle (R) is controlled by the needle valve (N).

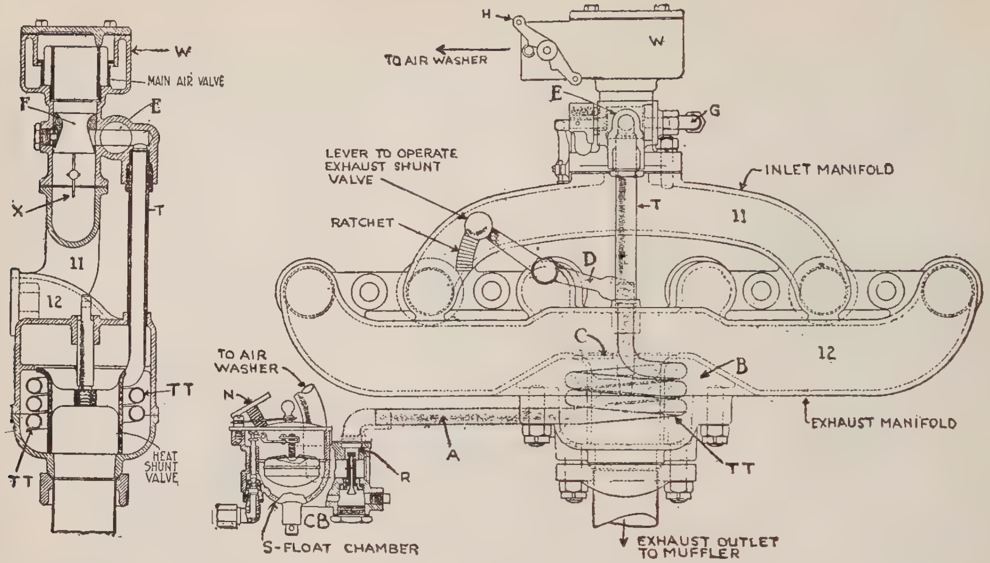


Fig. 15. Holley kerosene vaporizer.

FORDSON TRACTOR

A tractor is a "hard puller." It is designed for the purpose of pulling heavy loads at slow speeds over almost any kind of ground.

The Fordson tractor is manufactured by the Ford Motor Company, Detroit, Mich.

From an engineering standpoint, the Fordson tractor differs, and possesses characteristics which distinguish it from others.

Specifications

Price f.o.b. Detroit, $395.00.

Engine: Four-cylinder; cylinders cast en bloc; bore 4"; stroke 5"; extra large bearings throughout; all bearings burned in.

Lubrication: Splash system; oil circulation is maintained by oil thrown off the flywheel by centrifugal force; capacity of oiling system, 2¼ gals.

Cooling: Thermo-syphon system; radiator is of vertical-tube type, and is cooled by a fan.

Fuel: Engine is started with gasoline from a two-quart gasoline tank; once started, the engine is operated by kerosene from 21-gallon kerosene tank; fuel supplied by gravity feed.

Air washer: The air supply is drawn through water which removes all dust, thus reducing wear on the cylinder walls.

Transmission: Constant mesh selective type, three speeds forward and one reverse; all shafts run on ball bearings.

Clutch: Multiple disk, running in oil.

Front axle: Drop-forged and heat-treated; it is attached in the center directly to the front of the engine, giving three-point suspension to the tractor.

Steering is through a bevel-gear sector and pinion, with a ball-end drop arm connecting through a large rod to the front axle cross-arm; system is fore-and-aft type.

Wheels: Front wheels have steel spokes cast in the hub and riveted to the rim.

Rear axle: Semi-floating, four-pinion differential running on ball bearings.

Belt pulley: Special fibre paper construction, does not require refacing, and prevents slipping of drive belt (optional).

Performance: Size of thresher 20" x 36"; plows, 2–14"; average work, 6 acres in 10 hours.

Turning circle: 21-foot radius.

Data

Weights: Weight of tractor less driver, water, oil, and lugs, 2,425 lbs.; **total weight** of tractor, including all liquid supplies and 150 lb. driver, 2,920 lbs.; **distribution of weight,** front wheels 1,063 lbs., rear wheels 1,857 lbs.; weight of engine with vaporizer and coils, 661 lbs.

Dimensions: Wheel base, 63"; distance between front rims, 40⅛"; distance between rear rims, 37⅜"; width of front rim, 5"; diameter of front rim, 28"; width of rear rim, 12"; width of extension rim, 7" (for light soil); diameter of rear rim, 42" (3" cleats riveted on rim); **overall length** of tractor, 102"; **overall width** of tractor, 61⅜"; **overall height** of tractor, 54¾"; ground clearance, 11⅝", lowest point being the flywheel housing; height of draw bar from ground, 12"; lateral adjustment, 7"; vertical adjustment, none.

Engine: L-head type with detachable cylinder head; has 4 cylinders and 8 valves; firing order, 1, 2, 4, 3. Three main bearings, 2" diameter by 3" long; connecting-rod bearings 2" diameter by 2¼" long; pistons have 3 rings each; piston clearance, top .0150", bottom .0045"; piston displacement, 251.3 cu. in.; oil system capacity, 2¼ gals., using heavy gas-engine oil; temperature of oil when pulling steady maximum load, 150° to 200° F.

Cooling: Fan, 18" ball-bearing belt-driven; water capacity, 12 gal.; vertical tube radiator.

Ignition: Current supplied by flywheel magneto; there are 16 magnets clamped to the flywheel which rotate behind the stationary armature; **voltage of magneto** varies with speed of engine; a high-tension coil is used; the timer and distributor (commutator) are fastened on the end of the cam shaft.

Carburetion: See description of Holley vaporizer on page 988.

Air washer: Float type, 7-quart capacity.

Clutch has 17 hardened disks running in oil; spring pressure is 900 lbs. total, or 3.41 lbs. per sq. in.; lubricated by oil in the crank case.

Transmission gears: Speeds based on 1,000 r.p.m. of engine.

Gear	Final Ratio	Worm R.P.M.	Axle R.P.M.	Tractor Speed
Low..........	84.28	207.6	11.86	1.48 M.P.H.
Intermediate. .	45.77	382.3	21.85	2.73 M.P.H.
High..........	18.26	958.3	54.76	6.84 M.P.H.
Reverse.......	47.76	366.4	20.9	2.61 M.P.H.

Lubricant, heavy gear oil, capacity 3¾ gals.; oil temperature when pulling steady maximum load, 175° to 250° F.

Worm: Of undermounted type; it has two threads (see Index under "Worm gears"); it is made of chrome vanadium steel; the worm shaft is supported at the rear end by a duplex ball bearing which withstands both radial and end thrusts.

Worm gear (worm wheel): Made of aluminum bronze; it has 35 teeth.

Belt pulley: Width, 6½"; diameter, 9½"; spiral-bevel gear drive from transmission drive shaft; belt speed, 2,480 ft. per minute at 1,000 r.p.m. of engine (Ford data sheet gives the belt horsepower as 18).

Description of Fordson Tractor

As already stated, the purpose of a tractor is to pull heavy loads at slow speeds over almost any kind of ground.

Energy is put into the tractor in the form of kerosene. The vaporizer and mixing chamber change this kerosene into a combustible gas by mixing it with clean moist air from the air washer. The engine burns this gas and converts it into mechanical energy, causing a rotation of the crank shaft. This power is passed through the clutch and is delivered to the transmission, where the speed of rotation is changed or the direction reversed. The power is then delivered to the worm drive, which further reduces the speed of rotation, and, by means of the rear axle shafts, turns the rear wheels, thus causing the motion of the tractor.

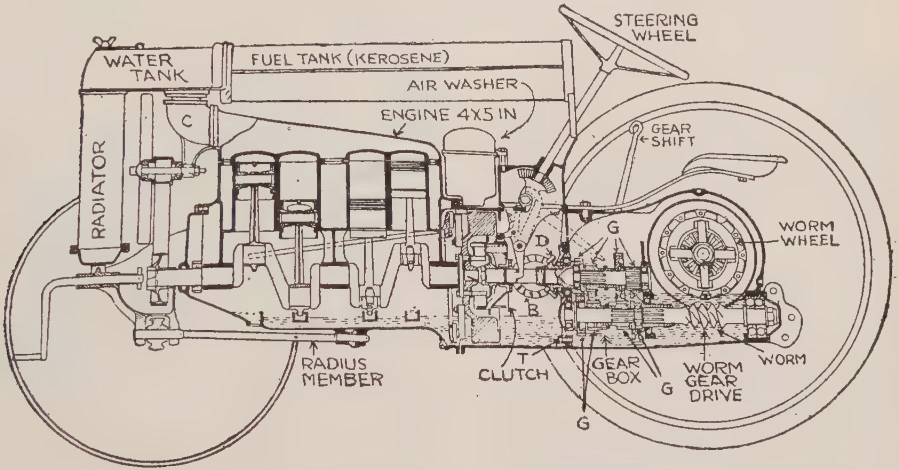


Fig. 16. Sectional view of Fordson tractor. The drawbar cap is shown in the extreme rear.

The crank case, gear box, and axle housing serve as the frame of the machine.

The engine is similar in design to that of the Ford model "T" (see Index under "Ford model T"), the main differences being as follows:

1. The bore and stroke of the engine are greater than in the model "T."
2. The water connections between the radiator and the water jacket are effected with iron connectors instead of with rubber hose, as in the model "T."
3. The fan is larger, runs on ball bearings, and is supported by a bracket from the upper water connector, instead of from the cylinder block, as in the model "T."
4. There is no removable plate in the bottom of the crank case to permit access to the connecting rods, it being necessary to remove the entire crank case for this purpose.

The ignition is similar to that of the Ford model "T" (see Index).

Carburetion is obtained by Holley vaporizer (see page 988).

Transmission is for the purpose of driving the tractor at various speeds according to the class of work to be done. This device also permits the tractor to be reversed. These speed variations are obtained by engaging different sets of gears (G) (Fig. 16).

Clutch: The clutch is inserted between the engine and transmission, and permits the engine to be completely disconnected from the transmission when it is disengaged. When engaged, it first slips a trifle, thus permitting the motion of the engine to be gradually imparted to the transmission and remaining portions of the machine, and consequently no jerk occurs.

The operation of the clutch is as follows (Fig. 16): The gradual "take up" of the load is effected by friction between several disks. The driving disks are fastened to the flywheel by six studs. The driven disks are keyed to the transmission through the clutch drum. When the clutch pedal is allowed to rise, the clutch springs are permitted to press on the clutch drum, thus pressing the disks together and therefore making a connection from the engine to the transmission drive shaft.

Rear axle: The rotation from the transmission is reduced in speed and imparted to the rear wheels by the rear axle. The principal parts are, the worm, the worm wheel (gear), the differential gears and pinions, and the rear axles as shown in Fig. 16. The worm is connected directly to the transmission, and, owing to the engagement of its threads with the teeth of the worm wheel, it causes the latter to rotate. The rotation of the worm wheel can be imparted to either of the rear wheels or to both, in any desired ratio, the parts effecting this result being the differential gears and pinions. Thus it is possible to turn the tractor.

Operating Instructions

Always hitch to the draw-bar cap (Fig. 19), **never to the rear axle housing.**

To operate the tractor, proceed as follows:

1. Fill the radiator with as clean water as it is convenient to get.
2. Lubricate thoroughly (see section on "lubrication" farther on).
3. Fill the air washer with clean, fresh water until it runs out of the filler hole.
4. Fill the fuel tanks with clean fuel that is free from water.
5. For operation of the vaporizer, see page 989.
6. See that the gear shifter is in neutral position (Fig. 17).
7. Lift the spark lever (on the dash) to the third or fourth notch from the bottom.
8. Open the throttle (under the steering wheel) one-third of the way toward the driver.

9. Crank the engine by **lifting upward.**
10. After the engine starts, advance the spark until the engine runs at the maximum speed without knocking.
11. Always release the clutch before attempting to shift the gears. Select the speed desired and shift to this speed immediately. The various gear-shift positions are shown in Fig. 17.

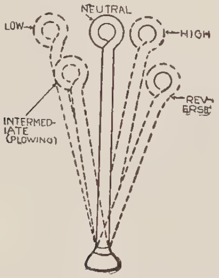


Fig. 17. Gear-shift positions of Fordson Tractor.

12. The speed of the engine is controlled by the throttle. The engine should never be run at speeds greater than 1,000 r.p.m. This speed can be judged by watching the rear wheels.

In **low gear** the rear wheels turn 12 times per minute.

In **intermediate gear** they turn 22 times per minute.

In **high gear** they turn 54 times per minute.

In **reverse** they turn 21 times per minute.

13. To stop the tractor, partly close the throttle; push down on the clutch pedal, shift gears to neutral, release the clutch pedal, turn off the fuel at the sediment bulb, and the engine will stop. In cold weather, it is sometimes a good idea to turn the shifter valve to gasoline; then pull out the choker, and the engine will stop, the cylinders being filled with a rich gasoline mixture, thus facilitating the next start.
14. The radiator can be filled with cold water when the engine is hot, providing the top tank (Fig. 16) is not empty. To prevent freezing of water in cold weather, the following solutions of wood or denatured alcohol should be used:

20 per cent solution freezes at 15° above zero
30 per cent solution freezes at 8° below zero
50 per cent solution freezes at 34° below zero

The fins of the radiator and the outside of the tubes should be kept reasonably clean.

15. The air washer should be flushed out daily through the drain cock on the side.
16. If it is desired **to run the tractor on gasoline** instead of kerosene, **the gasoline should be put into the main fuel tank,** and the exhaust shunt valve (**C**) (Fig. 15, page 990) should be kept at the "off" position.

Lubrication

The engine: The engine is lubricated by the splash system. Heavy, high-grade motor oil should be poured through the strainer in the breather pipe at the left side of the engine until the level in the crank case reaches the upper pet cock at the side of the crank case. When the tractor is being run continuously, the oil should be drained through the drain plug underneath the crank case every week. Flush the case with a quart of kerosene; then refill with motor oil to the level of the upper pet cock. Under no circumstances should the oil be permitted to reach a level below the lower pet cock. Tests should be made with the tractor on level ground.

The transmission and rear axle are both lubricated from the same case. Heat heavy fluid gear oil to about 100° F. With the tractor on level ground, pour this warm oil through the filler hole in the gear-shifter cover until it reaches the level of the filler hole. Plenty of time should be allowed to permit the oil to reach the worm-gear drive. The system holds 3¾ gals.

When the tractor is operated continuously, the oil should be drained every two weeks. This is done through the drain plug underneath the housing. Flush out with a quart of kerosene, and refill.

The commutator (timer): Put a little oil into the commutator twice daily.

The rear-axle roller bearings should be oiled through the plugs with heavy fluid gear-oil weekly. The felt washer at the end of the axle shaft should be replaced when dirty. Remove the rear wheels (the method is explained under "Repairs") below; then pry off the steel cover with a screwdriver, after which the felt can be taken off.

The steering joints and front-axle trunnion should be oiled daily with heavy motor oil.

The grease cups on the steering spindles should be given a few turns daily.

The fan should be oiled weekly with heavy fluid gear-oil.

REPAIRS ON THE FORDSON TRACTOR

Tools for disassembling and assembling various parts of the tractor are essential. The socket type shown in Fig. 18 is an efficient set designed for use on the Fordson tractor.

The Engine

Engine: To **remove the cylinder head,** (1) drain the radiator through the pet cock; (2) shut off the fuel at the sediment bulb and remove the fuel tank; (3) disconnect the wires from the engine and take off the coil box (the timer wires should not be disconnected from the commutator case, but the case should be removed with them); (4) disconnect the cylinder-head from the radiator connector (**C**) (Fig. 16); (5) remove the cylinder-head cap screws, after which the cylinder-head can be lifted off; be careful not to damage the cylinder-head gasket; (6) when **replacing the cylinder head,** clean the surfaces well, turn the engine till Nos. 1 and 4 pistons are at top of stroke, replace the gasket, and pull down the cap screws **tightly.** When the gasket becomes hard, it should be replaced with a new one.

To remove the crankcase: (1) drain the oil from the engine; (2) remove the radius member (Fig. 19); (3) remove the crank-case bolts, and take down the crank case, being careful not to let it fall.

To remove connecting rods and pistons: (1) remove the cylinder head and crank case (see above); (2) disconnect the connecting-rod bearing caps, being careful to note their position (light file marks on the connecting rod and bearing caps will help you); (3) remove the piston with the connecting rod through the top of the cylinder.

To fit new piston rings (see Index under "Fitting piston rings").

Valve timing: Valves have a 5/16″ lift.

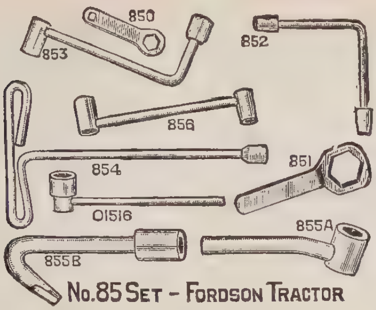


Fig. 18. **Walden No. 85 Fordson tractor socket-wrench set:** (850) wrench for adjusting fan nut and screw; (851) for clutch-shaft nut; (852) for clutch-housing bolt; (853) for crank-shaft cap and main bearing nuts; (854) for gear-shifter plate cap screw; (855**A**) for front-wheel spindle nut; (855**B**) for differential housing; (856) for crank-case bolt and nut.

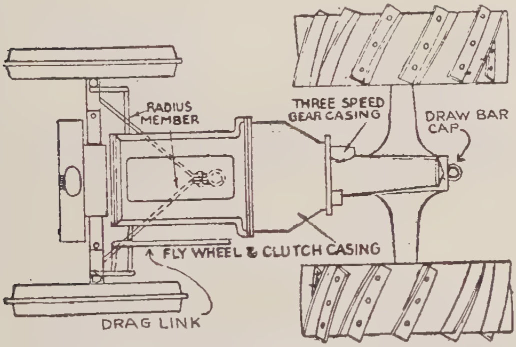


Fig. 19. Top view of Fordson tractor.

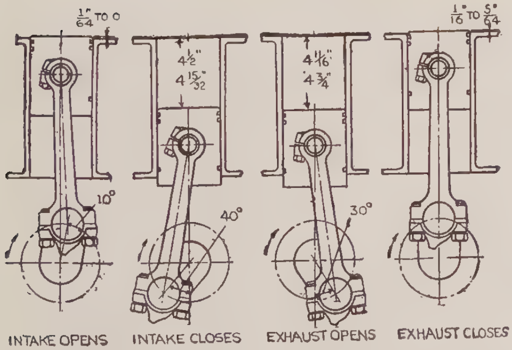


Fig. 20. **Valve-timing diagram,** showing the position of the piston and the crank shaft at the opening and closing of the valves. As in timing the model "T," it is recommended that the valves be timed by the piston travel.

The inlet opens 10° past upper dead center, with the piston 1/64″ above the top of the cylinder; the **inlet closes** 40° past lower dead center, with the piston 4½″ to 4 15/32″ below the top of the cylinder. **The exhaust opens** 30° ahead of lower dead center, with the piston 4 11/16″ to 4¾″ below the top of the cylinder; **the exhaust closes** on upper dead center, with the piston 1/16″ to 5/64″ above the top of the cylinder. **The tappet clearance** is .007″ to .022″.

Grinding valves (see Index under "Grinding valves").

Worn valves or push rods should be replaced with new ones.

Removing carbon (see page 763, under "Removing carbon").

To tighten connecting-rod bearings by removing shims (see page 799).

To tighten the main crank shaft bearings by removing shims (see page 783).

To Remove the Engine from the Transmission

1. Drain the crank case of oil.
2. Drain the water from the radiator and jackets.
3. Shut off the fuel at the sediment bulb, and remove the fuel tank.
4. Remove the air washer and gasoline tank.
5. Disconnect the steering arm from the drag link (Fig. 19).
6. Disconnect the control rods from the vaporizer and commutator.
7. Remove the dash; there are four cap screws holding it to the transmission housing.

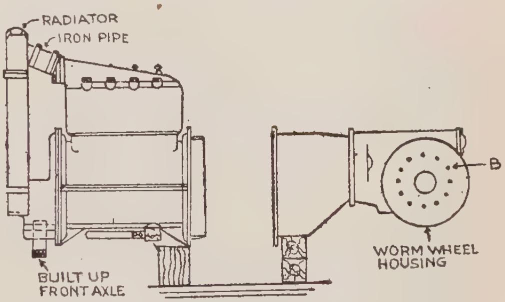


Fig. 21. Showing the method of **removing the engine from the transmission** housing.

8. Block up the transmission housing and the engine, as shown in Fig. 21.

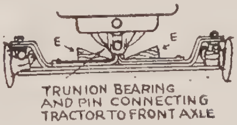


Fig. 22

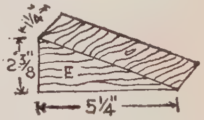


Fig. 23

Figs. 22, 23. Method of **blocking up the engine** before removing it from the transmission housing.

9. Avoid rocking of the engine by placing wedges (Fig. 23) between the front axle and the cylinder front cover, as shown in Fig. 22.
10. Remove the bolts holding the engine to the transmission housing.
11. Pull apart, as shown in Fig. 21.

Gaskets: Where paper gaskets are used, it is best to make new ones before replacing the parts.

Radiator

A small leak may be temporarily repaired with white lead or brown soap, but should be soldered as soon as possible.

To remove: (1) drain off the water; (2) remove the cap screws which hold the radiator to the front cylinder cover; they are underneath the bottom tank; (3) disconnect the fuel-tank strap from the radiator cover; (4) disconnect the radiator from the top tank by removing the four cap screws under the top tank; (5) lift off the radiator.

Fan Belt

To tighten: (1) remove the cotter pin from the nut at the rear of the fan shaft; (2) loosen the nut); (3) the belt can then be tightened by turning the square end of the shaft with a wrench; (4) holding the shaft in this position, tighten the nut with another wrench; (5) replace the cotter pin.

Fuel System

The vaporizer has but one adjustment; that is the needle valve (N) (Fig. 15, page 990). **When the tractor is running, make adjustment as follows:**

1. Retard the spark lever to the fourth notch.
2. Screw up the needle valve (N) until the engine begins to misfire.
3. Gradually unscrew the needle valve until the engine attains maximum speed and no smoke comes from the exhaust.

Dirt in the shifter valve can be removed as follows: (1) remove the shifter-valve cover; (2) set the valve in gasoline position; (3) insert fine wire into the passage.

Dirt in the kerosene spraying nozzle is removed as follows: (1) remove the plug which screws into the float chamber just under nozzle; (2) clean and replace.

Throttle adjustment is obtained by adjusting the screw (see Index).

Ignition System

Repairs on the ignition system are made in a manner similar to those on the Ford model "T" (see Index).

When replacing the coil units on the Ford tractor, use regular tractor coils which are marked on the front of the unit: "Tractor Unit." These coils are equipped with special vibrator points designed for high-speed, heavy duty work. The coils are also fitted with a special composition to withstand the high temperature developed by continuous service. Do not use model "T" coil units on the Tractor.

Clutch

No adjustment is necessary. **If the clutch slips,** the springs (1) (Fig. 24), or the plates (2) and (3) (Fig. 24) should be replaced. **If the clutch fails to release,** the plates are probably bent and should be renewed.

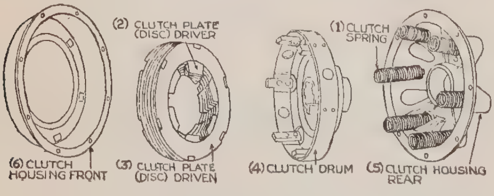


Fig. 24. Clutch assembly of Fordson tractor.

To remove and disassemble clutch: (1) remove the engine from the transmission housing, as described above; (2) remove nut (7) (Fig. 25); (3) pull the clutch from the transmission drive shaft; (4) provide a means of gradually releasing the clutch spring tension, such as a bolt and nut (Fig. 26), or (C) clamps (Fig. 27); (5) disconnect the front from the rear clutch housing by removing the eight bolts which pass through holes (8) (Fig. 26); (6) gradually release the clutch-spring tension by the means provided; (7) remove the housing, as shown in (Fig. 28).

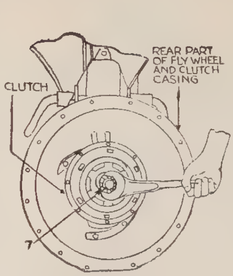


Fig. 25

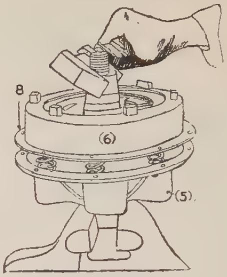


Fig. 26

Fig. 25. Method of removing clutch nut.

Fig. 26. Method of gradually releasing clutch-spring tension.

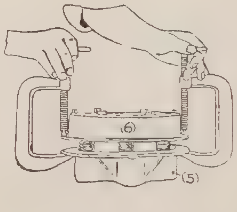


Fig. 27

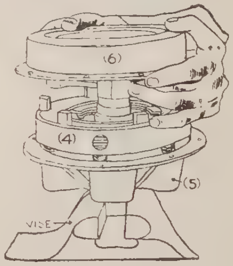


Fig. 28

Fig. 27. Another method of releasing clutch-spring tension.

Fig. 28. Method of removing clutch housing.

Transmission

To remove the transmission gears: (1) remove the engine from the transmission housing, as described above; (2) drain the transmission housing through the plug under the gear-shifter cover; (3) remove the gear-shifter cover from the transmission housing by unscrewing the four cap screws which hold it; (4) remove the clutch, as described above; (5) remove the eight cap screws (T) (Fig. 16); (6) pull on the drive shaft of the transmission, thus removing the transmission plate and the lower transmission shaft in one unit; (7) remove the upper transmission shaft with the gears; (8) when replacing the ball bearings, the stampings on the outer rings must face the ends of the shaft.

Rear Wheels

To remove the rear wheels do the following: On the rear wheel hubs, there are four bolts passing through the wheel bushings. Between each pair of bolts is a **tapped hole.**

1. Jack up the rear wheel.
2. Unscrew the four hub bolts.
3. Screw two of them into the **tapped holes** mentioned.
4. Screw up equally, thus drawing out the bushing until the wheel is free.
5. Pry the bushing off the axle with the hooked end of bar No. 855-B (Fig. 18).
6. When replacing, the four bolts are screwed into their correct positions by drawing them up equally until the wheel is flush with the end of the axle.

Rear Axle

To remove the rear axle: (1) drain the transmission housing through the plug under the gear-shifter cover; (2) remove the rear wheels as described above; (3) remove the twelve cap screws (**B**) (Fig. 21) from each rear axle housing; (4) draw off the axle housings; (5) remove the rear axles and the worm wheel with the differential as one complete unit; (6) take out the bolts which pass through holes (**A**) (Fig. 29); (7) pull the housings apart, thus exposing the parts as shown in Fig. 29.

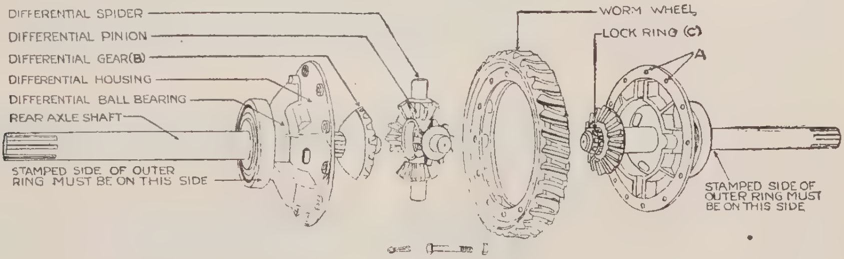

DIFFERENTIAL SPIDER
DIFFERENTIAL PINION
DIFFERENTIAL GEAR(B)
DIFFERENTIAL HOUSING
DIFFERENTIAL BALL BEARING
REAR AXLE SHAFT
STAMPED SIDE OF OUTER RING MUST BE ON THIS SIDE
WORM WHEEL
LOCK RING (C)
A
STAMPED SIDE OF OUTER RING MUST BE ON THIS SIDE

Fig. 29. Differential and rear-axle assembly of Fordson tractor.

To remove the differential gear (**B**) (Fig. 29): (1) press the gear toward the wheel end of the shaft until locking ring (**C**) is exposed; (2) remove ring (**C**); (3) press the gear off the differential end of the shaft.

Front Wheels

To remove the front wheels: (1) remove the hub cap; (2) jack up the front axle; (3) remove the cotter pin and nut from the wheel spindle; (4) pull off the wheel; (5) when replacing the wheels, see that the stampings on the outer rings of the roller bearings face each other.

Roller bearings of front wheels: The cups should be a good press fit into the hubs. The cones should be an easy free fit on the spindles, so that they may turn on them. **To adjust the bearings,** draw up the wheel nut until the wheel binds. Then back off one-third or two-thirds of a turn, so that the wheel turns freely but has no end play.

Front Axle

To remove the front axle: (1) jack up the front of the tractor; (2) remove the front wheels as described above; (3) remove the drag link (Fig. 19) from the steering arm; (4) remove the radius member (Fig. 19) from the crank case; (5) remove the front axle trunnion pin (Fig. 22) and the front axle.

To straighten the front axle, do not heat, but straighten cold.

Steering Gear

To tighten the steering gear: (1) remove the sockets from the ball joints at the end of the drag link (Fig. 19); (2) file off these sockets; (3) replace; if the spindle pins are loose, the bushings should be renewed.

Belt Pulley

To install the pulley attachment: (1) block the tractor; (2) jack up the tractor under the right side of the draw-bar cap (Fig. 19); (3) remove the right rear wheel, as described above; (4) remove the foot bracket and see that the tractor is equipped with the transmission drive-shaft spiral bevel gear (**D**) (Fig. 16); (5) place paper gaskets on the pulley housing; (6) insert the pulley attachment in such a manner that the hole in the housing points down, so that the oil drains back into the transmission; (7) tighten up the six cap screws; (8) test the pulley with the hands for slight backlash (play); (9) if there is none, more paper gaskets must be inserted; (10) if there is too much, remove some of the gaskets. Gear (**B**) (Fig. 30) (below) is meshed with gear (**D**) (Fig. 16, page 991). Thus with gear shift in neutral, belt pulley can revolve without driving tractor.

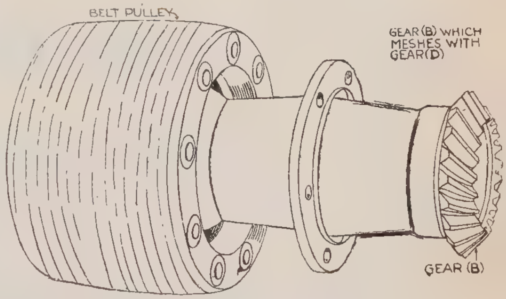


Fig. 30. Belt pulley for Fordson tractor.

Engine Troubles and Causes: Fordson Tractor

Engine fails to start:

1. Gas mixture too lean, or poor grade of gasoline.
2. Water in fuel.
3. Vibrators adjusted too closely.
4. Water or congealed oil in commutator.
5. Magneto contact point obstructed with foreign matter.
6. Gasoline supply shut off.
7. Lack of water in air washer.
8. Water frozen in bottom of gasoline tank.
9. Water on spark plugs or wire terminals.

Engine lacks power:

1. Poor compression on account of leaky valves.
2. Imperfect gas mixture.
3. Spark plugs dirty.
4. Coil vibrator burned or improperly adjusted.
5. Air leak in intake manifold.
6. Weak exhaust valve spring.
7. Too great clearance between valve stem and push rod.
8. Spark plugs dirty or points imperfectly adjusted.
9. Commutator contact imperfect.
10. Burnt out vapor tube or coils (TT Fig. 14, page 989).

Engine overheats:

1. Lack of water.
2. Lack of oil.
3. Fan belt torn, loose, or slipping.
4. Carbon deposit in combustion chamber.
5. Spark retarded too far.
6. Gas mixture too rich or too lean.
7. Water circulation retarded by sediment in radiator.
8. Dirty spark plugs.
9. Lack of water in air washer.

Engine knocks:

1. Carbon deposit on piston heads.
2. Loose connecting-rod bearings.
3. Loose crank-shaft bearings.
4. Loose piston or piston pins.
5. Spark advanced too far.
6. Motor overheated.
7. Gas mixture too rich or too lean.

SPECIFICATIONS OF TRACTORS (1922)

(From *Motor Age*)

Name and Model	Price	Plow Capacity	Plowing Speed M. P. H.	H. P. Rating	ENGINE						ENGINE						ENGINE			
					Make	No. Cyl. Bore and Stroke	Cylinder Type	R. P. M.	Engine Type	Cylinder Cast	Make of Governor	Type of Governor	Weight	Cooling Fluid	Cooling Capacity	Radiator Make	Fluid Circulation	Lubrication System Type	Oil Pump Type	Carburetor Make and Size
All-In-One A	$1,975	2–3	2⅓	15–30	Weidely	4-4 x5½	I	900	Vert	Block	Weidely	Cent		W	12½	Own	Pump	Hol. C. S.	Piston	Kingston 1¼
Allis-Chalmers		1	2½	6–12	LeRoy	4-3⅛x4½	L	1000	Vert	Block	LeRoi	Cent		W	3½	Own	Ther	Cir. Spl	Piston	Kingston ⅞
Allis-Chalmers		3	2½	14–27	Midwest	4-4⅛x5¼	I	1100	Vert	Pairs	Midwest	Cent	905	W	6	Own	Pump	Hol. C. S.	Gear	Kingston 1¼
Allis-Chalmers		3–4	2⅓	18–30	Own	4-4¾x6½	I	830	Vert	Block	Own	Cent	1580	W	10	Own	Pump	Hol. C. S.	Gear	Kingston 1½
Allis-Chalmers		4	2½	22–38	Own	4-4¾x6½	I	930	Vert	Block	Own	Cent	1580	W	10	Own	Pump	Hol. C. S.	Gear	Kingston 1¾
Allwork G		3	2½	14–28	Own	4-4¾x6	L	900	Vert	Singly	Own	Cent	1180	W	10	Perfex	Pump		Piston	Kingston 1½
Allwork C		3	2¾	14–28	Own	4-5 x6	L	900	Vert	Singly	Own	Cent	1200	W	12	Perfex	Pump	Hol. C. S.	Gear	Kingston 1½
Andrews Kinkade D	2,400				Climax	4-5 x6½	L	800	Vert	Pairs	Climax	Cent	1175	W	12	Spirex	Pump	Hol. C. S.	Vane	Stromb'g 1½
Appleton	1,500			12–20	Buda	4-4¼x5½	L	1000	Vert	Block	Pickering	Cent	800	W	8	Modine	Pump	Hol. C. S.	Gear	Schebler 1¼
Aro	495					1-4½x5		800	Vert	Singly				W	2	S.-J.	Ther	Cir. Sp.	Piston	Schebler 1¼
Aultman and Taylor		4	2¼	15–30	Climax	4-5 x6½	L	900	Vert	Pairs	Climax	Cent	1100	W	8⅛	G. & O.	Pump	Hol. C. S.	Vane	Kingston 1⅜
Aultman and Taylor		6	2¼	22–45	Own	4-5½x8	I	600	Hori	Pairs	Own	Cent	2875	W	85	Own	Pump	Mech		Kingston 2
Aultman and Taylor		8–10	2¼	30–60	Own	4-7 x9	I	550	Hori	Pairs	Own	Cent	3790	W	120	Own	Pump	Mech		Kingston 2½
Automotive	1,785	3		12–24	Hercules	4-4 x5⅛	L	1000		Block	Pierce	Cent	850	W	7½	McC.-T.	Pump	Pres	Gear	Kingston
Avery		2–3		8–16	Own	2-5½x6	I	750	Opp	Singly	Own	Cent	925	W	12½	Own	Ther	Cir. Sp	Gear	Kingston 1¼
Avery		3–4		12–20	Own	4-4½x6	I	950	Opp	Block	Own	Cent	1250	W	11	Own	Pump	Mech		Kingston 1¼
Avery		3–4		12–25	Own	2-6½x7	I	700	Opp	Singly	Own	Cent	1350	W	17½	Own	Ther	Cir. Sp.	Gear	Kingston 1½
Avery		3–4		14–28	Own	4-4⅝x7	I	900	Opp	Block	Own	Cent	1620	W	30	Own	Ther	Cir. Sp.	Gear	Kingston 1¼
Avery		4–5		18–36	Own	4-5½x6	I	750	Opp	Pairs	Own	Cent	2150	W	33	Own	Ther	Cir. Sp.	Gear	Kingston 1½
Avery		5–6		25–50	Own	4-6½x7	I	700	Opp	Pairs	Own	Cent	2700	W	55	Own	Ther	Cir. Sp.	Gear	Kingston 2
Avery		8–10		45–65	Own	4-7¾x8	I	600	Opp	Pairs	Own	Cent	3300	W	90	Own	Ther	Cir. Sp.	Gear	Kingston 2
Avery		2			Own	6-3 x4	I	1250	Vert	Block	Own	Throt	470	W	6¾	Own	Ther	Cir. Sp.	Gear	Kingston ⅞
Avery Track Runner		3	2 1/16		Own	4-4 x5½	I	1000	Vert	Block	Own	Hydro		W			Pump	Hol. C. S.		Kingston
Bates		3	2½	15–25	Own	4-4¼x6	I	800	Hori	Block	Own	Cent	975	W	8	Own	Pump	Hol. C. S.	Gear	Own 1½
Bates (Steel Mule) F		3	3½	18–25	Midwest	4-4⅛x5¼	I	1100	Vert	Pairs	Simplex	Cent	1000	W	6	Perfex	Pump	Hol. C. S.	Gear	Bennett 1¼
Best 30	3,100	4	3 1/16	18–30	Own	4-4¾x6½	I	800	Vert	Singly	Own	Cent	1600	W	9	Own	Pump	Ho. C. S.	Gear	Ensign 1½
Burn-Oil	1,495	3	4	15–30	Own	2-6¼x7	I	700	Hori	Pairs	Own	Cent		W	16	Eureka	Pump	Mech		Schebler 1½
Case 10-18		2	3	10–18	Own	4-3⅞x5	I	1050	Vert	Block	Own	Cent		W	9	Own	Pump	Hol. C. S.	Piston	Kingston 1⅛
Case 15-27		3–4	2¼–3	15–27	Own	4-4½x6	I	900	Vert	Block	Own	Cent		W	11	Own	Pump	Hol. C. S.	Piston	Kingston 1⅜
Case 22-40		4–5	3¼	22–40	Own	4-5½x6¾	I	850	Vert	Pairs	Own	Cent		W	15½	Own	Pump	Mech		Kingston 2
Catterpillar T-11		4	3	25–	Own	4-4¾x6	I	900	Vert	Pairs	Own	Cent	1400	W	7½	Modine	Pump	Hol. C. S.	Gear	Schebler 1½
Catterpillar T-16		6	3	40–	Own	4-6½x7	I	700	Vert	Singly	Own	Cent	2300	W	12	Own	Pump	Hol. C. S.	Gear	Kingston 2
Chase 12-25	1,825	3	2¾	12–25	Buda	4-4½x5½	L	1050	Vert	Block	Pierce	Cent		W	8½		Pump	Hol. C. S.	Gear	Kingston 1½
Cletrac F	795			9–16	Own	4-3¼x4½	L	1600	Vert	Block	Own	Cent		W		McCord	Pump	Cir. Sp	Piston	Tillotson 1
Cletrac W	1,345	2	3½	12–20	Own	4-4 x5½	I	1265	Vert	Block	Own	Cent		W		McCord	Pump	Mech	Gear	Kingston 1¼
Dakota	1,750	3	2¾	15–27	Doman	4-4¾x6	T	800	Vert	Pairs	Doman	Cent	800	W	16	S. & J.	Pump	Hol. C. S.	Gear	Linga 1¼
Depue A	2,800	3		20–30	Buda	4-4½x6	L	1000	Vert	Block	Simplex	Cent	950	W	8	Perfex	Pump	Hol. C. S.	Gear	Stromb'g 1½
Emerson-Brant 12-20		3	2.7	12–20	Own	4-4¾x5	L	900	Vert	Pairs	Own	Cent	997	W	7½	Modine	Pump	Cir. Sp	Piston	Stromb'g 1½
Emerson-Brant Q		3	2.26	12–20	Own	4-4¾x5	L	850	Vert	Pairs	Pickering	Cent	1100	W	9	Perfex	Pump	Cir. Sp	Piston	Bennett 1½
Emerson-Brant 16-32		4	2.26	16–32	Own	4-5¼x7	L	750	Vert	Pairs	Pickering	Cent	2000	W	10	Modine	Pump	Cir. Sp	Piston	Stromb'g 1¾

[*continued on next page*

continued from page 996]

Fageol D	......	2	2	9-18	Lycom.	4-3½x5	L.	1200	Vert.	Block	Red Devil	Cent.	....	W.	..	Perfex	Pump	Cir. Sp.	Piston	Tillotson....
Farm Horse B	1,885	4	2.5	18-30	Climax	4-5 x6½	L.	850	Vert.	Pairs	Climax	Cent.	1400	W.	10	S. & J.	Pump	Mech.	Vane	Bennett..1½
Farquhar 15-25	......	3-4	2	15-25	Buda	4-4½x6	L.	1000	Vert.	Block	Pierce	Cent.	1057	W.	12	Perfex	Pump	Hol. C. S.	Gear	Kingston.1¼
Farquhar 4-30	......	4-5	2.3	18-35	Own	4-6 x8	I.	550	Vert.	Pairs	Own	Cent.	....	W.	94	Own	Pump	Cir. Sp.	Gear	Kingston...2
Farquhar 4-40	......	6-7	2.3	25-50	Own	4-7 x8	I.	550	Vert.	Pairs	Own	Cent.	....	W.	94½	Own	Pump	Cir. Sp.	Gear	Kingston...2
Fordson	625	2	2.5	-18	Own	4-4 x5	L.	1000	Vert.	Block	......	......	650	W.	12	Own	Ther.	Cir. Sp.	......	Holley...1¼
Fox E	3,100	4	2.6	20-40	Own	4-5½x7½	I.	650	Hori.	Pairs	Own	Cent.	2017	W.	12	Perfex	Pump	Hol. C. S.	......	Kingston.1½
Frick A	......	2-3	2⅓	12-20	Erd	4-4 x6	I.	900	Vert.	Block	Erd	Cent.	900	W.	7¾	Perfex	Pump	Cir. Sp.	Piston	Kingston.1¼
Frick C	......	3-4	2.1	15-28	Beaver	4-4¾x6	I.	900	Vert.	Block	Taco	Cent.	1000	W.	9¾	Perfex	Pump	Hol. C. S.	Gear	Bennett..1½
Gray	......	4	3	18-36	Wauk.	4-4¾x6¾	L.	950	Vert.	Pairs	Waukesha	Cent.	840	W.	8	......	Pump	Cir. Sp.	Gear	Bennett..1½
Hart-Parr	945	2	3	-20	Own	2-5¼x6½	I.	800	Hori.	Pairs	Own	Cent.	890	W.	7¾	Perfex	Pump	Mech.	Piston	Schebler..1¼
Hart-Parr	1,295	3	3	-30	Own	2-6½x7	I.	950	Hori.	Pairs	Own	Cent.	1170	W.	10	Perfex	Pump	Mech.	Piston	Schebler..1½
Heider D	870	2	2.5	9-16	Wauk.	4-4¼x5¾	L.	1000	Hori.	Pairs	Waukesha	Cent.	800	W.	9	Perfex	Pump	Cir. Sp.	Gear	Kingston...1
Heider C	995	3	2.25	12-20	Wauk.	4-4½x6¾	L.	900	Hori.	Pairs	Waukesha	Cent.	900	W.	10	Perfex	Pump	Cir. Sp.	Gear	Kingston.1¼
Huber	1,185	3	2.5	12-25	Wauk.	4-4½x5¾	L.	1000	Vert.	Pairs	Waukesha	Cent.	600	W.	8	Perfex	Pump	Cir. Sp.	Gear	Kingston.1¼
Huber	1,885	3	3	15-30	Midwest.	4-4½x6	I.	1000	Vert.	Pairs	Taco	Cent.	1200	W.	11¼	Perfex	Pump	Hol. C. S.	Gear	Kingston.1¼
Illinois C	......	4	2.5	15-30	Climax	4-5 x6½	L.	850	Vert.	Pairs	Climax	Cent.	1000	W.	7	Modine	Pump	Hol. C. S.	Eccentr.	Stromb'g.1½
Imperial	5,000	12	2.25	40-70	Own	4-7½x9	I.	400	Hori.	Singly	Own	Cent.	4500	W.	45	Own	Pump	Mech.	Piston	Kingston...2
Indiana F	895	1	2.5	5-10	LeRoi	4-3⅛x4½	L.	1000	Vert.	Block	LeRoi	Cent.	335	W.	5	Candler	Ther.	Cir. Sp.	Piston	Kingston...1
International 8-16	900	2	2.75	8-16	Own	4-4¼x5	I.	1000	Vert.	Block	Own	Cent.	....	W.	11	......	Ther.	Cir. Sp.	Piston	Ensign......
International 15-30	......	3	3	15-30	Own	4-4½x6	I.	1000	Vert.	Block	Own	Cent.	....	W.	..	......	Ther.	Cir. Sp.	Gear	Ensign......
International 15-30	......	4	2.4	15-30	Own	4-5¼x8	I.	575	Hori.	Pairs	Own	......	....	W.	40	......	Pump	Mech.	......	Own......
Klumb	......	4	2.5	18-32	Climax	4-5 x6½	L.	850	......	Pairs	Own	Cent.	1150	W.	10	S. & J.	Pump	Pres.	Vane	Stromberg...
Knudson	2,000	4	3	25-45	Own	4-5⅛x9	I.	500	Vert.	Singly	Own	Cent.	1500	W or O	35	Own	Ther.	Cir. Sp.	Eccent.	Own....1¾
Lauson S	1,495	3	3.25	12-25	Midwest.	4-4⅛x5¼	I.	1200	Vert.	Pairs	Taco	Cent.	950	W.	8	Perfex	Pump	Hol. C. S.	Gear	Kingston.1¼
Lauson 15-30	1,985	3-4	2.5	15-30	Beaver	4-4¾x6	I.	950	Vert.	Block	Taco	Cent.	1100	W.	12	Perfex	Pump	Hol. C. S.	Gear	Kingston.1½
Leader M	......	3-4	2.25	16-32	Climax	4-5 x6½	L.	800	Vert.	Pairs	Climax	Cent.	1200	W.	12	......	Pump	Hol. C. S.	Gear	Stromb'g.1½
Leader G-U	......	3-4	2.25	18-36	Climax	4-5 x6½	L.	900	Vert.	Pairs	Climax	Cent.	1200	W.	12	......	Pump	Cir. Sp.	Gear	Stromb'g.1½
Leonard	2,530	3	2.7	20-30	Buda	4-4½x6	L.	1000	Vert.	Block	Duplex	Cent.	....	......	..	......	Pump	Hol. C. S.	Gear	Zenith...1¼
Linn	5,100	6	2	......	Wauk.	4-5 x6¼	L.	1000	Vert.	Pairs	Waukesha	Cent.	1000	W.	..	McCord	Pump	Cir. Sp.	Gear	Schebler..1½
Little Giant B	2,200	4	2.5	16-22	Own	4-4½x5	L.	950	Vert.	Pairs	Own	Cent.	1250	W.	9	S. & J.	Pump	Cir. Sp.	Gear	Kingston.1⅓
Little Giant A	3,300	6	2.5	26-55	Own	4-5½x6	L.	750	Vert.	Pairs	Pickering	Cent.	1650	W.	10	S. & J.	Pump	Cir. Sp.	Gear	Stromb'g.1¾
Minneapolis	900	3	2.21	12-25	Own	4-4½x7	....	750	......	Block	Own	Cent.	....	W.	8⅞	Cellulos.	Pump	Mech.	......	Kingston.1½
Minneapolis	......	3-4	2.75	17-30	Own	4-4¾x7	....	775	......	......	Own	Cent.	....	W.	8½	S. & J.	Pump	Mech.	......	Kingston.1¾
Minneapolis	......	4-5	2.7	22-44	Own	4-6 x7	....	700	......	Pairs	Own	Cent.	....	W.	14	S. & J.	Pump	Mech.	......	Kingston...2
Minneapolis	......	8-10	2.1	35-70	Own	4-7¼x9	....	550	......	Pairs	Own	Cent.	....	W.	60	......	Pump	Mech.	......	Kingston.2½
Mohawk E	785	....	2.25	8-16	Light.	4-3¼x4½	L.	1000	Vert.	Block	Pierce	Cent.	365	W.	6	Bush	Ther.	Cir. Sp.	Piston	Kingston...1
Moline D	990	2-3	3.0	9-18	Own	4-3½x5	I.	1400	Vert.	Block	Remy	Elec.	720	W.	6	Modine	Ther.	Hol. C. S.	Gear	Holley...1¼
Nilson	2,475	4	2.5	20-40	Wauk.	4-5 x6¼	L.	900	Vert.	Pairs	Waukesha	Cent.	1000	W.	14	S. & J.	Pump	Hol. C. S.	Gear	Stromb'g.1½
Oil Pull K	1,485	3	2.1	12-20	Own	2-6 x8	I.	560	Hori.	Pairs	Own	Cent.	....	O.	10½	Own	Pump	Cir. Sp.	......	Own.....2¼
Oil Pull H	2,285	4	2.1	16-30	Own	2-7 x8½	I.	530	Hori.	Pairs	Own	Cent.	....	O.	15	Own	Pump	Cir. Sp.	......	Own.....2½
Oil Pull G	3,175	6	2.0	20-40	Own	2-8 x10	I.	450	Hori.	Singly	Own	Cent.	....	O.	17	Own	Pump	Cir. Sp.	......	Own.....2¾
Oil Pull E	4,590	8-10	1.9	30-60	Own	2-10 x12	....	375	Hori.	Singly	Own	Cent.	....	O.	70	Own	Pump	Cir.Sp.Me.	......	Own.....3¼
Oshkosh M	650	1	2.5	6-12	Own	2-4 x6	I.	1000	Hori.	Pairs	Own	Cent.	600	W.	8	Modine	Pump	H.C.S.Me.	Piston	Kingston.1¼
Oshkosh H	985	3	3.0	12-24	Own	2-6 x7	I.	900	Hori.	Pairs	Own	Cent.	900	W.	10	Modine	Pump	Hol. C. S.	Piston	Kingston.1¾

ABBREVIATIONS—**B. & B.**—Borg & Beck; **H. B.**—Horizontal Bars; **W.**—Water; **Hol. C. S.**—Hollow crankshaft; **Gr.**—Gravity; **Vac.**—Vacuum; **P.**—Pump; **Brlng.**—Berling; **D. D.**—Dry Disk; **D. O.**—Disk in Oil; **Struct.**—Structural Steel; **Cent.**—Centrifugal; **Cir. Sp.**—Circulating splash; **Rev.**—Revolv-

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								ENGINE				ENGINE							ENGINE		
	Price	Plow Capacity	Plowing Speed M. P. H.	H. P. Rating	Make	No. Cyl. Bore and Stroke.	Cylinder Type	R. P. M	Engine Type	Cylinder Cast.	Make of Governor	Type of Governor	Weight	Cooling Fluid	Cooling Capacity	Radiator Make	Fluid Circulation	Lubrication System Type	Oil Pump Type	Carburetor Make and Size
Peoria......L	1,600	3	3.0	12–25	Climax..	4–5 x6½	L...	800	Vert..	Pairs......	Climax....	Cent......	1000	W....	11	Eureka....	Pump.....	Hol. C. S..	Ecc.....	Stromb'g. 1½
Pioneer......	......	4	2.5	20–40	Own....	4–5½x6	L...	750	Opp...	Pairs......	Pierce.....	Cent......	....	W....	20	S.-J.......	Pump.....	Hol. C. S..	Gear....	Kingston. 1½
Pioneer......	......	10	2.5	40–75	Own....	4–7 x8	L...	650	Opp...	Pairs......	Own......	Cent......	....	W....	35	S.-J.......	Pump.....	Hol. C. S..	Gear....	Kingston...2
Port Huron......A	1,500	3	......	12–25	Chief...	4–4¾x6	I...	900	......	....	Pickering..	Cent......	1000	W....	8¾	Bremer....	Pump.....	Pres......	Gear....	Kingston....
Reliable......	......	2	2.25	10–20	Own....	2–6 x7	I...	600	Hori..	Pairs......	Own......	Cent......	1120	W....	40	Own......	Ther......	Mech......	Piston...	Own.....1¼
Rex......	1,600	3	2.5	12–25	Wauk...	4–4¼x5¾	L...	900	Vert..	Pairs......	Waukesha.	Cent......	....	W....	....	....	Pump.....	Cir. Sp....	Gear....	Kingston. 1½
Samson......M	......	2–3	2.5 3.25	......	Own....	4–4 x5½	L...	1100	Vert..	Block......	Own......	Cent......	839	W....	10	....	Pump.....	Hol. C. S..	Gear....	Kingston. 1¼
Sandusky......J	1,250	2	2.0	10–20	Own....	4–4¼x5¼	L...	1050	Vert..	Block......	Own......	Cent......	849	W....	8	Perfex....	Pump.....	Cir. Sp....	Piston...	Kingston. 1¼
Sandusky......E	1,750	4	2.0	15–35	Own....	4–5 x6½	L...	750	Vert..	Singly......	Own......	Cent......	2060	W....	30	Perfex....	Pump.....	Cir. Sp....	Piston...	Kingston...2
Shelby......C	......	2	2.6	9–18	Wauk...	4–3¾x5¼	L...	1000	Vert..	Block......	Waukesha.	Cent......	625	W....	8	Modine...	Pump.....	Cir. Sp....	Gear....	Kingston. 1¼
Shelby......D	......	3	2.7	15–30	Beaver..	4–4¾x6	I...	900	Vert..	Block......	Taco......	Cent......	1000	W....	10	Modine...	Pump.....	Hol. C. S..	Gear....	Kingston. 1½
Steady Pull......	1,485	3	2.5	12–24	Own....	4–4 x5	I...	900	Vert..	Block......	....	....	800	W....	6	Perfex....	Pump.....	Cir. Sp....	Gear....	Stromb'g. 1¼
Stinson......	1,835	4	2.85	18–36	Beaver..	4–4¾x6	I...	1000	Vert..	Block......	....	....	1000	W....	10	Todd.....	Pump.....	Hol. C. S..	Gear....	Kingston. 1⅜
Tioga......	2,625	3–4	2.7	15–27	W&MW	4–4½x6	I...	1000	Vert..	Pairs......	Pharo.....	Cent......	1200	W....	7¾	G. & O....	Pump.....	Hol. C. S..	Gear....	Stromb'g. 1¼
Titan......	900	3	2.75	10–20	Own....	2–6½x8	I...	575	Hori..	Pairs......	Own......	Cent......	....	W....	40	Own......	Ther......	Mech......	....	Ensign......
Topp-Stewart......B	3,500	4	2.5	30–45	Wauk...	4–4¾x6¾	L...	950	Vert..	Pairs......	Waukesha.	Cent......	....	W....	12	Bremer....	Pump.....	Cir. Sp....	Gear....	Stromb'g. 1½
Toro......	......	2	2.0	6–10	LeRoi...	4–3⅛x4½	L...	1200	Vert..	Block......	LeRoi.....	Cent......	325	W....	4	S.-J.......	Ther......	Cir. Sp....	Piston...	Kingston..⅞
Townsend......	895	2–3	2.5	10–20	Own....	2–6½x7	I...	550	Hori..	Pairs......	Own......	Cent......	1100	W....	50	Own......	Pump.....	....	Piston...	Own.....1½
Townsend......	1,485	3–4	2.5	15–30	Own....	2–7 x8	I...	500	Hori..	Pairs......	Own......	Cent......	1600	W....	70	Own......	Pump.....	Hol. C. S..	Piston...	Own.....1¾
Townsend......	2,750	6–8	2.5	25–50	Own....	2–8½x10	I...	475	Hori..	Pairs......	Own......	Cent......	2200	W....	100	Own......	Pump.....	Hol. C. S..	Piston...	Own.....2¼
Tracklayer......60	5,450	8	2.62	35–50	Own....	4–6½x8½	I...	650	Vert..	Singly......	Own......	Cent......	2600	W....	18	Own......	Pump.....	Cir. Sp....	Gear....	Ensign.....2
Traylor......	715	1	2.75	6–12	LeRoi...	4–3⅛x4½	L...	1200	Vert..	Block......	LeRoi.....	Cent......	330	W....	4	G. & O....	Ther......	Hol. C. S..	Gear....	Kingston..⅞
Trundaar......	3,750	4	2.5	25–40	Wauk...	4–5 x6¼	L...	850	Vert..	Pairs......	Waukesha.	Cent......	....	W....	11	Modine...	Pump.....	Hol. C. S..	Gear....	Stromb'g. 1½
Twin City......	1,580	3	2.9	12–20	Own....	4–4¼x6	I...	1000	Vert..	Block......	Pierce.....	Cent......	1040	W....	10½	Modine...	Pump.....	Hol. C. S..	Gear....	Holley...1¼
Twin City......	3,175	5	2.9	20–35	Own....	4–5½x6¾	I...	900	Vert..	Block......	Own......	Cent......	1800	W....	18	Modine...	Pump.....	Hol. C. S..	Gear....	Holley.....2
Twin City......	5,250	8	2.0	40–65	Own....	4–7¾x9	I...	535	Vert..	Singly......	Own......	Cent......	4125	W....	130	Own......	Pump.....	Mech......	....	Holley...2½
Wallis......K	......	2–3	3.5	15–25	Own....	4–4¼x5¾	I...	900	Vert..	Singly......	Own......	Hyd......	750	W....	6	Modine...	Pump.....	Cir. Sp....	Piston...	Bennett..1¼
Waterloo Boy......N	1,450	3	3.0	12–25	Own....	2–6½x7	I...	950	Hori..	Pairs......	Own......	Cent......	1200	W....	13	Modine...	Pump.....	Cir. Sp....	Piston...	Schebler..1½
Wellington......B	......	2–3	2.25	12–22	Erd.....	4–4 x6	I...	900	Vert..	Block......	Erd......	Cent......	860	W....	7	Modine...	Pump.....	Cir. Sp....	Piston...	Stromb'g. 1⅜
Wellington......F	......	3	3.0	16–30	Chief...	4–4¾x6	I...	1000	Vert..	Block......	Chief.....	Cent......	1020	W....	9	Modine...	Pump.....	Hol. C. S..	Gear....	Stromb'g. 1½
Wetmore......	1,585	3	3.37	12–25	Wauk...	4–4 x5¾	L...	1000	Vert..	Pairs......	Waukesha.	Cent......	900	W....	....	Ideal......	Pump.....	Hol. C. S..	Gear....	Schebler..1¼
Whitney......D	595	2	2.5	9–18	Own....	2–5½x6½	L...	750	Opp..	Singly......	Own......	Cent......	650	W....	....	....	Pump.....	Mech......	....	..........1½
Wichita......T	2,000	3–4	2.5	15–30	Beaver..	4–4½x6	I...	950	Vert..	Block......	Duplex....	Cent......	1080	W....	9	Perfex....	Pump.....	Hol. C. S..	Gear....	Ensign....1¼
Wisconsin......	2,450	4	2.5	20–40	Wauk...	4–5 x6½	L...	950	Vert..	Pairs......	Waukesha.	Cent......	1000	W....	12	Perfex....	Pump.....	Hol. C. S..	Gear....	Stromb'g. 1½
Wisconsin......	3,200	5	2.5	......	Climax..	4–5½x7	L...	800	Vert..	Pairs......	Climax....	Cent......	1500	W....	18	Perfex....	Pump.....	Hol. C. S..	Ecc.....	Stromb'g. 1½
Yuba......	3,100	....	......	15–25	Wisc....	4–4¼x6	L...	800	Vert..	Block......	....	....	920	W....	5½	Modine...	Pump.....	Cir. Sp....	Gear....	Stromb'g. 1¼
Yuba......	5,000	....	......	25–40	Own....	4–5¼x7	I...	700	Vert..	Pairs......	Own......	Cent......	....	W....	9	Modine...	Pump.....	....	....	Stromb'g. 1¼
Yuba......	4,650	....	......	25–40	Wisc....	4–5¾x7	T...	700	Vert..	Pairs......	Own......	Cent......	1543	W....	9	Modine...	Pump.....	Cir. Sp....	Gear....	Stromb'g. 1½
Zelle......	......	3	2.5	12–25	Buda...	4–4¼x5½	L...	1000	Vert..	Block......	Pierce.....	Cent......	....	W....	....	....	Pump.....	Hol. C. S..	Gear....	Carter......

ABBREVIATIONS—B. & B.—Borg & Beck; **H. B.**—Horizontal Bars; **W.**—Water; **Hol. C. S.**—Hollow crankshaft; **Gr.**—Gravity; **Vac.**—Vacuum; **P.**—Pump; **Brlng.**—Berling; **D. D.**—Dry Disk; **D. O.**—Disk in Oil; **Struct.**—Structural Steel; **Cent.**—Centrifugal; **Cir. Sp.**—Circulating splash; **Rev.**—Revclv.

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				Electrical System	CLUTCH		TRANSMISSION						WHEELS				FRAME			
Water Injected with Fuel	Fuel Feed	Fuel Tanks and Capacities	Air Cleaner Make	Ignition System Make	Make	Type	Make of Transmission	No. Forward Speeds	Final Drive	Differential Lock	Drive Wheel Axle Type	Steering Type	No. Driving Wheel	Diameter and Face	No. of Tracks	No. of Non-drive	Material	Wheelbase	Total Weight	
	Gr.	2-5G-22K	Vortex	Brlng	Detlaff	D. D.	Americ'n	2	Rim	No	Dead	Fork	2	52x 8		1	Struct.	94	4800	All-In-One A
No	Gr.	1-8½G	Taco		B. & B	D. D.	Own	1	Rim	No	Dead	Worm	2	48x 6		2	None	80	2500	Allis-Chalmers
No	Gr.	1-20G	Taco		Own	Shoe	Own	2	Rim	No	Rev	Knuckle	2	46x12		2	None	78	4400	Allis-Chalmers
Yes	Gr.	1-7¾G-25K	Taco		Own	Shoe	Own	2	Rim	No	Rev	Knuckle	2	50x12		2	None	94	6150	Allis-Chalmers
No	Gr.	1-35G	Taco		Own	Shoe	Own	2	Rim	No	Rev	Knuckle	2	50x12		2	None	94	6150	Allis-Chalmers
No	Gr.	2-5G-23K	Bennett	Bosch	Own	D. D.	Own	3	Spoke		Rev	Knuckle	2	38x12		2	Struct.	75	4800	Allwork G
No	Gr.	2-5G-24K	Bennett	Bosch & K.	Own	D. D.	Own	3	Rim	No	Rev	Knuckle	2	48x12		2	Struct.	80	5200	Allwork C
Yes	Gr.	2-25G-5K	Bennett	Dixie	Own	D. D.	Own	2	Spoke	No	Dead	Knuckle	2	54x14		2	Struct.	96	5000	Andrews Kinkade D
Yes	Gr.	2-5G-20K	Bennett		B. & B	D. D.	Nuttall	2	Rim	No	Rev	Knuckle	2	54x12		2	Struct.	96	4900	Appleton
	Gr.	1-2G	Donald'n	Brlng	Own			1	Axle	No	Live		2	30x 4		2	None			Aro
No	Gr.	2-6G-16K	Bennett	Eisemann	T. D	D. D.	Own	1	Rim	No	Rev	Knuckle	2	70x12		2	Struct.	98½	8100	Aultman and Taylor
Yes	Gr.	2-20G-35K		Eisemann	Own	Shoe	Own	2	Rim	No	Rev	Swinging	2	70x20		2	Struct.	102	12800	Aultman and Taylor
Yes	Gr.	2-20G-60K		Eisemann	Own	Shoe	Own	1	Rim	No	Rev	Swinging	2	90x24		2	Struct.	136	23400	Aultman and Taylor
No		1-18G	Bennett	Eisemann	B. & B	Plate	Own	2	Axle	Yes	Live	Power	2	40x10		2	Steel	70	3950	Automotive
Yes	Gr.	1-2¼G-13½K	Bennett		Own		Own	2	Spoke	No	Rev	Swinging	2	50x12		2	Struct.	90	4900	Avery
Yes	Gr.	1-6G-16K			Own	D. D.	Own	2	Hub	No	Rev	Knuckle	2	52x14		2	Struct.	80	6000	Avery
Yes	Gr.	1-3¼G-20K	Bennett		Own	Shoe	Own	2	Spoke	No	Rev	Swinging	2	56x20		2	Struct.	95	7500	Avery
	Gr.	1-3¼G-20K	Bennett		Own	D. D.	Own	2	Spoke	No	Rev	Knuckle	2	60x16		2	Struct.	96	7540	Avery
Yes	Gr.	1-5½G-34K	Bennett		Own	D. D.	Own	2	Spoke	Yes	Rev	Swinging	2	65x20		2	Struct.	97	9750	Avery
Yes	Gr.	1-5½G-34K			Own	D. D.	Own	2	Spoke	No	Rev	Swinging	2	69x20		2	Struct.	114	12500	Avery
Yes	Gr.	1-5½G-45K			Own	D. D.	Own	2	Spoke	No	Rev	Swinging	2	87½x24		2	Struct.	138	22000	Avery
No	Gr.	1-10K	Bennett		Own	D. D.	Own	3	Rim	No	Dead	Knuckle	2	38x10		2	Struct.	90	3164	Avery
	Gr.	1-30G	Opt	Dixie	Own	D. D.	Own	3				Knuckle			2				5000	Avery Track Runner
Yes	Gr.	2-2G-15K	Own		Own	Cont.	Own	3	Rim	Yes	Dead	Knuckle	2	54x12		2	Struct.	80	4000	Bates
No	Gr.	2-5 and 10G	R. W	Bosch	B. & B	D. D.	Own	2	Axle	Yes	Dead	Knuckle			2	2	Struct.	80	4850	Bates (Steel Mule) F
No	Vac.	2-2¾G-30K	Pomona	Brlng	Own	Plate	Own	2	Rim		Dead				2		None		7560	Best 30
No	Gr.	1-30K	Bennett		Own	Cont.	Own	2	Rim	No	Live	Knuckle	2	56x12		2	Cast			Burn-Oil
No	Gr.	2-2G-10½K	Own		Own	Shoe	Own	2	Spoke	Yes	Live	Knuckle	2	42x 9		2	Cast	65	3820	Case 10-18
No	Gr.	2-2¾G-20K	Own		Own & B. & B.	D. D.	Own	2	Spoke	Yes	Live	Knuckle	2	52x14		2	Cast	76½	6460	Case 15-27
Yes	Gr.	2-3¾G-26½K	Own		Own	Shoe	Own	2	Spoke	Yes	Live	Knuckle	2	56x16		2	Struct.	96	9700	Case 22-40
No	Vac.	1-45G	Own	Eisemann	Own	D. D.	Own	3	Axle						2		Cast	83	9300	Catterpillar T-11
No	Vac.	1-45G	Own	K. W	Own	D. D.	Own	3	Axle						2		Cast	98	19500	Catterpillar T-16
	Gr.	2-1G-9K		Dixie	Bierman	Shoe	Own	2	Rim		Dead	Knuckle	2	48x12		1	Struct.	69	5500	Chase 12-25
	Gr.	2-¼G-6K	Own		B. & B	Plate	Own	1	Axle	No		Swinging					None			Cletrac F
No	Gr.	2-¾G-13K	Own		B. & B	D. D.	Own	1	Axle	No					2		Struct.			Cletrac W
No	Vac.	1-20G	Cyclone		Bierman	Shoe	Own	1	Axle		Live	Knuckle	1	42x10		2	Struct.	108	5300	Dakota
No	Gr.	1-16G	Cyclone	Bosch	B. & B	D. D.	Own	3	Axle	No	Live	Swinging	4	40x12			Struct.	99	6800	Depue A
Yes	Gr.	2-4G-20K	Bennett	K. W	Own	Cone	Own	2	Spoke	No	Rev	Knuckle	2	54x12		2	Struct.	87½	4550	Emerson-Brant 12-20
Yes	Gr.	1-4G-16K	Bennett	K. W	Own	Cone	Own	3	Spoke	No	Dead	Knuckle	2	60x12		2	Struct.	93	6500	Emerson-Brant Q
Yes	Gr.	1-5G-35K	Bennett	Simms	Own	Cone	Own	2	Spoke	Yes	Dead	Swinging	2	72x16		2	Struct.	126	9400	Emerson-Brant 16-32

[continued on next page

continued from page 999]

				Electrical System	CLUTCH		TRANSMISSION						WHEELS				FRAME			
Water Injected with Fuel	Fuel Feed	Fuel Tanks and Capacities	Air Cleaner Make	Ignition System Make	Make	Type	Make of Transmission	No. Forward Speeds	Final Drive	Differential Lock	Drive Wheel Axle Type	Steering Type	No. Driving Wheel	Diameter and Face	No. of Tracks	No. of Non-drive	Material	Wheelbase	Total Weight	Name and Model
No	Gr.	1-12G	Own	Dixie	Own		Own	1	Axle			Knuckle	2			2	Struct.	97	3500	**Fageol D**
Yes	Gr.	2-5G-15K	Oren	Dixie	T. D.	D. D.		2	Spoke	No	Dead	Knuckle	2	52x26		2	Struct.	82	5200	**Farm Horse B**
No	Gr.	2-5G-25K	R. W.	K. W.	M. E.	D. D.	Own	2	Rim	No	Dead	Knuckle	2	54x10		2	Struct.	83	5700	**Farquhar 15-25**
No	Gr.	2-30G-30K		K. W.	Own	Fric.	Own	1	Rim	No	Dead	Swinging	2	84x20		2	Struct.	132	16000	**Farquhar 4-30**
No	Gr.	2-30G-30K		K. W.	Own	Fric.	Own	1	Rim	No	Dead	Swinging	2	84x24		2	Struct.	132	19000	**Farquhar 4-40**
Yes	Gr.	2-½G-21K	Own	Own	Own	D. O.	Own	3	Axle	No	Live	Knuckle	2	42x12		2	None	63	2425	**Fordson**
Yes	Vac.	2-2G-20K		Dixie	Own	Shoe	Own	3	Spoke	No	Dead	Knuckle	2	60x12		2	Struct.	90	6700	**Fox E**
No	Gr.	2-3G-20K	Bennett		Own	Shoe	Nuttall	2	Rim	No	Rev.	Knuckle	2	60x10		2	Struct.	92	5700	**Frick A**
No	Gr.	1-3G-17K	Bennett		Own	Shoe	Nuttall	2	Rim	No	Rev.	Knuckle	2	60x12		2	Struct.	92	6450	**Frick C**
No	Gr.	1-34G	Bennett	Bosch	Own	Cone	Own	2			Rev.	Knuckle	1	54x54		2	Struct.		6200	**Gray**
Yes	Gr.	2-1G-14K	Own	K. W.	Own	Cont.	Own	2	Rim	No	Rev.	Knuckle	2	46x10		2	Struct.	76	3750	**Hart-Parr**
Yes	Gr.	2-1G-23K	Own	K. W.	Own	Cont.	Own	2	Rim	No	Rev.	Knuckle	2	52x18		2	Cast.	89	5275	**Hart-Parr**
Yes	Gr.	2-7G-14K	Bennett				Own	7	Axle	No	Live	Knuckle	2	54x 8		2	Struct.	90	4000	**Heider D**
Yes	Gr.	2-7G-14K	Bennett				Own	7	Axle	No	Live	Knuckle	2	57x10		2	Struct.	96	6000	**Heider C**
Yes	Gr.	1-1½G-22K	Bennett	Kingston	Own	Shoe	Own	2	Rim	No	Rev.	Knuckle	2	60x10		2	Struct.	91	5000	**Huber**
No	Gr.	1-23½G	R. W.	Eisemann	Own	D. D.	Own	2	Rim	No	Rev.	Knuckle	2	60x10		2	Struct.	91	5800	**Huber**
No	Gr.	1-3G-15K	Bennett		T. D.	D. D.	Foote	4	Axle	No	Live	Knuckle	2	54x12		2	Struct.	92	5000	**Illinois C**
Yes	Gr.	1 or 2-70G	Bennett	K. W.	Own	Shoe	Own	2	Rim	Yes		Swinging	2	96x30		2	Struct.	137	20800	**Imperial**
	Gr.	1-12G	Bennett	Kent	Own		Own	4	Spoke	No	Dead	Swinging	2	50x12		2	Cast.		2200	**Indiana F**
No	Gr.	2-1½G-11½K	Own	Dixie	Own	D. D.	Own	3	Spoke		Dead	Knuckle	2	40x12		2	Struct.	85	3600	**International 8-16**
Yes	Gr.	2-1G-16K	Own		Own	D. D.	Own		Axle		Live	Knuckle	2	50x12		2	Cast.	85	5400	**International 15-30**
Yes	Pres.	2-24K	Own		Own		Own	2	Spoke		Dead	Knuckle	2	66x14		2	Pressed	94	8700	**International 15-30**
Yes	Gr.	5G-20K	Bennett	Splitdorf	Own	Shoe	Own	2	Axle	No	Live	Knuckle	2	48x12		2	Channell	84	6000	**Klumb**
Yes	Gr.	2-2G-40K	Own	Kingston	Own	Shoe	Own	2	Axle	Yes	Rev.	Swinging	2	60x18			Struct.	42	6000	**Knudson**
No	Gr.	1-19G	Taco	Splitdorf	Own	Shoe	Own	2	Spoke	No	Rev.	Knuckle	2	48x12		2	Struct.	78	4500	**Lauson S**
	Gr.	1-2G-18K	Taco	Splitdorf	Own	Shoe	Own	2	Rim	No	Rev.	Knuckle	2	54x12		2	Struct.	86	6000	**Lauson 15-30**
No	Gr.	1-3½G-30K	United	Dixie	B. & B.	D. D.	Own	2	Rim	No	Rev.	Knuckle	2	54x12		2	Struct.	76	5800	**Leader M**
No	Gr.	1-3½G-20K	United	Dixie	B. & B.	D. D.	Own	2		No	Dead					2	Struct.		6800	**Leader G-U**
No	Vac.	1-28G	Own	Dixie	Hilliard	D. D.	Own	2		Yes			4	50x12			Struct.	98	5500	**Leonard**
No	Vac.	1-30G		West'house	B.-L.	D. D.	B.-L.	4		No	Dead	Knuckle	2		2		Struct.	135	11000	**Linn**
Yes	Gr.	1-5G-20K	Donald'n		Own	Cone	Own	3	Rim	No	Dead	Knuckle	2	54x14		2	Struct.	87	5000	**Little Giant B**
Yes	Gr.	1-5G-35K	Donald'n		Own	Cone	Own	3	Rim	No	Dead	Knuckle	2	66x20		2	Struct.	102	8500	**Little Giant A**
Yes		2-3G-18.3K		K. W.			Own	2	Axle		Live	Knuckle		56x12			Struct.	100	6600	**Minneapolis**
Yes		2-6G-17K	Bennett	Dixie	Own	D. D.	Own	2	Axle		Live	Knuckle		54x12			Struct.	79⅞	6400	**Minneapolis**
Yes		2-9G-30K		K. W.			Own	2	Axle		Live	Swinging		62x10			Struct.	109½	12410	**Minneapolis**
Yes		2-20G-80K		K. W.			Own	2	Axle		Live	Swinging		85x30			Struct.	136	22500	**Minneapolis**
No	Gr.	1-2G-10K	Bennett		B & B	D. D.	Own	1	Axle	No	Live	Swinging	2	42x8		2	Cast.	67½	2300	**Mohawk E**
No	Gr.	1-15G	Bennett	Remy	B. & B.	D. D.	Own	1	Rim	Yes	Dead		2	52x8			None		3380	**Moline D**
No	Gr.	1-28G	Bennett	Bosch	T. D.	D. D.	Own	2	Axle	No	Live	Knuckle	3	52x10		2	Struct.	100	6850	**Nilson**
Yes	Pres.	2-1G-23K	Donald.		Own	Shoe	Own	2	Rim	No	Rev.	Knuckle	2	51x12		2	Struct.	80	6682	**Oil Pull K**
Yes	Pres.	2-1G-31K	Donald.		Own	Shoe	Own	2	Rim	No	Rev.	Knuckle	2	56x16		2	Struct.	92½	9600	**Oil Pull H**
Yes	Pres.	2-1G-45K	Donald.		Own	Shoe	Own	2	Rim	No	Rev.	Knuckle	2	64x20		2	Struct.	103	12820	**Oil Pull G**
Yes	Pres.	2-3G-70K			Own	Shoe	Own	1	Rim	No	Rev.	Swinging	2	80x30		2	Struct.	141	26700	**Oil Pull E**
No	Gr.				Own		Own	1	Rim	Yes	Dead	Knuckle	2	48x7		2	Struct.	72	3000	**Oshkosh M**
Yes	Gr.	2-1G-13K	Bennett	Kent	Own	Cont.	Own	1	Rim	Yes	Rev.	Knuckle	2	56x10		2	Cast.	90	3800	**Oshkosh H**

ing; **Dist.**—Distillate; **Hori.**—Horizontal; **Pres.**—Pressure; **Throt.**—Throttle; **Cont.**—Contracting Band; **Fric.**—Friction; **G.**—Gasoline; **K.**—Kerosene **O.**—Oil; **B.-L.**—Brown-Lipe; **Ecc.**—Eccentric; **Hyd.**—Hydraulic; **T. D.**—Twin Disk.

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No	Gr	1-5G-25K	Taco	Eisemann	Own	Cone	Own	3	Axle	No	Live	Knuckle	2	50x12		2	None	84	4700	**Peoria**	**L**
Yes	Gr	1-30G	Bennett		Own	D. O	Own	3	Hub	No	Live	Knuckle	2	60x18		2	Struct.	89	6500	**Pioneer**	
Yes	Gr	2-75G-30K	Bennett	K. W	Own	D. D.	Own	3	Hub	No	Live	Knuckle	2	96x24		2	Struct.	156	24000	**Pioneer**	
No	Gr	5G-25K	Own	Eisemann	Rock	Fric	Own	2	Rim	No	Rev	Knuckle	2	56x10		2	Chan	93	5960	**Port Huron**	**A**
Yes	Pres	1-15K		Dixie	Own	Shoe	Own	1	Axle	No	Live	Swinging	2	48x10		2	Struct.	66	3785	**Reliable**	
No	Gr	1-5G-20K		K. W		D. D.	Own	2	Rim	No	Live	Knuckle	2	60x10		2	Struct.		5600	**Rex**	
No	Gr	2-3G-20K	Own	Simms	Own	D. O.	Own	2	Axle	No	Live	Knuckle	2	45x12		2	None	64¼	3034	**Samson**	**M**
Yes	Gr	1-5G-15K	Bennett		Own	Cone	Own	2	Rim	No		Knuckle	2	48x12		2	Struct.	96	4724	**Sandusky**	**J**
Yes	Gr	1-5G-25K	Bennett		Own	Shoe	Own	3	Rim	No		Swinging	2	56x16		2	Struct.	100	8228	**Sandusky**	**E**
No	Gr	1-17G	Bennett	Dixie	Fuller	D. O.	Fuller	3	Axle	No	Dead	Knuckle	2	42x12		2	Struct.	72	3300	**Shelby**	**C**
No	Gr	2-4G-14K	Bennett	Dixie	T. D.	D. D.	Foote	2	Rim	No	Live	Knuckle	2	48x12		2	Struct.	80	4500	**Shelby**	**D**
No	Gr	1-15G	Oren	Bosch	T. D	D. D.	Foote	2	Spoke	No	Dead	Knuckle	2	42x12		2	Struct.	87	3450	**Steady Pull**	
Yes	Gr	1-32½K	Own	Dixie	Own	Cont	Own	1	Axle	No	Live	Knuckle	2	60x12		2	Cast	114	7200	**Stinson**	
No	Gr	2-1G-24K	Optional	Dixie	T. D	D. D.	Own	2	Hub	Yes	Dead	Knuckle	2	36x16		2	Struct.	81⅞	5200	**Tioga**	
No		1-16K	Own	K. W	Own	Shoe	Own	2	Spoke	No	Dead	Knuckle	2	54x10		2	Struct.	91	5710	**Titan**	
No	Gr	1-25G	Bennett	Eisemann	Hilliard	D. O.	Own	3	Rim	No	Dead	Swinging	4	42x12			Struct.	100	7800	**Topp-Stewart**	**B**
No	Gr	1-11G	Donald		Own	Cont	Own	2	Spoke	No	Dead	Knuckle	2	41x6		2	None	54	2600	**Toro**	
Yes	Pres	1-12K	Optional	K. W	Own	Shoe	Own	1	Axle	No	Live	Knuckle	2	48x12		2	Struct.	84	4500	**Townsend**	
Yes	Pres	1-18K	Optional	K. W	Own	Shoe	Own	1	Axle	No	Live	Knuckle	2	56x18		2	Struct.	90	6500	**Townsend**	
Yes	Pres	1-35K	Optional	K. W	Own	Shoe	Own	1	Axle	No	Live	Knuckle	2	60x24		2	Struct.	110		**Townsend**	
No	Vac	2-5G-55K	Pomona	K. W	Own	Plate	Own	2	Rim	No	Dead				2		Struct.			**Tracklayer**	**60**
No	Gr	1-12G	Oren	Dixie	B. & B	D. D.	Own	1	Rim	No	Dead	Knuckle	4	38x10		2	Struct.	76	1750	**Traylor**	
	Gr	2-3G-26K	Own	Bosch	Hilliard	Plate	Own	2	Axle	No	Live				2		None		9200	**Trundaar**	
No	Gr	2-1½G-23K	Bennett	Bosch	T. D	D. D.	Own	2	Axle	No	Live	Knuckle	2	50x12		2	Cast	84	4660	**Twin City**	
No	Gr	2-1½G-40K	Bennett	Bosch	T. D	D. D.	Own	2	Axle	No	Live	Knuckle	2	60x20		2	Cast	97	8440	**Twin City**	
No	Gr	2-10G-95K		K. W	Own	Cont	Own	1	Rim	No	Rev	Knuckle	2	84x24		2	Struct.	144	23700	**Twin City**	
No	Gr	1-20G or K	Bennett	Brlng	T. D	D. D.	Own	2	Axle	No	Live	Knuckle	2	48x12		2	Pressed	84	3560	**Wallis**	**K**
Yes	Gr	2-1G-20K		Dixie	Own	Cont	Own	2	Rim	No	Rev	Knuckle	2	52x12		2	Struct.		5910	**Waterloo Boy**	**N**
No	Gr	2-10G-20K	R. W	Dixie	T. D	D. D.	Foote	2	Spoke	No	Rev	Knuckle	2	48x12		2	Struct.	85½	4500	**Wellington**	**B**
No	Gr	2-10G-15K	R. W.	Dixie	T. D	D. D.	Foote	2	Axle	No	Live	Knuckle	2	48x12		2	Struct.	75½	5000	**Wellington**	**F**
No	Gr	2-2G-12K			Fuller	D. O.	Fuller	3	Spoke	No	Dead	Knuckle	2	46x10		2	Struct.	74	2900	**Wetmore**	
No	Gr	2-2G-15K			Own	Cont	Own	3	Axle	No	Live	Knuckle		48x10			Pressed	81	3000	**Whitney**	**D**
No	Gr	2-½G-28K	Bennett		T. D	D. D.	Nuttall	2	Axle	No	Live	Knuckle	2	48x12		2	Struct.	93⁵⁄₁₆	6000	**Wichita**	**T**
No	Gr	2-5G-25K	Optional		T. D	D. D.	Foote	2	Rim	No	Rev	Knuckle	2	52x12		2	Struct.	90	5440	**Wisconsin**	
No	Gr	2-5G-25K	Optional		T. D	D. D.	Foote	2	Rim	No	Rev	Knuckle	2	52x12			Struct.	92	7800	**Wisconsin**	
No	Gr	2	Pomona	Bosch	Paragon	D. D.	Own	2		No		Swinging			2		Struct.	90	5680	**Yuba**	
No	Gr	2-4G-21D	Pomona	Bosch	Paragon	D. D.	Own	2		No		Swinging			2		Struct.		9980	**Yuba**	
No	Gr	2-8G-38K	Pomona	Bosch	Paragon	D. D.	Own	2		No	Dead	Swinging			2		Struct.		9980	**Yuba**	
Yes	Vac	2-5G-25K	Leonard	Bosch	B. & B	D. D.	Own	4	Rim	No	Rev	Knuckle	2			2	Struct.	72	3800	**Zelle**	

ing; **Dist.**—Distillate; **Hori.**—Horizontal; **Pres.**—Pressure; **Throt.**—Throttle; **Cont.**—Contracting Band; **Fric.**—Friction; **G.**—Gasoline; **K.**—Kerosene; **O.**—Oil; **B.-L.**—Brown-Lipe; **Ecc.**—Eccentric; **Hyd.**—Hydraulic; **T. D.**—Twin Disk.

INSTRUCTION No. 78

MISCELLANEOUS ENGINES: Farm Lighting Plants; Two-Cycle Engines; Diesel Engines; Gas Producers

THE DELCO-LIGHT PLANT

This outfit consists of a gasoline engine of the four-cycle type, together with an electric generator of 32 volts, which is direct driven, as shown below (Fig. 1). A set of batteries (32 volts) is provided. The generator charges the battery in a similar manner to that in which the battery is charged on an automobile. An automatic cut-out is used which disconnects the battery from the generator.

The gasoline engine runs the generator or dynamo which charges the batteries; thus the electric supply for lights, power, etc., is taken from the battery when the engine is not running. The manufacturer is the Delco-Light Co., Dayton, Ohio.

Specifications of the Delco-Light Plant as Shown in Fig. 1

Engine: Air-cooled, single cylinder; Delco-Light battery ignition; simple mixing valve; operates on kerosene, gasoline, or natural gas; self-cranking; stops automatically when battery is charged; splash system of lubrication—one place to oil; height 30″; length, 25″; width, 20″; bore 2½″, and 5″ stroke.

Generator: Direct connected to engine; for 32-volt service; full-load output, 850 watts.

Switchboard: Mounted on generator frame.

Battery (not shown); 160 ampere-hour capacity.

850-watt generating unit only; shipping weight, one crate 425 lbs.

No. 866: 850-watt plant with 160 A.H. battery (glass jar); shipping weight, five crates, 1,273 lbs.

Uses: General farm, school, store, church, and country-home service, with sufficient power to operate motors up to ¾ h.p., when engine is running.

Addresses of Manufacturers of Farm-Lighting Plants

Cushman Motor Works, Lincoln, Neb.
Delco-Light Co., Dayton, Ohio.
Edison: Edison Storage Battery Co., 195 Lakeside Ave., Orange, N.J.
Fairbanks, Morse & Co., 900 South Wabash Ave., Chicago, Ill.
Globe Electric Co., 13 Keefe Ave., Milwaukee, Wis.
Kohler Co., Kohler, Wis.
Lalley Light Corp., 3171 Bellvue Ave., Detroit, Mich.
Main Electric Company, Merion Bldg., Cleveland, Ohio.
Matthews Engineering Co., 450 Monroe St., Sandusky, Ohio.
National Electric Lighting Co., Wilton, Iowa.
Phelps Light & Power Co., Rock Island, Ill.
Regal Gasoline Engine Co., Coldwater, Mich.
Stearns Motor Mfg. Co., Ludington, Mich.
Sunbeam Electric Co., Morgan Ave. and Read St., Evansville, Ind.
Nichols-Wright Motor Co., 38 Parkridge St., Buffalo, N.Y.
Warnerlite Products Corp., 518 Harrison St., Davenport, Iowa.
Western Electric Co., 195 Broadway, New York City, N.Y.

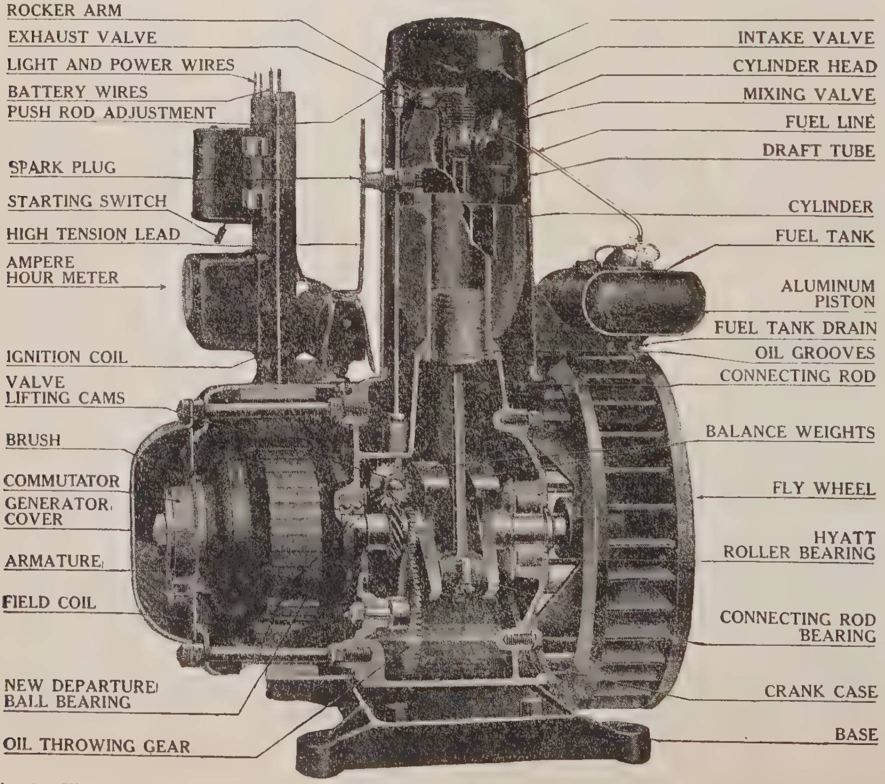

Fig. 1. Illustration showing the parts of the Delco-light plant (850 watt capacity; 32 volts), model 866.

THE TWO-CYCLE ENGINE

The two-cycle type of engine is especially adapted for small-powered launches, where light weight and medium power are the main requisites.

The two-cycle engine is divided into three types: the "two-port," which is adapted for slow speed; the "three-port" high-speed; and the combined "two and three-port," suitable for power work.

The **fuels** generally used are gasoline and kerosene, and on heavy-duty commercial boats a still lower grade of oil is used. On larger heavy-duty engines of this type, the four-cycle principle is generally employed.

The Two-Port Two-Cycle Engine

The action of the two-port two-cycle engine is explained in the illustrations (Figs. 2 and 3).

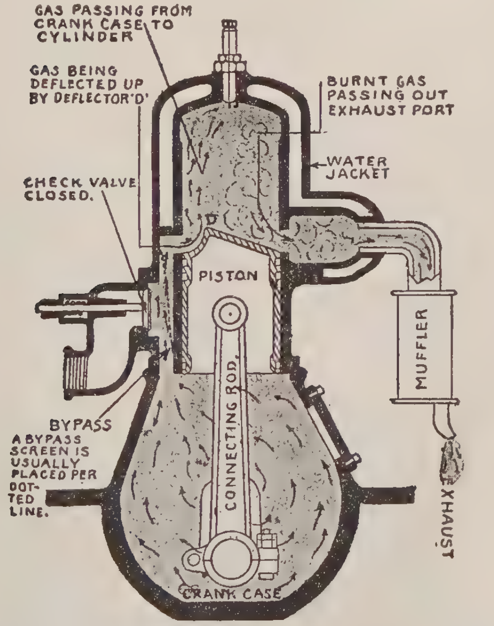
GAS PASSING FROM CRANK CASE TO CYLINDER
GAS BEING DEFLECTED UP BY DEFLECTOR 'D'
BURNT GAS PASSING OUT EXHAUST PORT
WATER JACKET
CHECK VALVE CLOSED.
D
PISTON
MUFFLER
CONNECTING ROD
BYPASS
A BYPASS SCREEN IS USUALLY PLACED PER DOTTED LINE.
EXHAUST
CRANK CASE

Fig. 2. **Two-port two-cycle engine.** The **piston** is now at the **bottom** of its stroke. Notice that two actions are taking place: (1) gas is entering the cylinder from the crank case through the "by-pass" port; (2) the combusted gas is passing out of the exhaust port. Thus we have intake and exhaust occurring simultaneously.

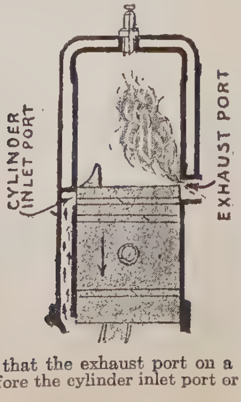

Fig. 3. Note that the exhaust port on a two-cycle engine opens slightly before the cylinder inlet port or "by-pass" opens.

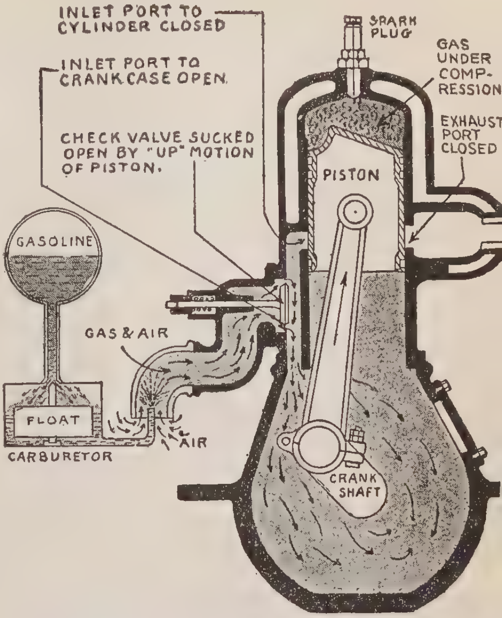
INLET PORT TO CYLINDER CLOSED
INLET PORT TO CRANKCASE OPEN.
CHECK VALVE SUCKED OPEN BY "UP" MOTION OF PISTON.
SPARK PLUG
GAS UNDER COMP-RESSION
EXHAUST PORT CLOSED
PISTON
GASOLINE
GAS & AIR
FLOAT
AIR
CARBURETOR
CRANK SHAFT

Fig. 4. The **piston is almost at top of stroke.** Note tha two actions are taking place: (1) the gas is being compresse and the spark is just about to take place; (2) fresh gas is entering the crank case from the carburetor through the inlet por to the crank case.

The two-cycle or "valveless" type of engin derives its name from the fact that the gas is le into and out of the cylinder through "port-holes' as they are uncovered by the piston. These port

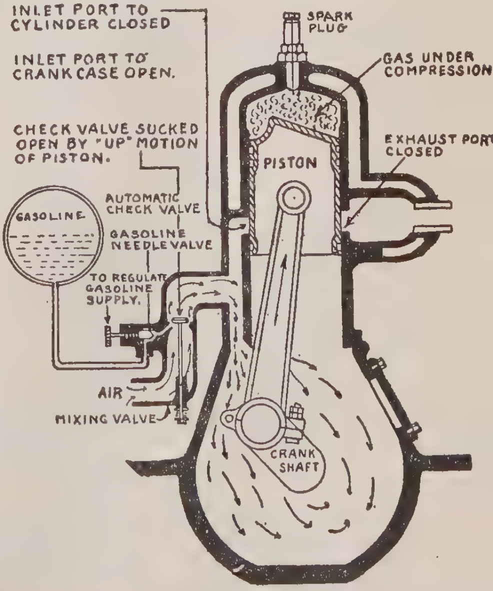
INLET PORT TO CYLINDER CLOSED
INLET PORT TO CRANKCASE OPEN.
CHECK VALVE SUCKED OPEN BY "UP" MOTION OF PISTON.
SPARK PLUG
GAS UNDER COMPRESSION
EXHAUST PORT CLOSED
PISTON
AUTOMATIC CHECK VALVE
GASOLINE
GASOLINE NEEDLE VALVE
TO REGULATE GASOLINE SUPPLY.
AIR
MIXING VALVE
CRANK SHAFT

Fig. 5. When a mixing valve is used, the check valve is part of the mixing valve.

When a **carburetor** is **used** with a "two port" type of engine a check valve must be used, as shown in Figs. 2 and 4 A carburetor can be used, however, with a three-port typ without a check valve, as the port is opened and closed b the piston; in fact, this is where the **three-port type** engin differs from the two-port type.

take the place of valves as used on a four-cycle engine.

During **two** movements or strokes of the piston, the four operations of intake, exhaust, compression, and explosion occur during **one** revolution.

On a four-cycle type of engine this would require **four** strokes of the piston or **two** revolutions.

The terms two-cycle and four-cycle are not appropriate. Originally the terms were "two-stroke-cycle" and "four-stroke-cycle," and these were more nearly correct.

Therefore with **two** movements of the piston, one up and one down, or **one** revolution of the crank shaft, four actions take place: (1) intake of gas into the cylinder; (2) exhaust; (3) compression and intake to the crank case; (4) explosion.

When the piston travels **up**, a vacuum is formed in the crank case which causes the gas to be sucked in through the crank-case inlet port or check valve.

When the piston travels **down**, a pressure is formed in the crank case (5 to 9 lbs.), which forces the gas in the crank case through the "by-pass" into the cylinder. A "baffle plate" (D) (Fig. 2) prevents fresh gas from heading toward the exhaust.

Note that when the piston is **down**, the pressure in the crank case forces the check valve of the carburetor to close (Fig. 2). When the piston is going **up**, the vacuum formed in the crank case sucks the check valve open (Fig. 4).

The crank case forms an intermediate reservoir for the gaseous mixture.

MARINE ENGINES

Marine engines are built along the same lines as the automobile engine when of the four-cycle type, but with the addition of a governor on large engines.

The smaller types of marine or motor-boat gasoline engines are frequently of the two-cycle type.

The marine engine is built heavier than the automobile engine because it is run most at full speed or power for long periods of time. However, the modern marine engine is capable of varying speed through the use of the throttle and spark, as in the case of the automobile engine.

The **ignition** for marine engines is similar to the automobile engine, but in many instances the "make-and-break" system, and oscillating type, as well as the K. W. is used.

On the small two-cycle type, the jump spark with vibrator coil and battery is used to a great extent and also the make-and-break system. In fact, the make-and-break system is used quite extensively on the large four-cycle type of marine engine because it is a low-speed engine and of the low-tension type of ignition, and is not affected by dampness, which is the case where high-tension current is employed. If high tension is used, then it must be well insulated, because of dampness.

The **carburetion** is similar, but on some of the larger and heavy-duty types of marine engines a double carburetor, using gasoline to start on and kerosene to run on, is quite often used.

The **clutch** is used between the engine and reverse gear, and employs practically the same principle as is found in an automobile clutch.

A **gearbox** is sometimes employed which gives one speed ahead with a lower ratio than the direct drive. The reverse gear is also employed. Sometimes, however, the propeller itself is made so that the blades will shift at various angles or pitch, (which reverses the direction of propulsion) in place of a speed gear and reverse.

Books on marine engines and motor boats:[1] We recommend the 4 volumes of the *Motor-Boat Handbook* to those interested in marine engines (price $3.00).

STATIONARY GASOLINE ENGINE

This type of internal combustion engine is usually of the four-cycle type. The cylinders are large in diameter, and the stroke is usually larger than the bore. The speed is slow (160 to 600 r.p.m.), but constant.

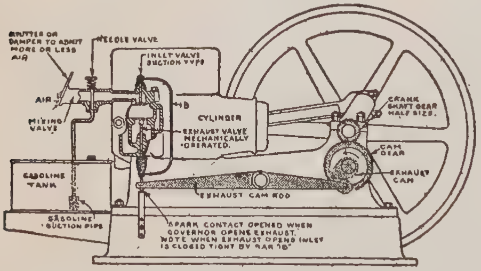
SHUTTER OR DAMPER TO ADMIT MORE OR LESS AIR
NEEDLE VALVE
INLET VALVE SUCTION TYPE
B
CYLINDER
CRANK SHAFT GEAR HALF SIZE.
AIR
MIXING VALVE
EXHAUST VALVE MECHANICALLY OPERATED.
CAM GEAR
GASOLINE TANK
EXHAUST CAM
EXHAUST CAM ROD
GASOLINE SUCTION PIPE
SPARK CONTACT OPENED WHEN GOVERNOR OPENS EXHAUST. NOTE WHEN EXHAUST OPENS INLET IS CLOSED TIGHT BY BAR "1B"

Fig. 6. **A horizontal engine** (Witte), with a rocker arm for operating the exhaust valve mechanically. The inlet valve is automatic, but note that when the exhaust valve is opened, the bar (1B) closes the inlet tight, although a spring is also provided.

A **governor** is used to keep the speed at a certain number of revolutions, and it is due to the governor action on a stationary engine that you will hear exhausts at uneven intervals.

Governors are divided into two general types: the "hit-and-miss" type, and the "throttling" type.

The "hit-and-miss" principle is generally used with engines using gasoline as fuel, and the "throttling" type, with engines using kerosene or lower grades of fuel.

The reason why the "throttling type" of governor is used with kerosene engines is the fact that kerosene, when used as a fuel, enters the combustion chamber almost in the form of a liquid, while gasoline enters more in the form of gas. The combustion chamber on a kerosene engine, accordingly, must be maintained at a fairly high temperature in order properly to vaporize the fuel, and this temperature should also be fairly uniform.

It is the writer's opinion that the reason trouble is experienced from carbon formation, where it is attempted to burn kerosene in a "hit-and-miss" governor engine, is that the combustion chamber on such engines cools off quite frequently during the time that explosions are cut out. This trouble can, of course, be avoided by using a pre-heater in the fuel line on such engines but this is a makeshift arrangement and not generally satisfactory. The "throttling type" of governor is best, as it comes nearer maintaining a uniform temperature.

On some of the engines using a low-grade fuel, no ignition device is used, as, for instance, the Diesel engine. On others, a hot tube is preheated and serves for ignition. The latter requires complete vaporization of the fuel (all of which is covered in Dyke's *Motor Manual*).

The fuel may be either gasoline, naphtha, kerosene, or any one of the many other petroleum products of low grade, when properly heated. Natural and artificial gas are also used.

Ignition is usually jump spark on small engines, and wipe spark, as described on page 187, which is similar to the "make-and-break," on the larger engines.

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[1] Can be secured of A. L. Dyke, Granite Bldg., St. Louis, Mo.

The "hit-and-miss" governor action is shown in Fig. 7.

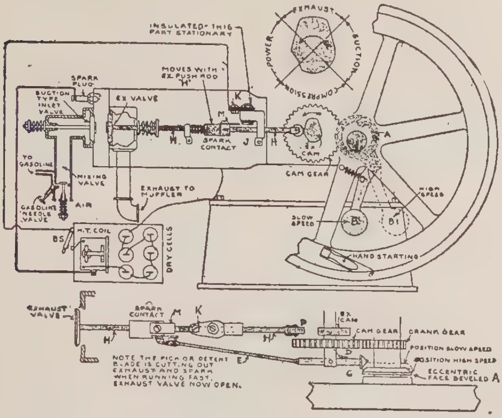


Fig. 7. Illustrating the operation of the "hit-and-miss" governor.

When **the speed of the engine increases** more than that for which the governor is set, the ball (**B**), by centrifugal action, assumes position (**B1**). This causes eccentric sleeve (**A**) to allow pick-blade (**E**) to catch in the notch part of (**M**). This holds open the exhaust valve and also prevents the spark contact (**M**) from coming in contact with (**K**), cutting off the ignition.

When **the speed decreases,** the ball (**B**) assumes a slow-speed position, which causes eccentric (**A**) to move out from the hub of the flywheel and to disconnect the "pick-blade" or "detent-rod" from the notch in (**M**); the engine fires again, and the exhaust valve assumes its regular work until the speed increases again, at which time the same action is repeated. This cutting in and out by the governor accounts for the uneven impulses one notices on a stationary engine.

The throttling type of governor controls the admission of gas into the cylinders instead of cutting off the spark. See Index under "Governor, throttling type."

DIESEL ENGINE

The Diesel engine is used quite extensively for stationary purposes. It is also the type used on submarines. The fuel is a low grade of oil, and ignition is accomplished by air compressed to several hundred pounds pressure, resulting in its temperature being raised sufficiently to ignite the fuel injected into the cylinder.

The fundamental principle is similar to that of the usual four-cycle engine. The main difference is that fuel is injected after the air has been compressed, and ignition is then obtained through the high compression of this air, instead of by an electric spark.

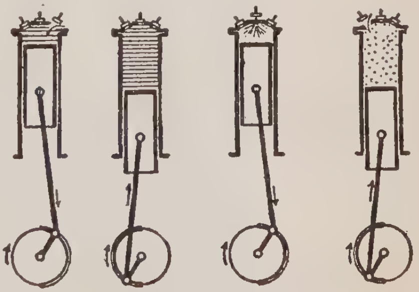
The principle of the "four-cycle" type of Diesel engine may be briefly described as follows: On the first or down stroke of the piston the cylinder is filled with air at the atmospheric temperature and pressure. No fuel is introduced. On the second stroke, the piston travels up and the air, drawn in during the preceding stroke, is compressed to about 500 lbs. per square inch, resulting in its temperature being raised to about 1000° F., or sufficient to ignite any liquid fuel. Then the fuel valve opens and a measured quantity of fuel, usually oil, is injected into the cylinder through an atomizer. The atomized fuel is ignited by the high temperature of the air, and the power stroke follows. On the fourth, or exhaust stroke, the piston travels up and the burned gas is expelled through the exhaust valve. The Diesel engine requires no ignition system, and uses the cheapest of petroleum, crude fuel oils or tar oils.

Diesel Four-Cycle Operation

Stroke 1—Admission or inlet: During this stroke the piston travels downward, and the cylinder is filled with pure air only—at atmospheric temperature and pressure—no fuel being introduced into the cylinder during this stroke.

Stroke 2—Compression: During this stroke the piston travels upward, and the air taken into the cylinder during the preceding stroke is compressed to about 500 lbs. per square inch, resulting in its temperature being raised to about 1,000° F., or sufficient positively to ignite any liquid fuel injected into it. No fuel is introduced into the cylinder until the completion of this stroke.

Stroke 3—Power or working stroke: When the piston has reached the upper end of the compression stroke (or slightly in advance), the fuel valve opens and a measured quantity of fuel oil is gradually injected into the cylinder through the atomizer. This breaks it up into a finely divided spray, the orifices in the atomizer being so proportioned that at full load the admission of fuel is distributed over about 10 per cent of the power or working stroke, the rate of admission being such that there is no appreciable rise of pressure within the cylinder beyond that of compression pressure.



Inlet of air · Compression of air · Combustion and power · Exhaust

Fig. 8. Illustrating the events during four strokes of the cylinder.

The quantity of fuel oil delivered to the atomizer chamber is adjusted to the various load requirements by the action of the governor upon the fuel pump.

The injection air at 750 to 950 lbs. per square inch is furnished by a small two or three-stage compressor, driven from the engine shaft. To prevent the possibility of preignition, this air is thoroughly cooled before being delivered to the atomizer.

When the measured charge of fuel has passed into the cylinder, and during and following combustion, the gases expand and drive the piston downward. When the piston reaches the lower end of the stroke (or slightly in advance), the exhaust valve opens and the remaining pressure is released to the atmosphere.

Stroke 4—Exhaust: During this stroke the exhaust valve remains open, the piston travels upward, and the products of combustion are expelled from the cylinder, completing the cycle.

Brief Explanation of Construction

The general arrangement of the valves and fuel injection apparatus of the Diesel engine, as illustrated in Edward Butler's book on *Carburetors, Vaporizers and Distributing Valves,* is shown in Fig. 9.

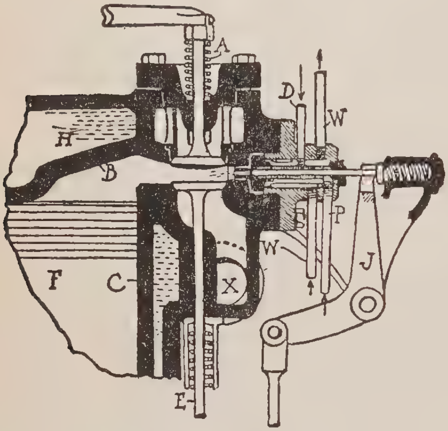


Fig. 9. Section of the Diesel engine. The oil is forced into the cylinder by air pressure.

The cylinder (C) has very little clearance between the top of the piston (F) and the bottom of the combustion chamber (B) at the end of the compression stroke. At this moment the injection valve operated by the lever (J) will be opened, to permit the injection of a charge of fuel forced (during about 20° of the crank revolution) from the supply pipe (P) assisted by an atomizing charge of super-compressed air through the pipe (D). **The cage** containing the injection valve is water-jacketed, water entering and leaving by pipes (W).

The operation of the air-admission valve (A) and the exhaust valve (E) is mechanically controlled in the conventional manner. The movement of the fuel-admission valve is very slight, giving a narrow annular opening for the entry of the oil. Surrounding the valve spindle are a series of brass washers perforated parallel to the spindle by numerous small holes.

The oil is pumped into the space around the valve spindle near its middle, and by capillary action finds its way between the washers and into the perforations.

The air for fuel injection is admitted behind the oil; and because of its high pressure, it blows the oil into the cylinder when the valve opens.

The amount of oil admitted is regulated by the governor, which controls the time of opening of a by-pass connecting the discharge and suction sides of the oil pump. At light loads the oil is pumped to the fuel valve for part only of the admission period, and air alone will enter past the valve for the remainder of the period. (*Motor Age.*)

One manufacturer of the Diesel Engine is the Busch-Sulzer Diesel Engine Co., Second and Utah Sts., St. Louis, Mo.

GAS PRODUCERS

Gas producers are not internal combustion engines, but are **generators** of gas from hard coal, coke, or charcoal.

There are two types, the pressure type and the suction type. The **pressure type** stores the gas into a tank or into the gasometer. The gas is then supplied to any regular type of gas engine as a fuel.

With the **suction type,** the gas is generated in the gas producer, then passes through a washer, and is then drawn into the cylinder of the engine by suction of the piston.

The process of generating gas by means of gas producers consists of passing air, or a mixture of air and steam, through a bed of burning coal, coke, charcoal, or wood contained in a suitable receptacle known as a generator. Dyke's *Motor Manual* explains the gas producer.

INSTRUCTION No. 79

MOTORCYCLES: Engines; Ignition; Carburetors; Transmissions

THE MOTORCYCLE ENGINE

The motorcycle engine is usually a four-cycle type of engine, and is made with one, two, and four cylinders. The air-cooled cylinder is in general use. The "twin type" of cylinder engine shown in the illustration is the most popular, and the cylinders are usually placed 42° to 45° apart.

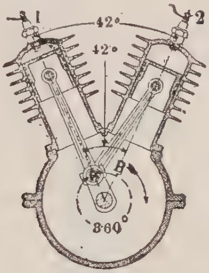


Fig. A

The connecting rods are usually placed on one crank pin. Sometimes there are two crank pins—in this case the firing impulse would differ. The flywheels are usually enclosed in the crank case.

The four-cylinder motorcycle engine is also in use, and is very similar to the automobile engine, but smaller and lighter.

How a Twin-Cylinder Engine Fires

An explanation of how often and the distance apart that the power impulses occur on a twin-cylinder "V"-type of engine, with cylinders placed 42° apart, is given under the illustrations, Figs. 1 to 5.

Indian Twin "V" Motorcycle Engine

Cylinders: Twin, of the V-type, 42° apart, air-cooled, 3⅛″ bore and 3 11/32″ stroke, with a piston displacement of 60.88 cubic inches; horsepower normal rating is 7; actually develops 15 to 18; the **bearings** of the connecting rods and the main crankshaft bearing are of the "roller" type; there are three **rings** to each piston.

Carburetor: Schebler. **Ignition,** Dixie high-tension magneto. Spark plugs are Splitdorf make, ⅞″–18 thread; **lubrication,** oil pump worm-gear driven, geared to the crank shaft.

Valves are the side-valve type, operated by lifter rods. **Valve timing** is correct when gears **(A)** **(B)** **(C)** and **(D)** are placed so that the marks register as shown. The pinion **(A)** is keyed on its shaft and retained by a washer and screw.

Inlet valve action can be understood by referring to Fig. 7. Note that the inlet cam (which is set behind the cam gear) operates against an arm, which operates against the inlet tappet or lift lever.

Exhaust valve action: The same kind of lifting arrangement is provided for the exhaust valve, but the exhaust cam, arm, and lift lever or tappet are placed back, or in rear of the inlet parts.

—Continued on page 1009.

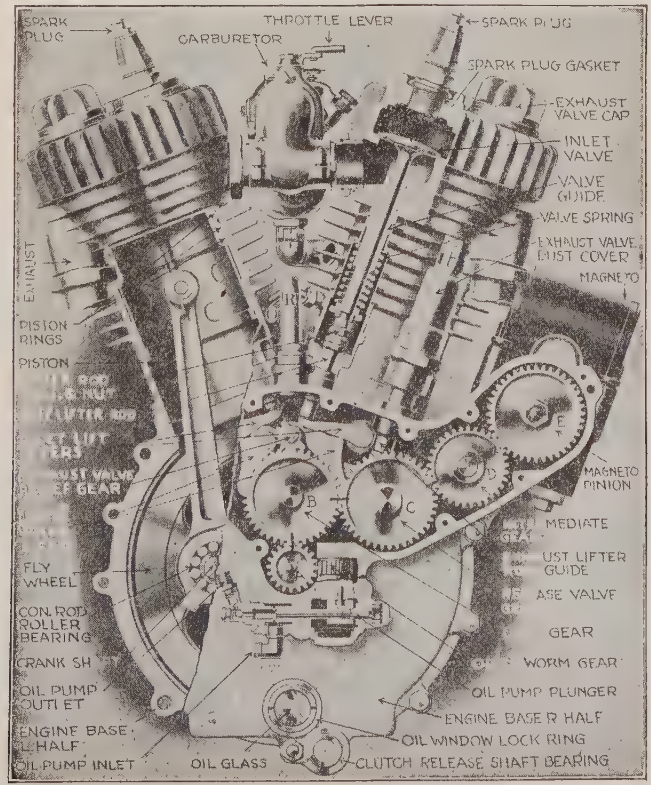


Fig. B. The Indian twin-cylinder motorcycle engine.

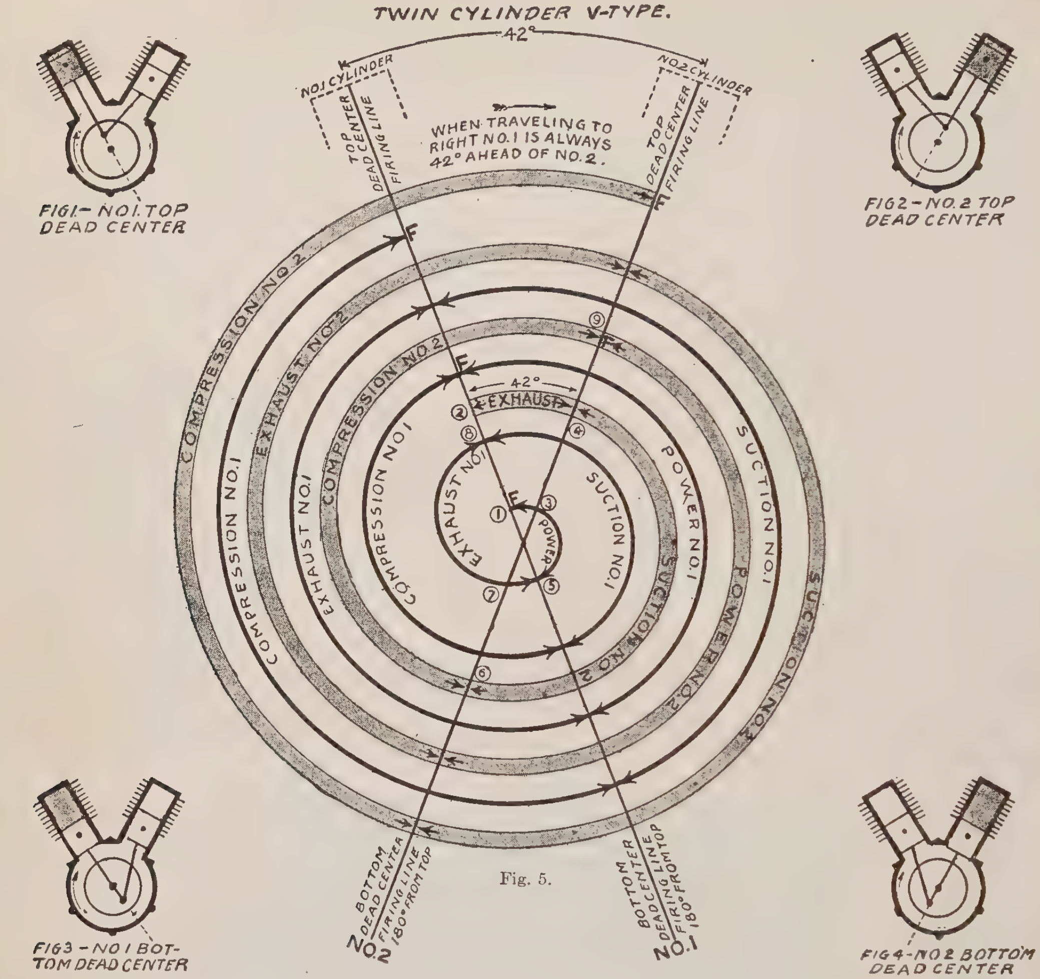


FIG1 – NO1 TOP DEAD CENTER

FIG2 – NO.2 TOP DEAD CENTER

FIG3 – NO 1 BOTTOM DEAD CENTER

FIG4 – NO 2 BOTTOM DEAD CENTER

Figs. 1, 2, 3, 4, 5: How a twin-cylinder engine fires, with cylinders 42° apart.

Fig. 1 illustrates two cylinders placed 42° apart. We will call the cylinder to the left No. 1, and the cylinder to the right No. 2. The bottoms of the connecting rods are together on one crank pin.

Note that No. 1 piston is on top of its stroke and that the connecting rod is straight up and down, in line with the crank pin; in other words, it is on its "firing center" (provided it is on top of the compression stroke, which we assume it to be). Piston No. 2 is not on top of its stroke; its connecting rod where it is attached to the crank pin is 42° away from its firing center. No. 2 has 42° yet to travel to complete its exhaust stroke (see 2 to 4, Fig. 5).

Fig. 2: No. 1 has fired and traveled 42° on its power stroke (see 1 to 3, Fig. 5). No. 2 piston is now on top of its suction stroke (4), and on its dead-center firing line.

Fig. 3: No. 1 has reached the bottom of its firing or power stroke (see 5, Fig. 5), having traveled 180°, or half a revolution. No. 2 is not quite down in its suction stroke, being 42° behind No. 1.

Fig. 4: No. 2 has now reached the bottom of the stroke on suction, having traveled 180°, whereas No. 1 is part of the way up on its exhaust stroke.

Therefore, starting with the firing of No. 1 at (1F), if No. 1 makes a complete revolution—one stroke down on power stroke and one stroke up on exhaust, from 1 to 8—it will have traveled 360°. No. 2, however, will lack 42° of completing its revolution, and will have to travel 42° more than 360° to complete its revolution from 2 to 9.

Therefore, after No. 1 fires, No. 2 must travel 360° + 42°, or 402°, before it fires. Or No. 1 will fire again, 318° after No. 2. fires.

Fig. 5: The black line shows the travel of No. 1, and the shaded line the travel of No. 2. The firing lines of each, or the top and bottom center, are lettered on the illustration.

Start with No. 1 firing at (F) and follow the stroke to the bottom, or a half-revolution; for instance, from 1 to 5 on No. 1 and 4 to 6 on No. 2; each represents a stroke or half-revolution, or 180°.

From 1 to 8 on No. 1 represents a revolution, or 360°.

From 2 to 9 represents 42° more than a revolution on No. 2. From 4 to 9 would represent a revolution on No. 2.

While observing the travel of No. 1, at the same time follow No. 2 and note what it is doing. For instance, when No. 1 is traveling from 1 to 3 on its firing or power stroke, No. 2 is traveling from 2 to 4 on its exhaust stroke, having 42° of its exhaust stroke to complete before it is on its dead center, when it starts on its suction stroke.

—*Continued from page* 1007.

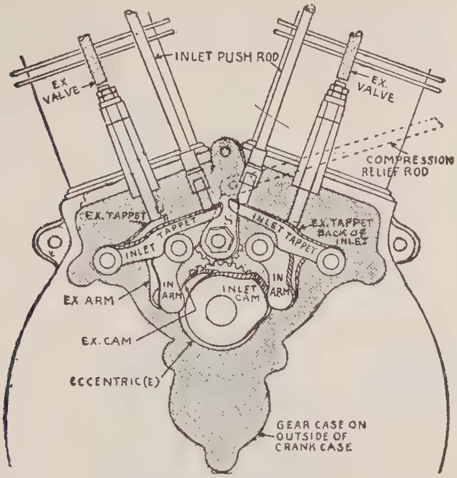


Fig. 7. Valve action.

A **"compression relief,"** or method of opening the exhaust valves to relieve the compression when starting an engine is provided. This is accomplished by a toothed part (**S**) in mesh with a thin eccentric or cam (**E**). When the rod is operated, it causes (**E**) to touch the exhaust rollers on the exhaust arms, which raises the exhaust valves independent of the exhaust cam.

Valve-clearance adjustment is .006″, about the thickness of heavy writing paper, when the engine is hot. Spark-plug gap, .025″.

(**O**) (Fig. **B**) is the oil-pipe connection.

(**R**) is the breather or crank-case vent.

Indian Twin-Opposed Cylinder Motorcycle Engine

Cylinders: two, opposite or 180° apart, instead of 42° as in the "V"-engine; **bore** 2″; **stroke** 2½″; **piston displacement,** 15.70 cubic inches; **horsepower,** normal rating 2¼, develops 4; pistons have two rings; **inlet and exhaust valves,** side by side on top of the cylinders; **timing gears,** in separate housing outside of the crank case; **carburetor,** Indian special; **ignition,** Dixie magneto, driven at engine speed, fixed or set spark. (Hendee Mfg. Co., Chicopee Falls, Mass.)

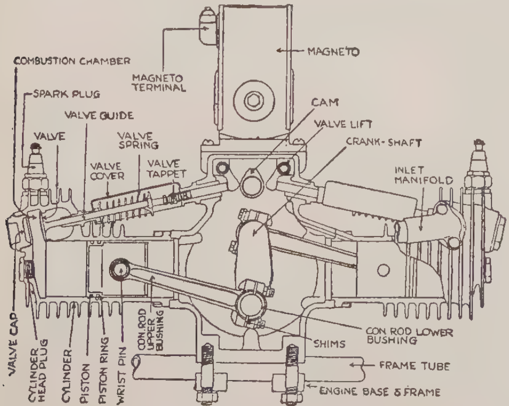
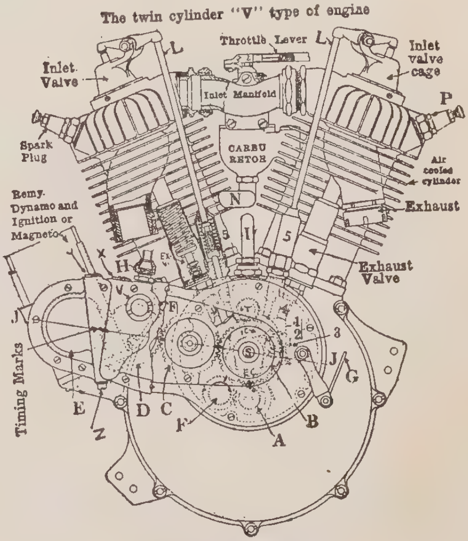


Fig. 8. Indian twin-opposed engine.

Harley-Davidson Twin "V" Motorcycle Engine

Cylinders set 45°; **valves,** inlet overhead in cage, operated by push rods (**L**); exhaust on the side; **bore** 3 5/16″ x 3½″ stroke; 60.34 cu. in. displacement; **valve clearance,** .004″ between exhaust lifter and valve stem (engine cold), on all single-cylinder models and twin engines prior to 1915. Allow .004″ clearance between inlet and rocker arm and valve stem on all models. On 1916 and 1915 twin engines, allow .004″ for rear cylinder and .006″ for front, and on 1917 to 1920 twin engines, allow .008″ to .010″ for both cylinders.



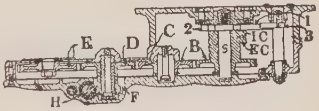


Fig. 9 (upper)
Fig. 10 (lower)

Fig. 9. Side view of H. D. engine.

Fig. 10. Top sectional view of gears and cams; (1) exhaust relief cam; (3) cam on arm of rod (G) (Fig. 9) which operates the relief cam; (EC) exhaust cam; (IC) inlet cam; (2) rollers on rocker arm; (S) cam shaft; (B) cam gear. Other gears correspond with the gears in Fig. 9.

Valve timing, on twin and single-cylinder engines: The exhaust valve should start to open about 9/16″ before bottom center; closes 1/32″ to 3/32″ after top. The inlet valves do not require independent timing. However, the inlet valves start to open 3/16″ before top and close ⅛″ to ⅜″ past top. When timing the ignition, be careful not to use the wrong cam in timing. The small cam is for the front cylinder, and the large cam is for the rear.

When fitting new gears, they should be lined up in accordance with the marks shown in Fig. 9, so that the marks come in a vertical line. (**A**) is the crank-shaft gear; (**B**) the cam gear.

The exhaust compression relief is to relieve compression in the cylinder for easy starting by opening the exhaust valve. When starting, the left-hand handle-bar grip is twisted to the left, which retards ignition, and further turning raises the exhaust valve through rod (**G**) (Fig. 9), which raises the exhaust valve through cams (1) and (3) (Fig. 10).

Crank-case compression relief: A vent (**I**) (Fig. 9) relieves the pressure in the crank case at every revolution. The gear (**F**) operates a rotary relief valve which should open 1/16″ to 3/32″ when the front piston is on top. This valve port opens gradually when the engine is turned in the direction in which it runs, and closes when the piston has reached bottom. This allows a vacuum on the upward stroke, to draw oil and oil vapor to all bearings. A pipe leads to the chain cover, and as it emits a slight amount of oil at each revolution, the chain is oiled.

Oiling system: Oil enters from the oil reservoir through pipe connection (H). It is then carried by a rotary valve pump geared to shaft (F) (Fig. 10), through sight glass (V) into the engine crank case.

If there is **too much oil,** remove screw (X); if oil does not overflow, turn the engine until it does. Replace (X). Then remove the plunger-chamber vent screw (Y) until oil flows in the same manner. Then regulate the oil supply by placing three .010″ washers on the adjusting screw (Z) (Fig. 9). Drain the engine and fill with 1½ pumpfulls of oil with the hand pump. **To increase the oil supply,** add thin washers, one at a time. **To decrease,** remove the washers. When all washers are removed the oil-pump plunger has no stroke at all.

Timing ignition: All twin engines, magneto equipped, fire ¼″ to 5/16″ before top of compression stroke with the spark lever advanced full. The spark occurs when the points are just separating.

All twin electrically equipped engines fire 7/32″ to 9/32″ before top. All single-cylinder engines fire 3/16″ to ¼″ before top.

Berling magneto: The lower cam on the interrupter times for the front cylinder and the upper cam for the rear.

Dixie magneto: No. 2 cam for front, No. 1 cam for rear.

Bosch magneto: Interrupter shoe No. 2 for front, and No. 1 for rear.

Remy generator interrupter: Small cam for front, and large cam for rear. (Harley-Davidson Motor Co., Milwaukee, Wis., Mfrs.)

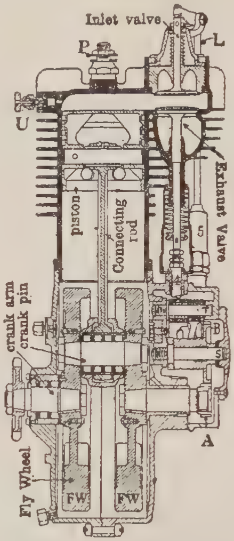


Fig. 11. Sectional view of engine shown in Fig. 9.

MOTORCYCLE CLUTCH AND TRANSMISSION (INDIAN THREE-SPEED AS EXAMPLE)

Operating plan of three-speed Indian motorcycle: The principle of construction and operation of the three-speed gear are identical with that of the two-speed, except that there is an extra set of gears for the intermediate ratio.

When gears (A) and (B) are locked together by dogs (G), the "high ratio" or "high speed" is coupled up.

When gears (B) and (E) are in mesh the "intermediate" or "second speed" ratio is obtained.

And when gears (B) and (C) are connected through the dogs (H), the "low speed" is obtained.

There are two "neutral" positions in this gear set: between the high and intermediate with the gears as shown in the illustration, and between the intermediate and low, with gear (B) on the other side with (E), with the same relative position.

—*Continued on page* 1012.

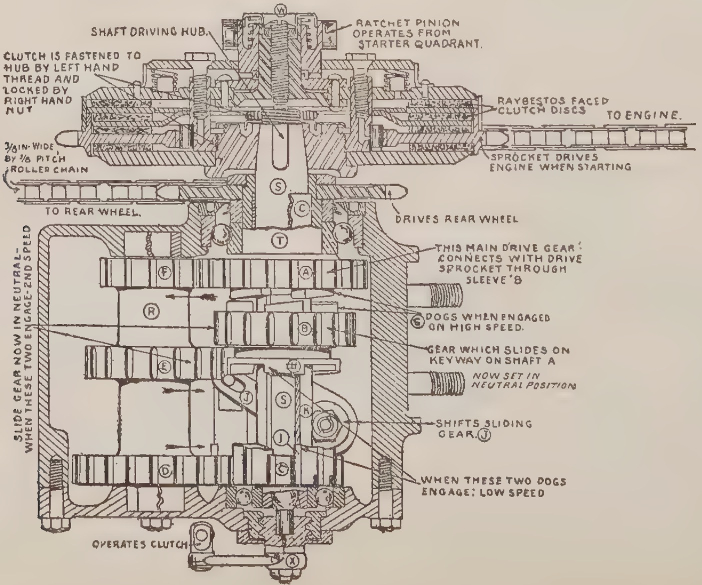

W
SHAFT DRIVING HUB.
RATCHET PINION OPERATES FROM STARTER QUADRANT.
CLUTCH IS FASTENED TO HUB BY LEFT HAND THREAD AND LOCKED BY RIGHT HAND NUT
RAYBESTOS FACED CLUTCH DISCS
TO ENGINE.
3/8 IN. WIDE BY 3/8 PITCH ROLLER CHAIN
SPROCKET DRIVES ENGINE WHEN STARTING
S
TO REAR WHEEL.
C
DRIVES REAR WHEEL
T
THIS MAIN DRIVE GEAR CONNECTS WITH DRIVE SPROCKET THROUGH SLEEVE B
F
A
R
B
G
DOGS WHEN ENGAGED ON HIGH SPEED.
GEAR WHICH SLIDES ON KEYWAY ON SHAFT A
SLIDE GEAR NOW IN NEUTRAL- WHEN THESE TWO ENGAGE-2ND SPEED
E
H
NOW SET IN NEUTRAL POSITION
J
S
K
SHIFTS SLIDING GEAR J
J
D
C
WHEN THESE TWO DOGS ENGAGE: LOW SPEED
OPERATES CLUTCH
X

Fig. 12. The Indian clutch and 3-speed transmission

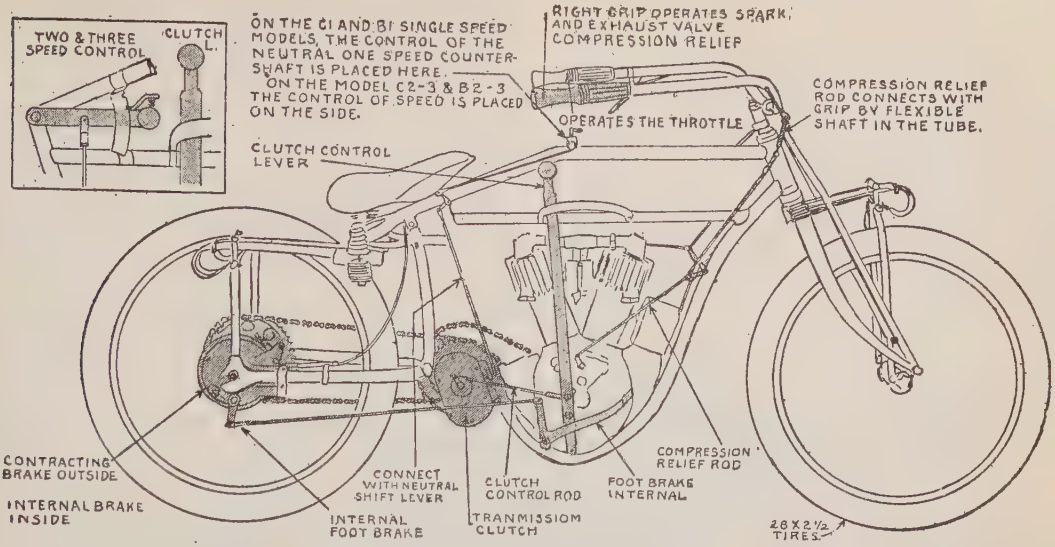

TWO & THREE SPEED CONTROL
CLUTCH L.
ON THE C1 AND B1 SINGLE SPEED MODELS, THE CONTROL OF THE NEUTRAL ONE SPEED COUNTER-SHAFT IS PLACED HERE.
ON THE MODEL C2-3 & B2-3 THE CONTROL OF SPEED IS PLACED ON THE SIDE.
RIGHT GRIP OPERATES SPARK, AND EXHAUST VALVE COMPRESSION RELIEF
COMPRESSION RELIEF ROD CONNECTS WITH GRIP BY FLEXIBLE SHAFT IN THE TUBE.
OPERATES THE THROTTLE
CLUTCH CONTROL LEVER
CONTRACTING BRAKE OUTSIDE
INTERNAL BRAKE INSIDE
CONNECT WITH NEUTRAL SHIFT LEVER
INTERNAL FOOT BRAKE
CLUTCH CONTROL ROD
TRANMISSION CLUTCH
FOOT BRAKE INTERNAL
COMPRESSION RELIEF ROD
28 X 2½ TIRES

Fig. 13. The Indian twin-type of motorcycle using a neutral counter shaft.

If the machine is equipped with this one-speed device, called a "neutral counter shaft," its purpose is mainly to promote starting without raising the rear wheel. By shifting the small lever underneath the handle bar, the dogs are disengaged, and the drive to the rear is cut out. The clutch is then engaged and the engine started. After the engine is started the clutch is disengaged until the machine is started.

If the three-speed gear box is used instead of a single speed, it is mounted in the same location, but a control lever is placed on the side, as shown at top left of the illustration, instead of the small hand lever. When starting with a two or three-speed the gears are shifted to neutral position and the action is just the same as above. Note the name and location of the parts as lettered.

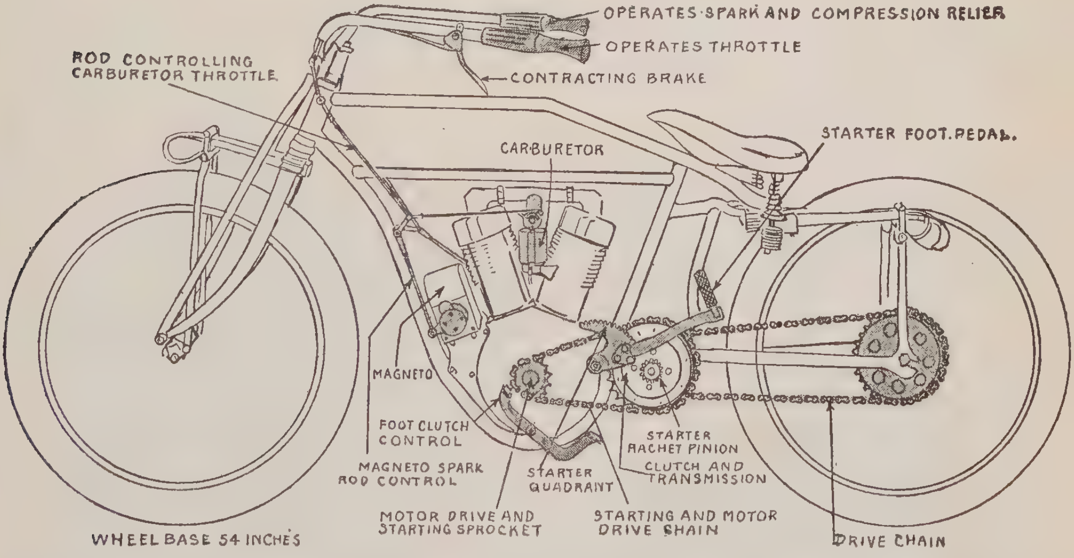


Fig. 14. **The Indian starter:** The down-pressure on the foot lever brings the quadrant into engagement with the pinion on the clutch and turns the engine over three times to each stroke, the clutch being engaged to obtain positive and full crank effect.

This starting of the engine can be done without jacking up the rear wheel, simply by putting the shifting lever into neutral on the three-speed machine and by disengaging the driving cog in the same manner on the single-speed model.

When the starting crank is released on the bottom of the stroke, it is automatically returned to the starting position by a strong coil spring, and when not in use is held in a convenient position by a strong clip. When the starting crank is in normal position, it is fully disengaged from the pinion which revolves with the clutch.

The mechanism consists of a quadrant with a reverse motion and meshes with a ratchet pinion on the clutch shaft. The ratio is three turns of the engine to one stroke of the starter, not taking into account the spinning effect and extra momentum gained.

Note. The models illustrated are the early models. Changes have been made on the later models. The "neutral counter-shaft" has not been used on the Indian since 1917, and wire controls have been used since 1918. The gear-shift lever and clutch pedal arrangement have also been changed. **The reason for showing the older model of motorcycle** is the fact that the older models are those more likely to need repairing, and they clearly explain the principles involved. Write the manufacturers for information on later models.

Continued from page 1010.

Indian Clutch

Construction: The Indian clutch is a multiple-disk dry-plate type. The drive is transmitted through four Raybestos-faced disks which engage with four polished steel disks, and are held in engagement by eight small springs equal distances apart.

This clutch is applied to the one, two, or three-speed transmission.

Operation: Lever (X) (Fig. 12) operates the clutch, and has about 45° travel. When pulled forward, it releases the clutch; when pulled backward, it engages the clutch.

It is connected with the foot pedal, which has a pull-back spring. Pressure on the pedal forward causes the plunger rod (marked by mistake, "shaft driving hub") to come in contact with the screw (W), which under pressure compresses the springs and pulls outward the whole assembly mounted on the inner plate, thus freeing the driving disks.

When the control pedal is released, the pull-back spring causes a reverse action through the mechanism, and again brings the disks into engagement.

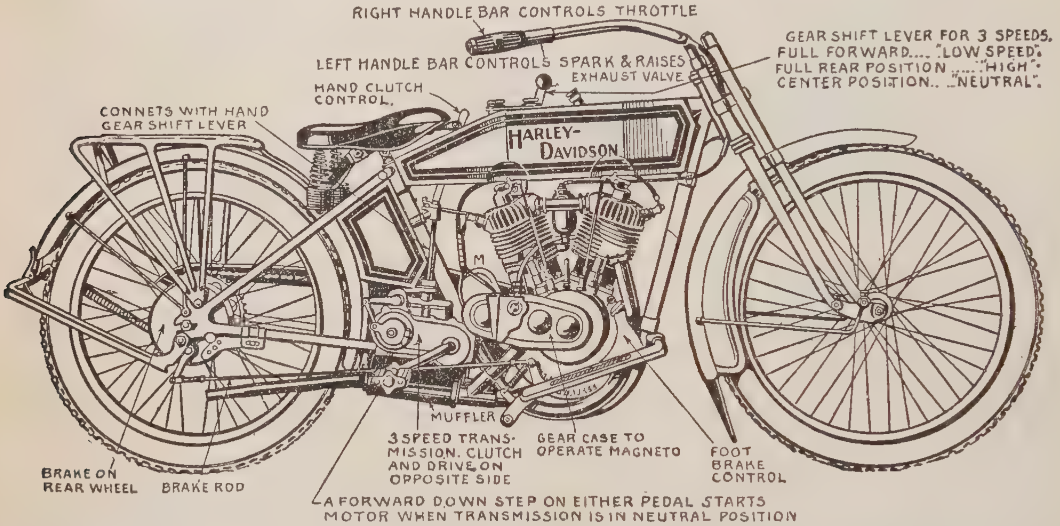

RIGHT HANDLE BAR CONTROLS THROTTLE
LEFT HANDLE BAR CONTROLS SPARK & RAISES EXHAUST VALVE
GEAR SHIFT LEVER FOR 3 SPEEDS. FULL FORWARD.... "LOW SPEED". FULL REAR POSITION ..... "HIGH". CENTER POSITION.. .."NEUTRAL".
HAND CLUTCH CONTROL.
CONNETS WITH HAND GEAR SHIFT LEVER
HARLEY-DAVIDSON
M
MUFFLER
3 SPEED TRANS-MISSION. CLUTCH AND DRIVE ON OPPOSITE SIDE
GEAR CASE TO OPERATE MAGNETO
FOOT BRAKE CONTROL
BRAKE ON REAR WHEEL
BRAKE ROD
A FORWARD DOWN STEP ON EITHER PEDAL STARTS MOTOR WHEN TRANSMISSION IS IN NEUTRAL POSITION

Fig. 15. The Harley Davidson, three-speed, model "11F" motorcycle. Note 3 speed transmission. Note lettering on illustration. To start the three-speed model engine, shift the gears into "neutral" position and have the clutch "in"; start the engine by the pedal. After the engine is started, release the clutch. To start the machine, place the gears in mesh, starting off on "low," and gradually applying the clutch.

MOTORCYCLE MAGNETO (THE DIXIE)

It will be noted that this magneto is similar in every respect to the Dixie magneto explained on page 272, except that a "collector spool" is provided on the drive-shaft end, instead of a distributor. The principle of this arrangement and the method by which two carbon brushes take the high-tension current from the collector spool is shown in Fig. 17. (This is not the exact construction, but it serves to explain the principle.)

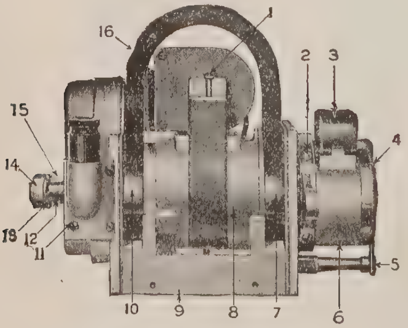


Fig. 16. The Dixie motorcycle magneto.

1. High-tension winding.
2. Advance-lever screw.
3. Breaker-box cover.
4. Condenser cover.
5. Spring.
6. Breaker box or interrupter.
7. Bearing holder (breaker end).
8. Pole structure.
9. Base.
10. Bearing holder (drive end).
11. Collector-spool housing
12. Drive shaft.
13. Shaft-nut washer.
14. Shaft nut.
15. Drive key.
16. Magnet.

Timing the Dixie magneto: Usually, the piston is placed on top of compression stroke with the contact breaker retarded, at which point the platinum points of the breaker should just begin to separate. This is taken care of in the meshing of gears as shown in Fig. **B,** page 1007, and varies in different motorcycles. For instance, an earlier setting is sometimes desired.

The distance between the platinum points in the contact-box, when separated, is .020″ or 1/50″.

To remove grease and dirt: Squirt a gunful of gasoline into the spool housing (11) (Fig. 16).

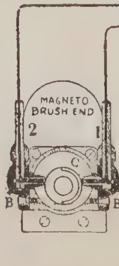


Fig. 17

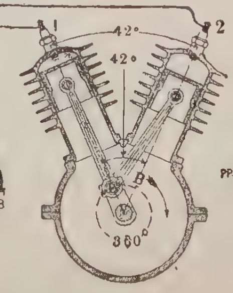


Fig. 18

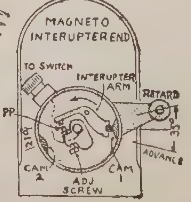


Fig. 19

The carbon brushes should project ¼″ from the brush holders; if the carbon brushes are glazed too much at the ends, rub them with emery paper.

The terminals on the magneto are in right-hand rotation. No. 1 terminal leads to the cylinder which fires first, and usually the rear cylinder.

If a **terminal comes loose** from the terminal to the brush holder, drill out the brass plug, and use ⅝″ cable, twist the copper strands, and insert them in the hole and solder.

A punctured brush holder may be detected by the smell of burned rubber.

Relation of Spark to Piston

On a twin-cylinder "V"-type engine, the firing order is not equal, that is, one cylinder would fire, then the next cylinder to fire would be 360° plus 42°, or 402° after the first. Therefore, the interrupter and brushes carrying the current to the spark plugs must be arranged accordingly.

Note in Fig. 17, that brushes (B1) and (B2) **conduct current to the spark plugs.** (B1) is now on contact, hence cylinder 1 would fire.

Note in Fig. 18, that the cylinders are 42° apart. If cylinder 1 fires now, crank pin (A) will travel a revolution back to (A) again, then 42° more to (B), or 360° and 42°, or 402° in all, before No. 2 fires. No. 1 will again fire, from point (B) to (A), 360° minus 42°, or 318°.

The armature travels at half the speed of the engine crank shaft, and makes a spark every half-revolution. Therefore the armature, with its interrupter and collector ring, would travel 201° when the crank travels 402°, when cylinder No. 1 fires.

When cylinder No. 2 fires, the crank pin on the engine will travel 318° before No. 1 would fire again. Since the magneto armature travels one-half as fast as the engine crank, it would travel from (B2) to (B1), or 159°. Thus we should have an unequal impulse.

It requires two revolutions of the crank to complete the four strokes or four-cycle operation. During these two revolutions **two sparks** are required. The **armature makes two sparks to one revolution.** Therefore it revolves but one revolution to two revolutions of the crank.

The illustrations (Figs. 17, 18, 19) are not of the Dixie magneto, but serve to explain the principle of how the motorcycle twin-type engine fires.

SPLITDORF MAG-DYNAMO, FOR MOTORCYCLE USE

This is a combination of a magneto and a dynamo. The dynamo armature which generates "direct" current is placed above, (I) being the commutator. The magneto armature (U) is a regular armature with wire revolving, generating "alternating" high-tension current, and is placed below. The two are entirely separate and independent.

The fields or magnets are not of the "permanent" type, but are of the "electro" type, excited in the first case by the current in the storage battery, or by the first few revolutions of the generator. The dynamo and magneto are separate and distinct otherwise, but combined in one unit.

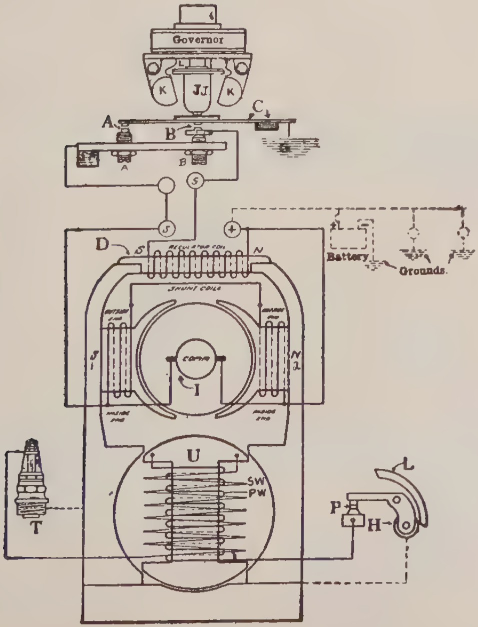


Fig. 20. Splitdorf mag-dynamo.

Magneto Part

The magneto part of the "mag-dynamo" supplies current for ignition. Its armature (U) is a double-wound (SW-secondary—PW-primary) high-tension revolving type. The interrupter parts are shown: (P) platinum points of contact breaker; (L) cam; (H) roller grounded with frame or base; (T) spark plug; (P) points are set at .015″, and spark plugs at .020″ gap.

Dynamo Part

The dynamo generates a "direct" current, which charges a storage battery, and also supplies current for lights. The armature is driven by a gear from the magneto or lower armature. With the battery "floating-on-the-line," the unit has a maximum output of 3 amperes at 7.5 volts at 1,400 r.p.m. of the engine, equal to 30 m.p.h. with average road gear.

Cut-Out Principle

The principle of the automatic cut-out used with the dynamo is as follows:

When the rider gives the starter pedal a downward thrust, as in starting, the mechanical governor part (J) is forced down by centrifugal action of arms (K), which acts upon the spring (C), bringing the main-line contacts (A) together; this allows about 1 or 1½ amperes to flow through the field winding (and armature), magnetizing it so that the lower or ignition armature may produce sufficient current to spark the engine.

If the engine is stiff or hard to turn over, the starting switch is depressed, allowing 4 amperes to go through the shunt fields and armature. The starting switch merely cuts around the contacts (A) so that a strong magneto field is obtained when the rotation of the armature is slow. Of course, when the battery is disabled, a powerful thrust on the starter pedal will rotate the generator armature fast enough to generate sufficient current to magnetize the field enough to furnish a spark at the plugs.

As the speed of the motorcycle increases up to about 30 m.p.h., the charging current also increases to about 3½ amperes. Then through the increased action of the governor spring, a second contact at (B) comes into action. This connects the regulator or bucking coil (D) into the circuit, and magnetizes the soft iron cores (N) and (S), which, you will note, is magnetized in the same way as the field coils. This action bucks the magnetic field of the generator armature and drives the magnetism down to the ignition armature field, weakening the generator field and strengthening the magneto field.

The ignition current is a straight high-tension current from the magneto at all times. When first starting, the magneto field is energized from the battery, and when running, from the generator. Otherwise that is all the connection the ignition or magneto has with the dynamo or generator.

Timing the Magneto on "Mag-Dynamo"

In the Indian, the Thor, and the Merkel, the piston is placed 5/16″ from top of compression stroke with the breaker box advanced. On the **Harley-Davidson** (Dixie magneto), 9/32″; on the **Excelsior,** 13/32″; on the **Pope,** ½″; on the **Dayton,** ⅜.″

Adjustments of Mag-Dynamo

To adjust the cut-out and current control: With the engine idle and all lights turned off, remove the regulator-box cover and adjust the current-control contact screw (A); the correct setting of the contact points should be between .015″ and .025″. This setting will permit the battery to discharge about 1 to 2 amperes. On the other side of the regulator box the setting of the main cut-out contacts can be made as follows: With the engine running slowly, loosen the lock nut and turn the current-control screw (B) several turns to the left. Increase the speed of the engine until the ammeter shows a 3-ampere charge. With the engine running at this speed (approximately 1,200 r.p.m.), turn screw (B) to the right until the ammeter needle drops back approximately to a 2-ampere charge; then set the lock nut.

The fuse used in the circuit is a 15-ampere fuse. The positive pole of the battery is connected to the fuse block, and the negative terminal is grounded.

In case of failure of the battery, three dry cells can be utilized, connected in series with a carbon pole to the fuse block and zinc grounded.

MOTORCYCLE GENERATOR (SPLITDORF DU 1)

On many motorcycles, the Dixie magneto is used, and a separate and distinct dynamo is mounted separately. One type of dynamo is termed the "DU-1" as described below.

The principle of the mechanical cut-out on the "DU-1" Splitdorf motorcycle lighting and battery-charging dynamo is shown in Fig. 21. Note that the centrifugal action of (G) on the armature shaft causes a sleeve at higher speeds to press against the arm (A), which, through hinge (S), makes contact at (B).

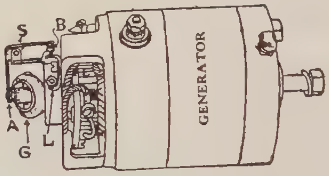


Fig. 21

MOTORCYCLE CARBURETOR (SCHEBLER)

Description: Model "H," ¾″ and 1″; Compensating type; variable fuel feed. The supply of gasoline is controlled by (Z), which raises the gasoline needle valve (I), giving an adjustment on low, intermediate, and high speeds. (C) is the air intake, and can be turned so that warm air can be drawn from the engine.

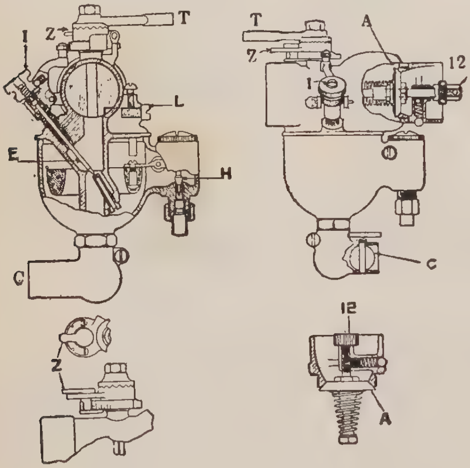


Fig. 22. Schebler motorcycle carburetor.

Low-speed adjustment: See that the leather air valve (A) seats lightly, but firmly. Then turn the knurled button (I) to the right until the needle point (E) sets in the spraying nozzle. Now turn (I) to the left about two turns, and open the low-speed adjusting screw (L) about three turns; then open the throttle about half-way to start the engine. After starting, close the throttle and turn the needle-valve adjusting screw (I) to the right or left until the engine runs smoothly without missing. If with this low speed adjustment, the engine runs too fast, turn the low-speed adjusting screw (L) to the right.

High-speed adjustment: Do not make the adjustment with the engine running idle. The machine should be run in high speed on the road. The throttle and spark should be advanced fully. The adjustment is now made by the pointer (Z), which, as it moves from (1) toward (3), increases the supply of gasoline. Moving the indicator from (3) toward (1) cuts down the flow of gasoline. When the indicator reaches the right point, the engine will run without missing or backfiring.

Starting: The air valve can be locked to assist in starting by pulling out button (12) and giving it a quarter-turn. When the engine starts, release air valve (A) by turning button (12) back.

Extra air port for high speed on the Harley-Davidson carburetor is provided inside the mixing chamber to admit more air at extreme high speed.

To set the float level: Place the float 19/32″ from the top of the bowl to the top of the cork float. The arm can be raised or lowered to meet these conditions.

THE NERA CAR

This machine is mounted on two wheels. A glance at the illustration will give the details.

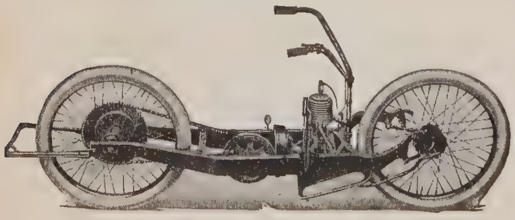


Fig. 23. Side view of Nera Car chassis.

Specifications

Wheel base: 55½ inches.

Length over all: 84 inches.

Frame: Pressed steel chassis, automobile type of construction.

Motor: 2-cycle, 2½ h.p., 2½″ x 2¾″; displacement, 13½ cubic inches.

Transmission: Friction drive to countershaft mounted on SKF bearings; five speeds.

Ignition: High-tension magneto.

Gasoline tank: 2 gallons.

Chain: Roller, ½″ pitch x 5/16″.

Springs: Load carried on barrel-type coil springs.

Saddle: Suspension type of best leather; combination flat and rear coil springs, giving vertical movement in horizontal plane.

Wheels: Wire, 26″ x 3″ with ball bearings; 36 spokes, S.A.E. standard.

Brake: Expanding brake in rear wheel, foot control.

Tires: 26″ x 3″ non-skid.

Speed: 35 miles per hour.

Color: Black.

Weight: Approximately 165 lbs.

Fuel consumption: 85 to 100 miles per gallon.

Non-skid—center of gravity below center line of wheels.

Manufactured by Nera-Car Corpn., 196 South Geddes St., Syracuse, N.Y.

INSTRUCTION No. 80

MISCELLANEOUS CARS: Woods Dual Power Car; Magnetic Gear Shift; Steam Car; Owen Magnetic Car (Electric Transmission). PRINCIPLE OF THE AIRPLANE

WOODS GAS-ELECTRIC CAR

The Woods dual power car: The power plant consists of a small gasoline engine and an electric motor-generator combined into one unit, as illustrated, and mounted on a three-point suspension. The movement of a finger lever on the steering wheel connects the engine to the electric motor-generator, which cranks the engine and develops power which is transmitted through the armature shaft of the electric motor and propeller shaft, direct to the rear axle. See Fig. 1.

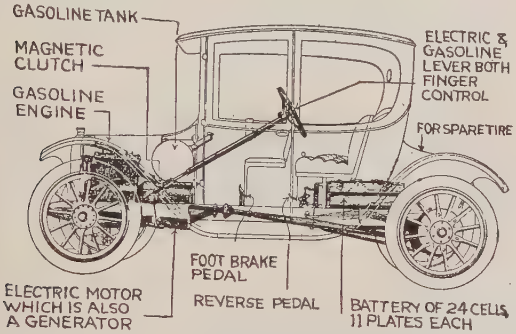

GASOLINE TANK
MAGNETIC CLUTCH
GASOLINE ENGINE
ELECTRIC & GASOLINE LEVER BOTH FINGER CONTROL
FOR SPARE TIRE
FOOT BRAKE PEDAL
ELECTRIC MOTOR WHICH IS ALSO A GENERATOR
REVERSE PEDAL
BATTERY OF 24 CELLS 11 PLATES EACH

Fig. 1

The car starts as an electric, by a simple movement of a finger-controlled lever on the steering wheel, which operates the means for connecting the battery to the motor, and increasing the speed, as the lever is advanced.

At any advanced position of the electric lever the first movement of the finger-controlled gasoline lever instantly starts the gasoline motor. As this lever is moved forward, it causes the car to be operated more on the gas, and at a certain point it will run as a straight gasoline car, neither charging nor discharging the battery. With a slight variation of the relative position of the two levers on the steering wheel, the battery may be either charged or discharged at will on any speed from ten miles an hour up to twenty-eight or thirty miles an hour. Electricity is generated and stored in the battery while the car is running.

At any speed above six miles an hour, dynamic breaking may be effected by retarding the electric lever. This causes the electric motor to run as an electric generator driven by the gasoline motor or by the momentum of the car. The power thus generated is used for charging the battery. The same effect may be obtained by a simple movement of the foot-brake pedal, which also acts as a mechanical brake below six miles per hour.

The parts of this car and their location are shown in the illustration, Fig. 1 (Woods Electric Vehicle Co., Chicago, Ill.).

MAGNETIC GEAR SHIFT

This device is used to shift the gears, taking the place of the hand shift lever and selector rods. It is attached to the side of the transmission. The **switch control** is placed under the steering wheel. This system is used on the Premier Car. (Device manufactured by Cutler Hammer Co., Milwaukee, Wis.)

Principle: If you press the switch button 1 (see Fig. 3), you close the circuit of solenoid 1, causing the shaft (**A**) to move to the left.

If you press button 2, you energize solenoid 2, causing the shaft (**A**) to move to the right.

If you press button 3, you energize solenoid 3, causing shaft (**B**) to move to the left. If you press button (**R**), energizing spool (**R**), you bring the reverse gear into mesh.

Pressing neutral button (**N**) and throwing out the clutch, places the gears in "neutral."

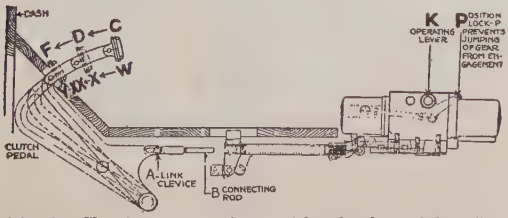


Fig. 2. Showing connections with clutch pedal. (CD) represents travel provided for clutch slippage, and possible throw of clutch pedal for coasting.

Pressing a push botton does not energize one of the solenoids; it merely partially closes the circuit to a certain solenoid, but the circuit is not completely closed until you **throw the clutch pedal down to the floor-board.**

The clutch pedal is so arranged that you can throw out the clutch in the usual manner by **partially** depressing the pedal, but if you push the pedal to the extreme position, you bring the switch (**M**) (Fig. 5) in contact for an instant and permit the electricity to flow to the particular solenoid which was selected when you pressed one of the push buttons.

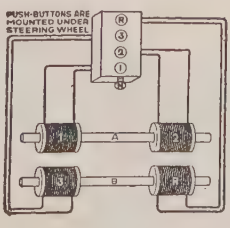


Fig. 3

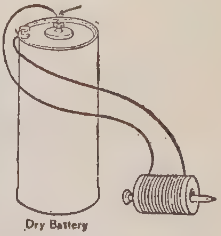


Fig. 4

Fig. 3. Simplified explanation of the **solenoid action.**

Fig. 4. **Principle of a solenoid** simplified: insulated wire is wrapped around the spool (solenoid). If the ends of the wire are connected with the battery the spool sucks up the nail.

The push buttons are therefore known as "selector switches," because they do not actually close the circuit but select in advance the circuit that will be energized when you push the clutch pedal to the extreme position, thereby closing switch (**M**).

A 12-volt battery is used: It is stated an 80 ampere-hour battery will operate the gear shift from 394 to 491 times.

Gear Changes

First speed: To start forward in first speed, push the "selector switch" button No. 1 (Fig. 3) down until it catches. Then depress the clutch pedal as far as it will go and the first-speed gears will instantly mesh. Allow the clutch pedal to return gently. The clutch will engage and the car will move forward in first speed.

Second speed: Press button No. 2 until it catches, and as soon as it is desired to shift the gears from first to second, depress the clutch as before to its extreme position. This brings the second speed gears into mesh. Engage the clutch.

Third speed: Press button No. 3 until it catches. Depress the clutch to its extreme position. Allow the clutch to return to engagement.

Dropping back: In dropping back from one gear to another, the operation is the same, i.e., press the button corresponding to the gear wanted, and when it is desired to shift, simply push the clutch to the extreme limit and the gears will automatically change.

Selection: Should button No. 2 be depressed and should it then be decided that No. 1 is wanted instead, all that is necessary is to press button No. 1. This automatically "kills" No. 2. Similarly, any button that is down is "killed" by pushing any other button. The gears may be selected in any order desired, for example, 1 to 3, 2 to 1, 3 to 1, etc. It is not necessary to press the buttons in numerical order.

Pre-selection: Speed changes may be prepared for at any time in advance of the actual shift by pressing the button corresponding to the gear into which it is next desired to shift.

When the car is stopped, the gears should always be neutralized before the driver leaves his seat, so that when the motor is again started, none of the gears will be in mesh.

Neutralizing: To throw the gears to neutral, press the (**N**) button, and then depress the clutch pedal to the limit. (The neutral button has no catch and does not remain down when it is pressed. Its function is simply to throw out the other buttons in order to break their electrical connections.)

Coasting: The clutch pedal may be thrown out far enough to free the clutch without neutralizing or shifting the gears. The shift takes place only when the pedal is thrown to the extreme position. This arrangement permits disengaging the clutch so that the car can "coast," no action taking place in the gear shift. See Fig. 2.

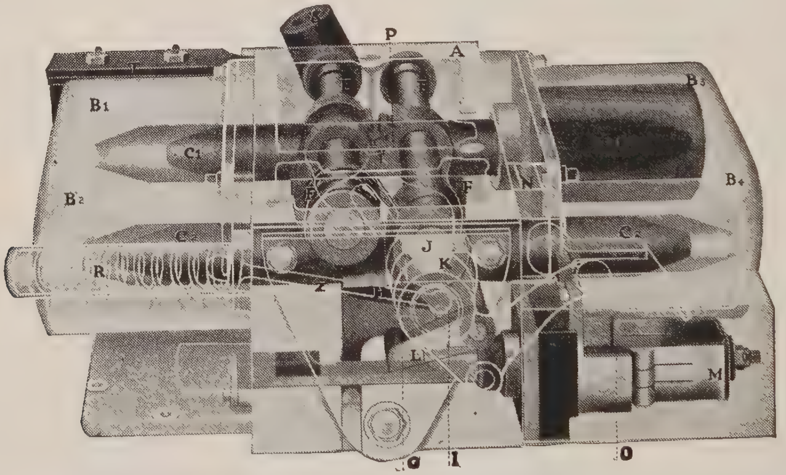


Fig. 5. (**A**) gear-shift housing; (**B-1-2-3-4**) coils; (**C-1-2**) magnet cores; (**E-E**) cam shafts; (**F-F**) neutralizing cams; (**G**) ratchet pawl lever; (**I**) rocker arm; (**J**) operating shafts; (**K**) operating lever; (**L**) pawl operating master switch; (**M**) master switch; (**N**) locking shaft; (**O**) master switch return spring; (**P**) neutralizing return spring; (**Z**) neutralizing return-spring shaft.

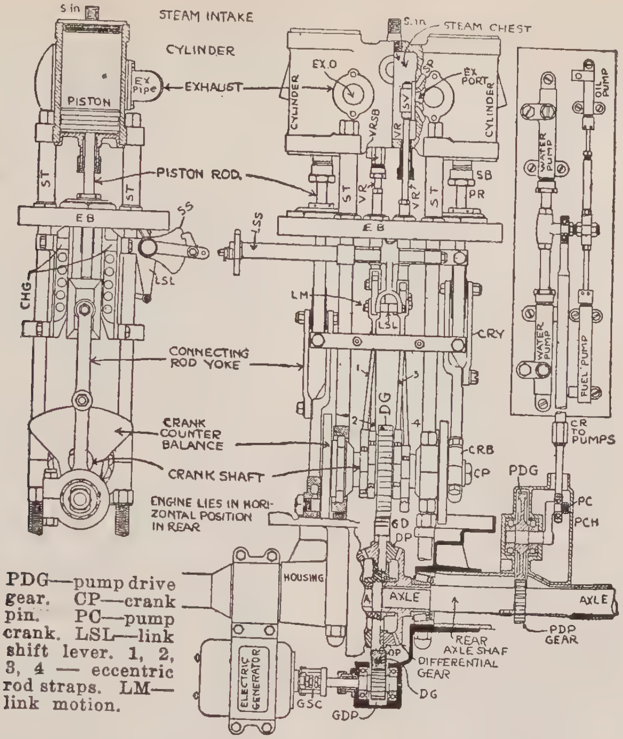
THE STANLEY STEAM CAR

Engine: Double acting, taking steam at each end of the cylinder. Slide valve, built in a unit with the rear axle, and driving through a spur gear on differential (**GD**) (Fig. 6). Crank shaft spur gear (DG) is the drive gear on engine.

The valves which control the admission and exhaust are operated from eccentrics on the crank shaft and through a link motion (**LM**), through (**LSS**) which is connected with left pedal (Fig. 10) and controls the range of motion of the valve.

There are three passages when the valve is open for a large part of the stroke. This admits steam at boiler pressure and shuts the valve a certain distance before the piston reaches the bottom of its stroke. For the rest of the traveling the piston is driven by the expansion of the steam. Pressing the pedal (T) (Fig. 10) forward until it catches or hooks up causes the valve to close earlier. This means that less steam is taken from the boiler and the piston is driven a longer distance by the expansion. This, of course, is more economical of steam and is the condition for normal running.

The longer valve opening is used for starting, and practically for nothing else. With the pedal pressed forward, the operation of the valve is reversed so that the engine will run backwards, this giving the reverse motion.



PDG—pump drive gear. CP—crank pin. PC—pump crank. LSL—link shift lever. 1, 2, 3, 4 — eccentric rod straps. LM—link motion.

Fig. 6. **Stanley engine, rear axle, and pump gear.** The pumps are really mounted forward on the chassis, and are driven by a crank off the rear axle. The electric generator is also rear-axle driven.

After leaving the engine, the steam goes to feed the water heater, thence to the top of the radiator, upon passing through which it condenses into water and this water flows back to the main tank. Differing load and road conditions entail the loss of some steam, and it is this loss which has to be made up by refilling the water tank. However, sufficient water can be carried for 200 to 250 miles of ordinary running, or, in other words, it takes this amount of ordinary running before the slight loss of steam is equivalent to the whole tank full of water, which is about 20 gallons, and is placed underneath the car, below the frame.

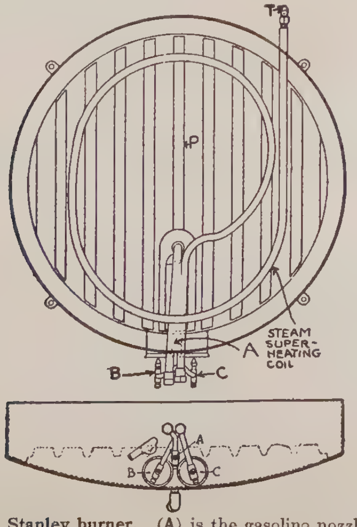


Fig. 7. **Stanley burner. (A)** is the gasoline nozzle for the pilot light and **(B)** and **(C)** the two main burner nozzles for coal oil or main fuel.

Boiler: Fire tube type, the flues being welded by the acetylene process to the bottom head.

Burner: When we want more power from the gas car the throttle is opened. When we want more power from a steam car the burner must supply more heat, thus generating a higher pressure of steam.

How kerosene is used: The kerosene under pressure is first led through a long coil placed on top of the boiler, where the exhaust gases of combustion yield up part of their waste heat, by preheating the kerosene. From this top or heating coil the kerosene passes by way of the automatic control and main burner valve to the vaporizer (located in the fire). Here the hot kerosene is transferred into a true gas, and after being mixed with a definite amount of air is burned with the blue "Bunsen" flame.

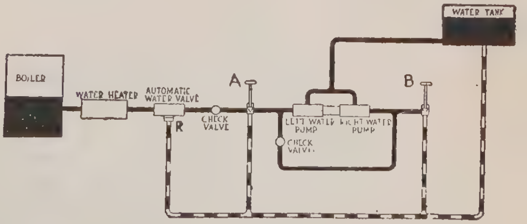


Fig. 8. **Diagram of water system of Stanley steam car.** Water is pumped toward the boiler by one or two pumps, according to the positions of the hand valves **(A)** and **(B)**. After reaching a proper level in the boiler, the release valve **(R)** is opened and the water then goes back to the main tank, whether the pumps are both working or not. In practice, the left pump always is in use subject to the automatic control, and the right pump is hardly ever called into service, but doubles the supply for emergency use.

Uniform water level: When the water reaches a certain height, it is forced to return to the supply tank by an automatic by-pass, thermostatically operated.

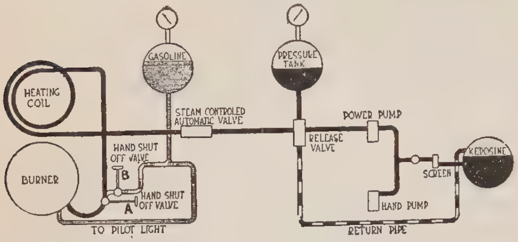


Fig. 9. **Diagram of fuel system of Stanley steam car.** The gasoline only supplies the pilot light, which never goes out, and the consumption is small, so the size of the tank is exaggerated in the cut. Kerosene, the operating fuel, is carried in the rear tank and pumped to the pressure tank from which the burner takes its supply. When the steam pressure reaches a predetermined point, the supply of fuel is cut off and the kerosene pumped is allowed to go back to the main tank. The heavy black line in the cut indicates the kerosene supply, the broken black line the return lines for surplus, and the grey lining, gasoline.

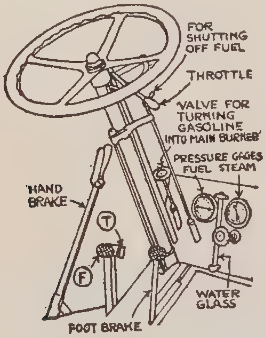

FOR SHUTTING OFF FUEL
THROTTLE
VALVE FOR TURNING GASOLINE INTO MAIN BURNER
PRESSURE GAGES FUEL STEAM
HAND BRAKE
T
F
WATER GLASS
FOOT BRAKE

Fig. 10. **Control of car:** The left pedal gives the two valve positions for forward running and the reverse. (**T**) is pressed forward half-way after starting and left there. (**F**) is the reverse pedal, and is pushed full forward when the car is reversed. The right pedal operates the service brake, the lever, the emergency brake. The throttle is the only control used while running. A little lever, partly concealed by the throttle lever, is for shutting off the fuel when making a long stop. When starting from dead cold, the valve turning the gasoline into the main burner is used. On the dash the left gauge shows the fuel pressure and is seldom looked at. The right gauge shows the steam pressure. In the center is the water glass that is carried only as an emergency indicator in the event of any trouble in the water-feed system. (The Stanley Steam Car Co., Newton, Mass., is the manufacturer.)

Questions Answered Relative to the Stanley Steam Car

Q. 1: Where is the engine located?

Ans.: The engine is located on the rear axle and supported from the rear Axel differential housing. It is swung at the other end, from the car frame, by means of a spring strap hanger.

Q. 2: How does the engine drive the rear axle?

Ans.: The engine frame, made up of four members, is carried through the differential housing, turning in an oscillating block at that point. Thus the engine and rear axle become a unit. The gear teeth of the engine's main drive mesh with those of the differential.

Q. 3: What is the ratio of the gearing?

Ans.: This depends upon the size, power, and type of car employed. In the older models it is 2:1, and in the later models 1½:1.

Q. 4: Where is the boiler located?

Ans.: The boiler is located in front of the dash, underneath the hood and behind the condenser, which is also a radiator.

Q. 5: What steam pressure is usually carried?

Ans.: All stock cars, regardless of model, operate on 600 lbs. pressure normally. However, for speed purposes this pressure is run up as high as 1,200 lbs. to 1,500 lbs.

Q. 6: What is the average time required to raise sufficient steam pressure when cold?

Ans.: The initial time of steaming a car when cold will take approximately fifteen minutes. This includes filling of the tanks and boiler, as well as the raising of steam pressure.

Q. 7: What time is required if the car has stood awhile, after having been used?

Ans.: No time whatever is required for raising the running pressure, inasmuch as that pressure has been maintained.

Q. 8: What is the fuel consumption?

Ans.: One of the Stanley five-passenger, big touring cars was run for three consecutive months, making an average of twelve miles per gallon of coal oil. On long runs, this figure is increased as high as sixteen or seventeen miles per gallon of coal oil.

Q. 9: How are the various speeds controlled?

Ans.: From zero to the world's record is obtained by the opening of the throttle, the handle of which is located on the steering wheel. There is no other movement on the part of the operator for increasing or retarding his speed, other than the throttle.

Q. 10: What is the water capacity and consumption?

Ans.: The water capacity is 20 gallons carried in a tank beneath the car frame and filled through a radiator. This capacity is sufficient for a day's run. We have known it to go as high as 350 miles.

Q. 11: Mention the control levers, valves, etc.

Ans.: When starting out with a car, a valve is opened which places the car under automatic control from that time on. When brought to a stop, this valve is closed. The operating controls are the throttle, the service and emergency brakes, and reverse.

Q. 12: Where are the control parts located?

Ans.: The throttle subimposes on the steering wheel. The foot brake is in the usual position. Reverse is a foot brake. The emergency is a handle brake, located on the side of the car.

Q. 13: What are the advantages of a steam car?

Ans.: Entire lack of vibration; freedom from gear shifting; absence of clutch; absolute flexibility; more power per weight than is possible in gasoline cars; a car that cannot freeze up in winter weather; simplicity of controls, but 32 moving parts, counting the wheels; low cost of upkeep; greater tire mileage; small depreciation factor; no smoke or steam visible in cold weather.

Q. 14: What are its disadvantages:

Ans.: These have in later models been overcome, but formerly they were: shape of hood; necessity for firing up; likelihood of freezing; necessity of taking on water every fifty miles (before the condensing system was used); steam in the street.

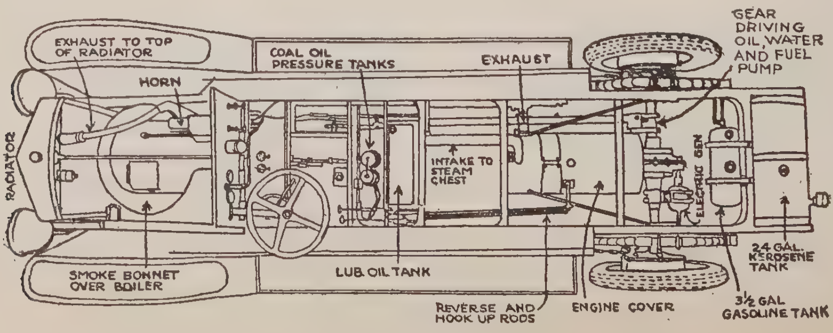


Fig. 11. Plan view of the Stanley steamer.

THE DOBLE STEAM CAR

How the Doble Differs from the Stanley

1. The Doble boiler is of the water tube type. The Stanley boiler is of the fire tube type.
2. The Doble boiler consists of 28 sections, placed in an insulated casing. The Stanley boiler is in reality a big drum standing over the burners.

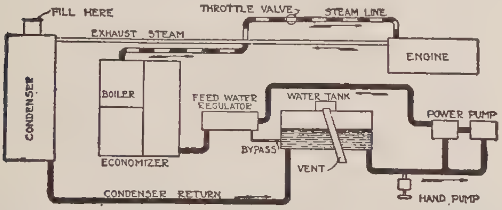


Fig. 12. **Water and steam piping diagram of the Doble steam car.** The cycle of operations is as follows: Water put into the condenser flows to the water tank by gravity. It is pumped by a power pump through the regulator and economizer into the boiler, where it is changed to steam. Steam from the boiler passes through the throttle into the engine, thence to the condenser, where it is reduced to water again.

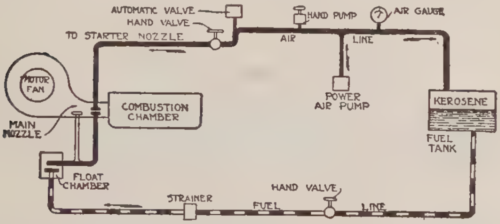


Fig. 13. **Air and fuel piping:** Air pressure of 2 lbs. per square inch is maintained in the fuel tank. The blower motor is started through a switch, after which speed is regulated automatically by the steam pressure.

3. The Doble has no pilot light (the mixture is ignited by electric spark). The Stanley has only a pilot light for ignition.
4. The Doble uses kerosene for both starting and running. The Stanley uses gasoline for starting, kerosene for running.
5. The Doble slide valve is used only for admission of steam to the engine cylinder. The Stanley slide valve regulates both admission and exhaust.
6. In the Doble the exhaust steam goes direct to the radiator. In the Stanley, the exhaust passes through a feed water heater before it goes to the radiator.

Features of the Doble

Sectional boiler: 20 sections used for generating steam and 8 sections used for feed water heater or economizer.

Absence of pilot light: This is a radical departure from the usual construction.

Kerosene for starting, as well as for running.

Wide pistons: Necessary on account of the pistons having to open and close the exhaust port (similar to a 2-cycle gasoline engine). This is termed the uniflow principle.

Absence of eccentrics: The valve gear is a modified form of the "Joy valve gear" in which modification the "correcting" and "anchor links" are eliminated, thus simplifying the construction.

Final drive (gear ratio): Almost 1 to 1, viz., 47 teeth in the drive gear and 49 in the differential.

A condenser is provided so that the steam is reconverted into water, and is used over and over again.

Lubricating oil is mixed with the water for lubrication of the cylinders. (Doble-Detroit Steam Motor Car Co., Detroit, Mich., manufacturers.)

Other steam car manufacturers: Gearless Steam Auto Mfg. Co., 635 Symes Bldg., Denver, Colo.

OWEN MAGNETIC CAR (ELECTRIC TRANSMISSION)

The Owen Magnetic makes use of an actual electric transmission, known as the Entz. The arrangement of this system permits the changing of all speeds by a small lever similar to a spark lever mounted on the steering wheels. The **difference between this and other gasoline cars** lies in the magnetic transmission.

Elementary Principle

Refer to Fig. 14: (A) shows a magnet with a "keeper" at bottom, familiar to everyone. (B) is a magnet and pedestal with a hand crank to revolve it.

(C) is a piece of steel on a pedestal placed within the magnet on the same line of travel. It will be apparent that as the magnet is revolved by turning the crank, it will attract the piece of steel which will revolve with it.

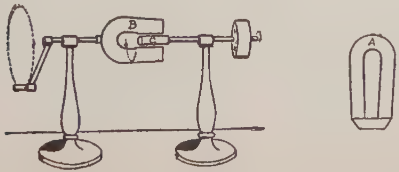


Fig. 14

Refer to Fig. 15: (B) is now revolved by the gasoline engine instead of the hand crank, taking the place of the flywheel, and revolves at engine speed regulated by the throttle. To describe it, we will now call (B) a revolving field.

(C) is now part of the propeller shaft, and to describe this, we will now call (C) an armature. When the car is running in "high speed," (C) follows (B), because it is magnetically locked, but it will be noted that we are **driving through an air space or gap,** there being no mechanical connection at any time between the rear axle and the gas engine, but only magnetism transmitting the torque of the gas engine to the rear axle.

When arriving at a grade which is too steep to climb on "high," we should now stall our gas engine unless we applied a form of speed reduction.

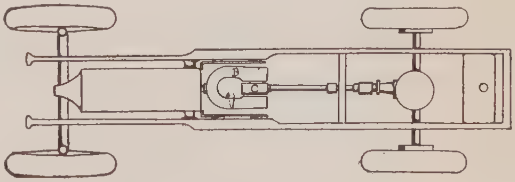


Fig. 15

Refer to Fig. 16: The conventional electric motor (**D**), as shown, gives us the reductions needed in the following manner:

We now drive through what is in effect a slipping clutch, and it is apparent that if it were possible to use the power that is lost in heat through the friction of the slipping clutch in the gear type of transmission car, all the power of the engine would be transmitted to the rear wheels and there would be no use for a gear box.

The magnetic transmission gives us this result, as we now find that (C) is trying to keep up with (B), but as (B) and (C) now have ceased to be magnetically locked, because we have changed the position of the control lever on the steering wheel, and are therefore slipping, the difference in their relative speeds generates electricity which is led to (D).

Armature (E), being of the same form as (C) and on the same propeller shaft, takes the electricity generated by the slip, and acts as a power booster on the propeller shaft, giving us innumerable speed reductions, wonderful flexibility, and absolute silence at all speeds.

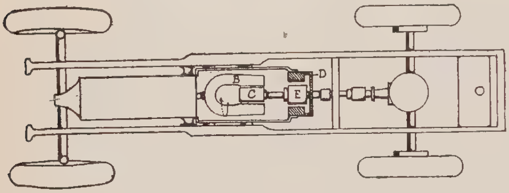


Fig. 16

The large horseshoe magnet (B) (Fig. 16) is revolved by the engine. The magnetic lines of force create a drag on the armature (C) which carries the armature with it. By elaborating on the construction as shown, the slip energy created by the difference in rotating speeds of magnet (B) and armature (C) is converted into potential electric force and carried to the motor whose field coils are shown as (D) and armature (E).

Control Lever Positions

Charging: Car stationary, engine running. Generator charging starting and lighting battery; seldom necessary, as battery is automatically charged on high-speed position when the car is in motion.

Starting: Current from the starting battery operates the generator as a motor for the starting engine. When the engine has started, bring the lever to neutral position.

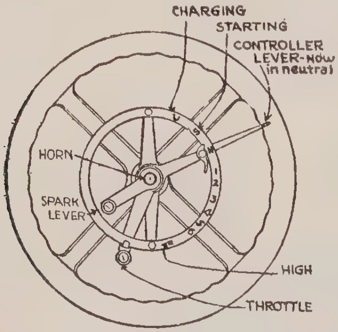


Fig. 17. Control lever positions of Owen Magnetic Car.

Neutral: Car stationary, engine running. The clutch generator circuit is open, and the motor is short-circuited on a resistance. Bring the lever to first position.

First position: Generator producing light clutching effect and maximum current for electric motor. The result is a maximum difference between engine speed and car speed, producing greatest torque or pulling power.

Second position: The clutching effect of the generator is increased and the supply of current to the motor is decreased. Result: the car speed is increased.

Third position: The clutching effect of the generator is further increased and more of the driving power is transmitted. The motor does correspondingly less work. Result: an increase in car speed.

Fourth position: The generator continues to transmit more and more of the driving power, the work of the motor gradually decreases. Result: car speed increases.

Fifth position: The same general action. The generator is carrying nearly all the load, while the motor is practically idling.

High: On this position clutching effect of the generator has increased nearly to the locking point, transmitting all the driving power. The motor no longer assists, but operates only as a generator to charge the starting and lighting battery.

The gear ratio on the Owen magnetic car, 7-passenger, is 4½ to 1, and on the 5-passenger car, 3½ to 1.

Principle of Construction

In place of the flywheel, clutch, gearset, starting and lighting system, and their auxiliary parts, two direct-current dynamo machines and a drum controller have been substituted.

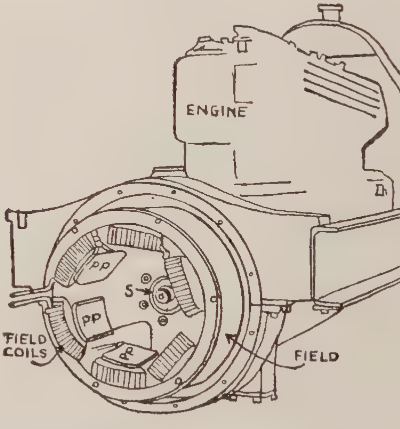


Fig. 18. Field coils, etc., of the electric transmission system forming the flywheel of the gasoline engine, as mounted on the Owen magnetic car.

Clutch generator: One of the dynamo machines has its field magnet frame directly connected to the engine crank shaft, taking the place of the ordinary flywheel (Fig. 18). The armature of this machine is mounted on a large, hollow shaft, which is directly connected to the propeller shaft (Fig. 19). This machine is called the "clutch generator," as it acts both as a clutch and as a generator. There is no mechanical connection between the engine and the rear axle; it is connected through an "air gap," which is entirely a **magnetic** connection.

The motor: The second dynamo machine has its armature mounted on the same hollow shaft as the first, and its field magnets are stationary; it is called the "motor," as it is generally used as a motor to help drive the propeller shaft, and to boost the effort of the engine as transmitted through the clutch generator, which, like any clutch, can transmit only the engine effort or torque.

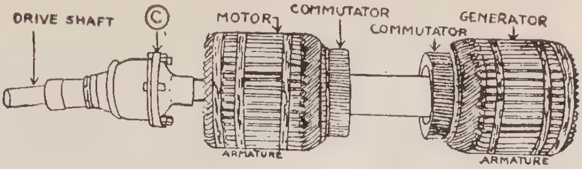


Fig. 19. Armature of motor and generator attached to the propeller shaft, as on the Owen magnetic car.

The clutch generator is used as a clutch alone, on the **high speed,** when it is short-circuited upon itself, and a small speed difference between armature and field, or a small slip, is necessary to establish the current in its windings which energizes it and causes it to act as a clutch.

On the **high-speed** position the **motor** plays no part in the transmission of power, but is used as a charging generator for the storage battery, which later is used for cranking the engine and for the electric lights.

The electric motor aids propulsion. On all power control positions other than the high, the motor helps turn the propeller shaft, by taking current from the clutch generator in which circuit it is included. At these times the slip in the clutch generator is greater than is needed to energize it as a clutch, and the **additional slip produces the current required for the motor,** which it utilizes for giving additional turning effort to the propeller shaft.

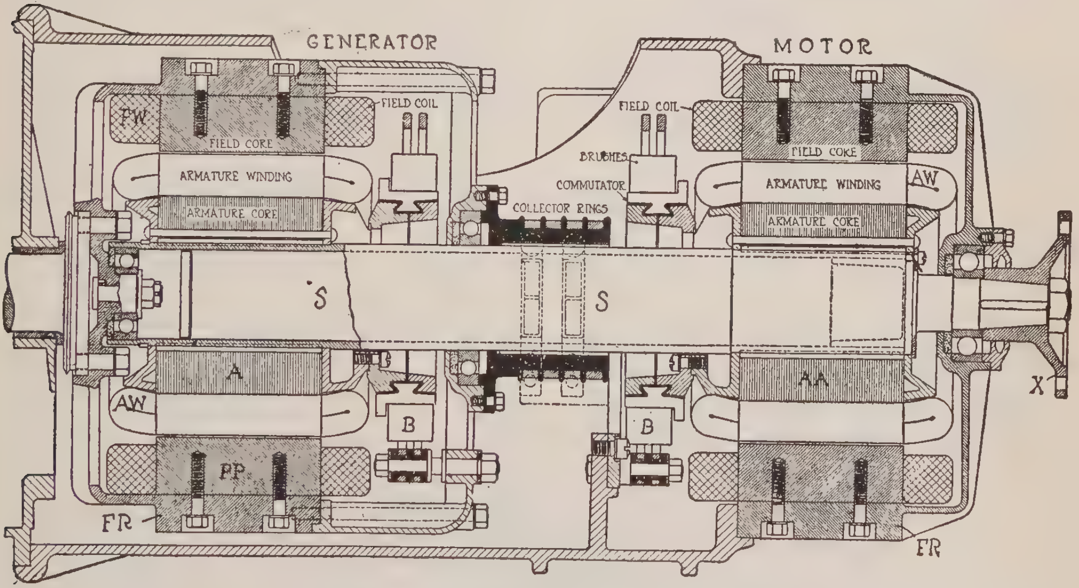


Fig. 20. **Section through Owen-Entz electric transmission.** Generator field cores and coils form the gasoline engine flywheel and the collector rings shown are for the purpose of connecting the field-current of the generator to the various circuits. The brushes of the generator revolve with the field. The two armatures are identical, and both are keyed to the hollow shaft which is attached to the propeller shaft and has no connection with the gasoline engine. (*Motor Age.*)

The different graduations of speed and torque are controlled by the relative strength of the generator and motor field. The weaker the generator field compared to the motor field, the greater the slip, and the more electrical energy goes to the motor for producing greater torque.

Besides the positions of power control, there is a neutral position in which the clutching effect is cut out, but the motor is so connected, through a resistance, as to act as an electric brake, in which case it becomes a generator, taking power to drive it, and so braking the car.

This brake is most effective when the speed is highest, and is ineffective below 15 m.p.h.; it will hold the car on any mountain grade to 20 m.p.h. without wear of any parts, and can be applied with the car going 60 m.p.h. It cannot hold the wheels, and there is little danger of skidding, as the braking effort disappears at speeds below 15 m.p.h.

Manufacturers of this car are the Owen Magnetic Motor Car Corporation, Wilkes-Barre, Pa.

Parts of Owen-Entz Electric Transmission as Shown in Fig. 20

A—Generator armature.
AA—Motor armature.
AW—Armature winding.
B—Brushes.
FW—Field windings
FR—Field rings (the fields FR may revolve without any motion of A).
S—Continuous shaft.
X—Coupling connected to the drive shaft.
PP—Pole pieces.

FUNDAMENTAL PRINCIPLE OF AN AIRPLANE

There are two essential factors necessary in order that the airplane, a heavier-than-air machine, rise from the ground. They are **thrust** and **lift.**

There are two factors which offer resistance to the airplane rising from the ground, they are known as **gravity** (resistance downwards) and **drift**[1] resistance horizontally, also known as "head-resistance").

The aerial screw or propeller produces the thrust through the air, which overcomes the resistance or drift. The **lift increases** as the speed of the thrust increases, therefore **gravity** is overcome and result is the wings have a lifting effect, produced as will be explained.

It is well to note that, for an airplane to be supported in the air, it is essential that it be kept in motion through the air and not by the motion of the air past the airplane stationary. In other words, the mass of air engaged, the velocity, and force with which the wing surfaces engage the air, is the theory advanced for the support of the plane in the air.

How this lifting effect is brought about, is explained as follows:

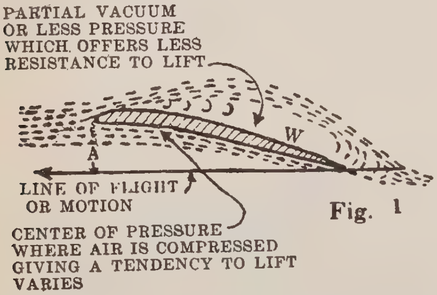


Fig. 1

Supporting and lifting effect under wing: The wing surface is (W) (Fig. 1). The horizontal line we will call the direction of line-of-flight-or-motion." The dotted lines represent the wind or air current, and at another point, say one-third of the way back from the front or leading edge of the wing tip, is the "center-of-pressure," which varies. As the bottom of the wing meets the air, it results in the air striking the under part of the wing, when it is compressed, causing the compressed air to push[2] **up** against the under surface of the wing. The air is gradually diverged downward, thereby giving the wing its supporting effect.

Lifting effect above wing: Over the upper surface of the wing the opposite action is taking place.

Instead of pressure above the wing, the theory is that a **partial vacuum** is created by the air striking the forward edge of the wing and being deflected upwards and over a greater part of the wing surface, as shown in Fig. 1. In other words, there is very **slight** air pressure above. The result is that if the pressure below the wing is greater than above it, and a partial vacuum is created above the wing, the mass of air engaged under the wing by motion produced by the thrust of the propeller, will cause the wing to have a **lifting** effect. This is the fundamental principle of flight.

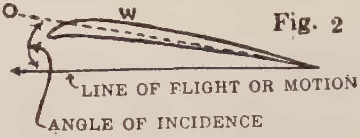


Fig. 2

The angle between this line (O) (Fig. 2) and the line-of-motion is termed the **"angle of incidence,"** and right here, together with the curve or camber of the wing, is what governs the lifting capabilities of an airplane, of course assuming that the thrust is equal.

Parts of an Airplane (Fig. 3)

1. **Propeller** or aerial screw.
3. **Radiator.**
5. **Cock-pits.**
6. **Fixed horizontal stabilizers** to buoy up the tail when flying, as the rear of the machine has a tendency to drop tail down when the wings at the front are at an extreme angle to the wind.
7. **Elevators** for ascending or descending; controlled from the cock-pit. Elevator **up** causes the machine to ascend, and **down,** to descend.
8. **Rudder,** controlling the direction or turning. The rudder is hinged and controlled from the cock-pit.
9. **Ailerons** produce side or lateral tilt. Used to balance the machine if inclined sidewise.
10. **Wing surface** or aerofoil.
11. **Body: Fusilage** is the frame work, separate from the wings. Chassis or landing gear are wheels underneath (not shown).

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[1] Drift also refers to resistance offered by the shape of wings, struts, etc., or any other factors which would have a tendency to oppose lift.

[2] The air must meet the wing surface at such an angle that a downward velocity be given to it after the plane has passed over it. The actual velocity required will depend upon the weight to be carried and the supporting surface that is used.

The machine will slightly "nose-down" when the power of the propeller or thrust is off. If nosed-down too much, descent will be too rapid; thus elevators are then used and the machine glides to a landing.

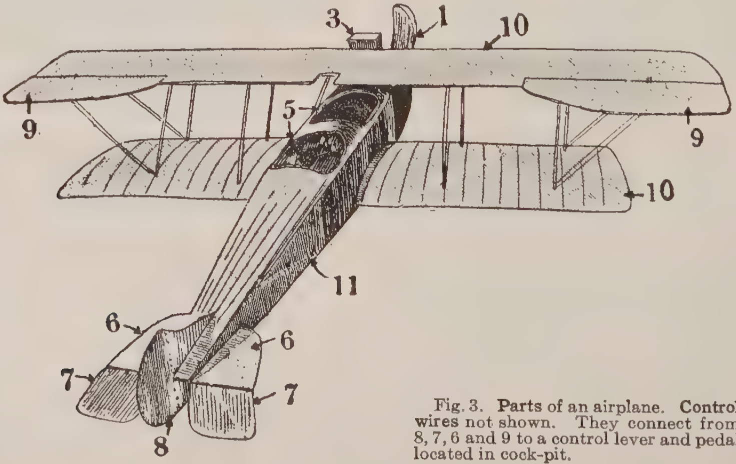

Fig. 3. **Parts of an airplane. Control wires** not shown. They connect from 8, 7, 6 and 9 to a control lever and pedal located in cock-pit.

INSTRUCTION No. 81

REMODELING OLD CARS: Speeding up Old Cars; Redesigning and Speeding up a Ford; How to Make a Motor Sled

DESIGNS FOR REMODELING OLD CARS

The following suggestions and illustrations are from *Motor Age*. Details as to construction are not given.

The different methods employed are shown in the dotted lines. For instance, in the Buick model "30," the idea is shown whereby bucket seats are installed and a cowl is built around the seats. The gear ratio is changed to 2¾ to 1.

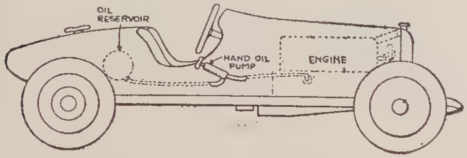

Fig. 1. Suggested method of connecting oil pump on side of racer body with oil tank in rear and motor crank case.

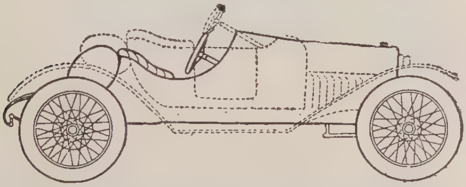

Fig. 2. Sketch showing how a model "30" Buick may be stripped down into a speedster.

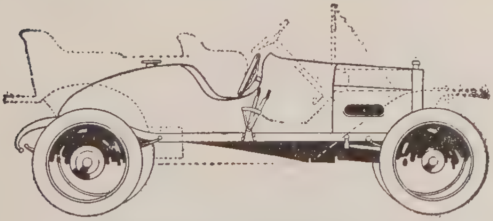

Fig. 3. Speedster body for model "19" Haynes.

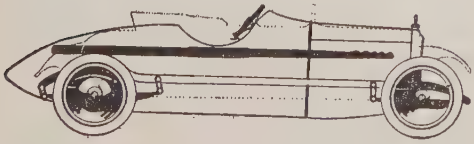

Fig. 4. Mercer with body similar to Mulford's Frontenac.

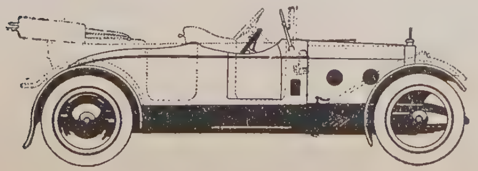

Fig. 5. Suggestion for roadster design for early Pierce-Arrow.

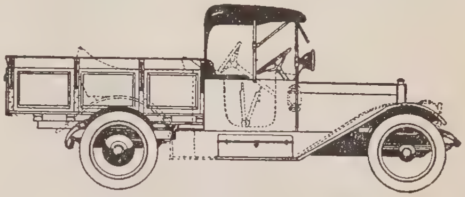

Fig. 6. How a farm truck might be made from an old Winton.

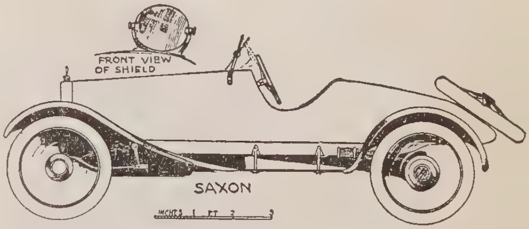

Fig. 7. Speedster body on Saxon "six" designed after ideas of *Motor Age* reader.

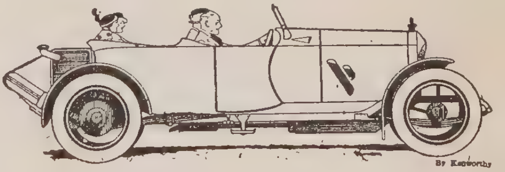

Fig. 8. An exclusive *Motor Age* design for a four-passenger touring roadster.

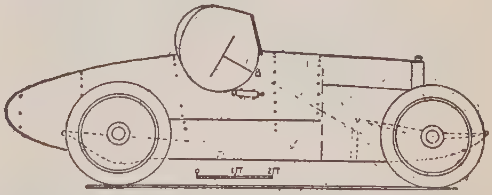

Fig. 9. Diagram showing how a *Motor Age* reader rebuilt an early model car.

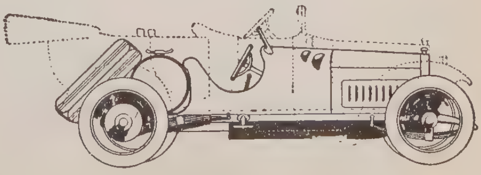

Fig. 9A. Speedster body for early model Cadillac "eight," with cantilever springs to reduce overall height.

REDESIGNING AND SPEEDING UP OLD CARS

Generally speaking, the replacing of the old body with a raceabout type is the most important consideration in rejuvenating an old body, but usually the steering column has to be lowered and sometimes a leaf removed from each of the springs to make up for the lighter body, although this latter is not essential by any means. All too often, old cars have springs that are too weak for the heavy bodies with which they were originally burdened, and these prove just about right for the lighter bodies.

Changes in the valve timing are often made to assist in the speed possibilities, and sometimes different axle gears are used so as to raise the ratio between engine and wheels. It must be borne in mind, however, that many chassis and engine changes of this kind will work to the disadvantage of the car for slow running. They will serve to make the machine faster, but they hamper the engine's ability at low-throttle running. In other words, it will not have the proper flexibility on high gear.

The body being the first consideration in making a speedster, it might be well to take up some of the possible designs. For Fords the combinations offered by concerns making a business of this kind of work are indeed attractive. You can get a complete outfit of radiator, hood, floor boards, rear gasoline tank, and body in the neighborhood of $100, and it is surprising what a difference these make. Other concerns make a specialty of the body proper, exclusive of radiators, hoods, tanks, etc., and it is also possible to get bucket seats alone, so that, with a little ingenuity, quite a presentable racy roadster can result from combinations with old chassis.

Dressing up the cars: The illustrations shown here are suggestions as to how to dress up the chassis in several ways. Many of the most attractive of the types that have come to our attention have been made by enthusiasts, with the assistance of a tinner or other tradesman of similar experience. The usual form of racing roadster is shown in Fig. 10.

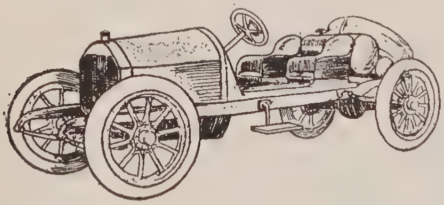

Fig. 10. Usual form of racy roadster with bucket seats.

This has bucket seats that are attached directly to the floor, with gasoline and oil tanks and tires carried at the rear in a way that adds to the appearance. The dash is sloped slightly, and the steering wheel brought down, so as to make steering easy with the seats in this low position. Sometimes running boards and mudguards are entirely eliminated, as shown, with steps at the side to assist in getting into the car, while often the owner prefers to have the mudguards as a matter of protection. They retard the speed a little where fast driving is the thing most sought, but it is a question if they do not also add to the appearance. Usually the hood is sloped somewhat as an added feature. Undoubtedly a high, narrow radiator also does its part in improving the looks, but this is carrying the alterations to an extreme.

Wind resistance is quite a factor in hampering the speed of a car, far more of a factor, in fact, than most motorists realize. To attain greatest speed, the head resistance, by which is meant the surface against which the wind strikes, must be made as small as possible, and the body must be so smooth along its length that there are no obstructions against which the wind can strike and thus form eddies. In other words, the air should be allowed to slide along the body without having to come in contact with lamps or other obstructions.

Getting streamline effect: This is the streamline idea, and in order to carry it out best, the radiator should be as narrow as consistent with proper cooling, the hood should slope, and the rear should taper. If a taper tail is fitted, this forms the most perfect form of body, so far as wind resistance is concerned, providing the rest of the body conforms with it. Tires and gasoline tanks obstruct the air, and wherever possible they should be placed within the tail, if one is fitted. It is not always easy to keep some parts from offering wind resistance, for generally the spare tires have to be carried outside. Two body designs that carry out the wind-resistance reduction theory very well are shown in Figs. 11 and 12.

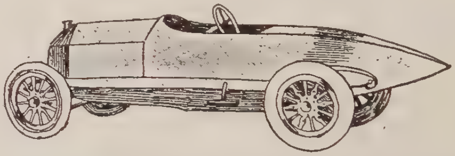

Fig. 11. Type of body designed for minimum wind resistance.

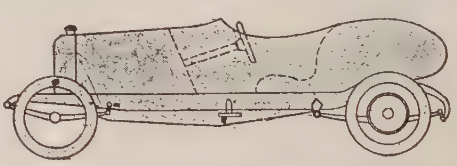

Fig. 12. A suggested body design for class and wind-resistance-lowering.

Thus, even if the engine and gear ratio are not altered at all, more speed is obtainable by cutting down the wind resistance and fitting the lighter body. Usually from 10 to 15 miles per hour are added to the possibilities of the vehicle by these changes alone, and sometimes, with the engine specially tuned for speed work, though timing and valves are not altered, it is possible to get even more. The reduction in wind retardation, however, permits of raising the gear ratio sometimes where it would not be practicable to do so otherwise. Often if a car is fitted with a standard ratio of 4 to 1, say, this can be raised to 3 to 1, if the other factors have first been changed.

One of the mechanical points that can be changed is **the carburetor setting,** adjusting it so that while it may not allow the engine to throttle down so well, it works better at the higher speeds. Usually this is the result of making the mixture leaner, and it ordinarily has the added advantage of preventing the engine from getting so hot.

The magneto or other ignition apparatus can also be altered to conform to the higher speeds, this usually being a matter of setting the timing ahead a slight amount, the exact extent of which depends entirely upon the engine.

More power, and consequently more speed, is often obtainable by reducing the vibration through accurately balancing the pistons. In other words, a set of pistons each of exactly the same weight should be used if possible. Often speed bugs have gone so far as to drill the connecting-rods in order to lighten these reciprocating parts as much as possible, but this ordinarily is not advisable, for the rods are undoubtedly weakened thereby, and not being designed for such treatment, they often will not stand the strain (determined by the amount of stock in the rods).

Extra lubrication is often advisable where the owner wishes to maintain excessively high speeds for any length of time. This can be attained very simply by rigging up an auxiliary supply that will feed directly into the crank case. An easy scheme to employ is shown in Fig. 13. A hand pump is pivoted to the floor of the car as indicated, and an air line runs from it to the top of the oil tank at the rear. The delivery pipe from the oil tank to the crank case runs from the lower side of the tank, and thus the air pressure, coming from the hand pump, forces the excess oil to the engine.

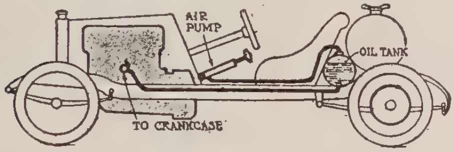

Fig. 13. One way to fit an auxiliary oil system when the tank is at the rear.

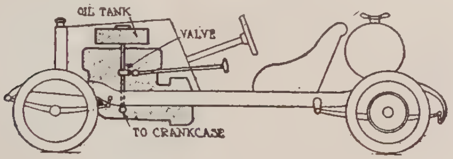

Fig. 14. Extra oil tank at top of motor, supply from which is controlled by a valve.

Sometimes an auxiliary oil tank is fitted to the engine and under the hood, if there is room. There is a pipe connecting from the bottom of this to the crank case, and a valve is interposed in the pipe to allow of controlling the oil from the seat by means of a rod.

Such auxiliary devices as these and the altering of the cam shaft and valves are extremes to which the average man cannot go, although they are conducive to surprising results where intelligently carried out. (*Motor Age.*)

Racing-Car Exhaust Effect

The low rumble in the exhaust of a racing car is due generally to the design and construction of the engine. One method of obtaining this effect is to magnify the sound as in Fig. 15.

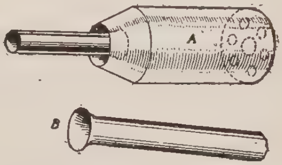

Fig. 15. Noise-amplifying exhaust to give racer sound to small engines.

This shows a large sheet-steel cylinder, (**A**), fitted with a conical-shaped head into which the exhaust pipe is led as shown. The end of the exhaust pipe should be flared, as shown at (**B**). The rear end of the cylinder (**A**) is covered with a metal cap into which several holes have been made.

We have seen this arrangement used very successfully on a small high-speed engine, the exhaust of which sounded like a high-powered racing car. Many of the racing cars give out a metallic-sounding exhaust because the exhaust pipes and headers are made of thin metal. This thin metal will vibrate under the periodic exhaust impulses and set up a peculiar ring of its own. Of course, the thinner the exhaust pipe, the better will be its radiating effect.

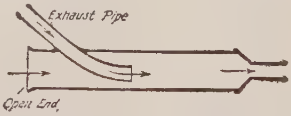

Fig. 16. To increase efficiency of exhaust for racing a method is to run pipes, with gradual bends from each exhaust port, to an expansion chamber. The pipe leading from expansion chamber to the rear should have a gradually increasing diameter to permit gases to expand as they cool.

SPEEDING UP A FORD[1]

As I have helped in rebuilding several Fords that turned out exceptionally fast for the money invested in the job, I believe that I have gained some experience that may be of value to others, so will set down what I have learned, and it may be taken for what it is worth.

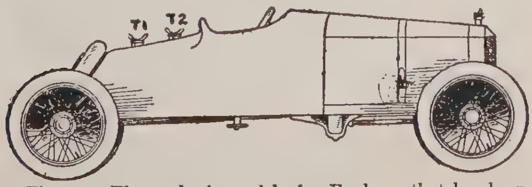

Fig. 17. The author's model of a Ford car that has been made fast.

There have been a few jobs turned out that ran into the thousands, you might say, and that were Fords in name only when finished. Of these I shall have little to say, taking it for granted that what is wanted is something that is within the ordinary man's reach, both in a pecuniary way and, if he delights in doing his own work, in a mechanical way.

Division of Work

The work naturally divides itself into two parts, the engine and chassis, or the running gear. I will discuss the engine first, it being the most important part.

Engine

The engine, as it comes from the factory, has bored cylinders, and as it is impossible, especially in a commercial way, to bore a perfectly true cylinder, the first thing you should do is to have your cylinders reground by a competent machinist, one who makes a specialty of this sort of work. Then you have a set of cylinders that are in line, have equal bore all the way through, and are as near round as it is possible to make them.

---

[1] From *Motor Age*, by Mr. E. B. Williams.

The pistons I have used were cast of aluminum alloy, of course, and were equipped with non-leaking rings. Whatever make is purchased, or if you have them made to order, see to the following things: There should be a rib or "reinforced run" from the piston-pin boss up to the piston head on the inside. Also several ribs should be cast across the inside of the head. This both stiffens the piston and helps in carrying away the heat from the explosions. If you have the pistons made to order, it is advisable to have them cast and machined for two rings rather than three. This cuts down ring friction, lightens the part, and will hold compression as well as three or more rings, if properly fitted.

In fitting the piston, plenty of clearance must be given—from .007″ to .008″ at the top being about right. This may seem excessive, but remember that the expansion of aluminum is much greater than of cast iron.

This large clearance may lead to oil pumping and foul plugs, and so I have always turned and drilled an oil groove in each piston just below the lower ring groove, as shown in Fig. 19. The grooves are about 1/16″ deep and 3/16″ wide, having the lower corner rounded off. There are eight ⅛″ holes drilled through the groove at equal distances around the piston, slanting down toward the inside. The top corner of the ring should also be slightly rounded.

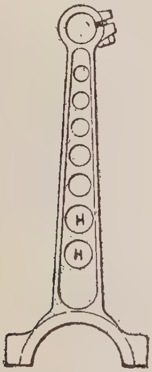

Fig. 18

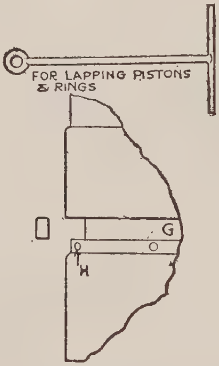

Fig. 19

Fig. 18. The connecting rod has been lightened by dressing with a file and drilling holes through the inside web.

Fig. 19. The tool at the top can be used for lapping the pistons and rings. At the bottom is illustrated the preparation of the piston and ring to prevent oil going into the cylinder.

As the piston goes up, the rounded edge of the ring and the groove tend to slide over the film of oil on the cylinder wall, while in going down, the sharp lower edge of the ring scrapes the oil in the grooves and it runs through the holes to the inside of the piston, and thus back to the crank case.

Lapping Rings to Fit

The rings should be of some good non-leaking type, or at least be step cut. Fit them in the cylinder with a gap of about .004″, then lap them to a fit. In lapping them in, they should be placed on an old piston (cast iron is best), and worked back and forth in the cylinder, keeping the cylinder walls well covered with a mixture of exceedingly fine carborundum, or some other abrasive, and oil. As the piston is moved back and forth, give it also a slight rotating movement. I have used a tool similar to the one shown in Fig. 19 for this purpose. The wrist pin goes through the hole shown.

This is a long tedious job, but you will be well repaid if it is properly done. It takes from 1,500 to 2,000 miles to wear in a set of rings under running conditions. Be sure to get all the abrasive from the cylinder walls and rings after the lapping is finished, or it will continue after the engine is running.

Treatment of Connecting Rods

You can **lighten the connecting rods** considerably by dressing them up with a file and drilling several holes through the inside web. This does not dangerously weaken them, judging from my experience. Do not drill any holes in the last inch toward the bottom, as this is where the most strain comes, and anyway, this part of the rod is more of a rotating than a reciprocating mass. In one car the rods were chucked up and the lower ends turned out and bearings (made of Kelly metal) were cast, turned to fit and installed. After 2,500 miles of driving, most of it at high speed, the engine was torn down and these bearings showed practically no wear. This metal, if used, must be fitted with plenty of clearance.

Large Valves Are Better

You will secure better results if the valve ports and pockets are turned out and larger valves are used. No trouble is liable to be encountered in boring the seats and ports from the top, but when going in from the side the tool will sometimes break through, and you will have to have the hole welded. It is best to do this before regrinding the block, as the heat, if welding is necessary, will warp the walls surrounding the weld. The ports can be enlarged 3/16″, and this is necessary if you expect good results. I have used tungsten steel valves, giving the stems plenty of clearance.

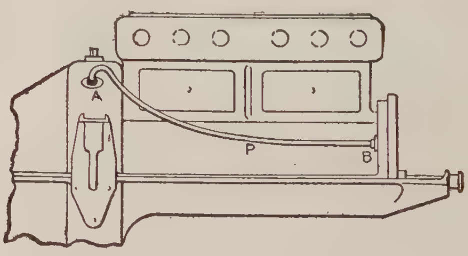

Fig. 20. One auxiliary oil system.

The valve springs must be stiffened considerably, either by installing heavier springs, or by placing spacers between the upper ends of the springs and the cylinder casting.

It is good practice to install adjusters, using the kind that screws into the valve push rod, it being necessary to anneal, drill, and tap the rod. While you are about it, drill the length of rod to the head, but not through. This lightens the part and cuts down inertia, thus helping the valve to close more quickly.

Cam Shaft

At this stage we come to the cam shaft, which should be of the high-speed type if you can afford it, several different makes being on the market. I have secured good results with shafts taken from Ford cars of early vintage. You will find them considerably different from the new type. If the regular shafts are used, do not try changing the timing, as one tooth on the coarse-pitched timing gears of the Ford throws the timing out too much.

Remove Magnets

Leave out the magneto armature coil assembly, and remove the magnets from the flywheel, screwing back the brass screws and brass magnet supports only. It will be necessary to shorten the screws a little. They will kick up almost as much oil as the magnets, and considerable drag will be removed.

Crank Shaft

Now see that the crank shaft is perfectly true; then assemble the crank shaft and gearset and try out in the lathe, first seeing that the bushing in the driving-plate assembly is a good fit on the gearset shaft. If there is any wobble, it will probably mean turning up both sides of the gearset-shaft flange and the back side of the crank-shaft flange. Now reassemble, and turn up the flywheel if necessary to make it run true. Take out the assembly and try on two perfectly level knife-edge testing bars for balance. If one side of the flywheel turns down, take out the material on that side until the wheel stays where you turn it. This may seem a lot of trouble, but it is essential that these parts be true and in perfect balance.

Gearset May Affect Bearings

The power and added strain at high engine speeds will sometimes cause the gearset to whip out the babbitt bearing at the rear in what is called the front ball cap. This will in turn loosen up the rear main bearing. I have found it advisable to turn out the ball cap and equip it with a bronze bushing, fitting it rather loose on the gearset driving-plate, assembly shaft to give lots of room for oil.

Lubrication

It is good practice to fit some auxiliary oiling system besides the gravity one with which the Ford is equipped. If money is no object, a force-feed system can be installed, which should have leads running to all four cylinders, being tapped through the walls on each side near the bottom of the cylinders, and also a large lead running to the front of the crank case. I have secured good results by cutting a ⅞″ hole near the top of the gearset case on the right side, and running a piece of brass or steel tubing, also ⅞″, to empty into the timing-gear case as shown in Fig. 20. The front end need be only a snug fit in the case, but the rear end must have a flange which can be bolted to the gearset cover, using a gasket between. A sheet-iron partition can be installed just back of No. 4 cylinder. This can be made as high as it is desired to carry the oil level under the connecting rods. Of course, every car intended for long distance should also have a hand oil pump convenient to the driver which will force oil from the reserve oil tank to the front of the engine.

High-Tension Magneto not Used

While I believe a good high-tension magneto to be the best ignition on earth, I have discarded it in Ford work on account of the additional power needed for driving. Turning a magneto armature over at two or three thousand revolutions a minute requires more power than is generally thought, in my estimation. I have used a battery-distributor system because it is light, is easily driven, and works on the open-circuit idea, thus requiring only four or five dry cells for current.

Cooling

Some additional cooling is needed. I have found the large "V" honeycomb type of radiator to be best. You will find that it will probably be unnecessary to use a fan with one of these. If you are building a streamline body, it will be better to have some radiator maker build one of the tall narrow kind to order, or you may purchase a stock radiator. If it is necessary to use the original radiator, have a good tinsmith build on an extra tank to the top, either back under the hood, or point it and extend it out in front. Anyway, the original equipment must be improved upon for fast work.

Carburetion

For a carburetor I recommend a 1¼″ type, with a 1¼″ built-up steel-tubing manifold. The one illustrated in Fig. 21 has given good results. No cast manifold is efficient, as the rough surface inside, with possible fins and irregular turns, seriously hampers the flow of gas.

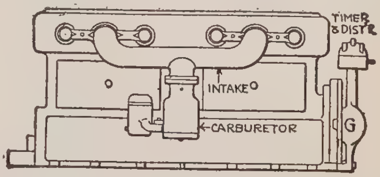

Fig. 21. Ford block showing installation of built-up manifold, carburetor, and ignition apparatus.

Air Pressure on Gasoline Tank

It will be necessary to use air pressure on your gas supply, as the carburetor should be set high, thus shortening the manifold.

Inlet and Exhaust Manifold

Each end of the intake manifold has a collar brazed or welded about 3/16″ from the end; so also the exhaust pipes, which are of steel tubing and run straight out through the hood. A copper-asbestos gasket is slipped over the end of the manifold and makes a tight fit between the collar and the cylinder casting. The manifolds are held on by crows' feet, which slip over the original studs and bear against the outside of the collars.

Running Gear

When we come to the running gear, we have two things to consider: If the car is to be used for fast track work only, by all means lower it. But if you want it for other work too, you will probably have to leave it up in the air, and sacrifice some efficiency.

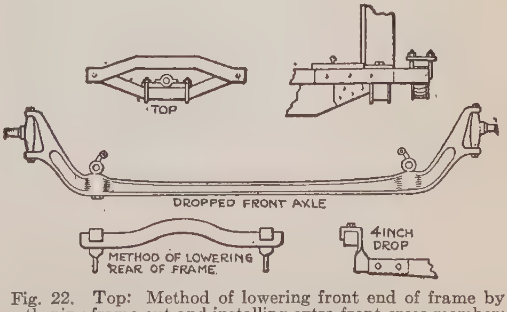

Fig. 22. Top: Method of lowering front end of frame by lengthening frame out and installing extra front cross-member; center: dropped front axle; bottom: method of lowering rear end of frame 4 in.

The best way to lower the front end, to my notion, is to have a new axle made similar to the one illustrated (page 1027, Fig. 22). It leaves your frame strong and rigid, and an added advantage is that your radius rods are still in a straight line.

The rear end of the frame can be lowered by cutting off the side members just in front of the rear cross-member, and using steel forgings as shown in Fig. 22.

The front end, if a cheaper construction is desired, may be lowered as shown in Fig. 22, by riveting pieces of channel iron on the sides of the frame, letting them stick out in front about 5 inches.

An extra cross-member, similar to the regular Ford front cross-member, but with a high instead of a low center, is riveted across the front to the two new side-extensions. This sets your front axle ahead enough to clear the radiator, and the amount of frame drop depends on the shape of your new cross-members (as can readily be seen) which carry the spring. With this method it will be necessary to lengthen out your radius rods and the starting crank.

Assembly Should Be Kept Rigid

In tilting the steering post, it is desirable to keep the assembly as rigid as possible. Have it bolted to the dash securely, blocking behind the dash plate with a wedge-shaped piece of hardwood shaped to fit the space caused by lowering. It will be necessary to drill a new hole in the side of the frame for bolting down the bracket. You can block under the bracket where it tips from the frame with steel washers before bolting.

Steering

The steering-gear connecting rod and the spindle-arm connecting rod should both be stiffened. An easy way to do this is to place a piece of small channel iron or steel tubing alongside the rod and bind the two together with several layers of tape, taping the whole length of the rods, and then shellacing the whole job. This is cheap, easy to do, and makes a permanent job.

Axle

See that the axle tips (casters) **toward the back of the car at the top.** The nearer vertical the axle is set, the harder it is to steer, and when the top of the axle gets ahead of the bottom, it is almost impossible to keep the car in the road.

A good gear ratio for a car put up like this one is about 2 4/7 to 1. While I have always made my own special gears, several concerns are making and advertising them. Some makes sell for $15.

While you have the rear end down, see that the **differential gears** are a good fit on the inside ends of the axles. These sometimes get loose and tear the key seats out of the axle.

The rear hub brakes on the Ford were only intended for holding the car when standing still, and if used when running, they do not last long, and are not very efficient at that. The best brakes I have used so far were secured from Los Angeles, Cal., costing $16 per set. They have large drums and external contracting bands lined with raybestos.

Be sure to see that the **transmission bands** are a perfect fit on the drums and are not adjusted too tight. They can set up quite a drag if not properly set.

Speed thus Obtained

I had one of these cars do 68 m.p.h., and another one equipped with wire wheels 71 m.p.h. Of course, if economy is no object, a new cylinder head with overhead valves and cam shaft, wire wheels, etc., can be added, the stroke lengthened, and in this way a few miles per hour can be gained, but for the man of moderate means the foregoing described car will go fast enough and furnish lots of pleasure in the building.

Cost

The job I have described will run from $200 to $350, depending on how much of the work the builder is able to do himself.

I have not taken up **the construction of the body,** as that depends upon the taste or ability of the man who is building the car, and also upon the use to which it is to be put.

For racing, a pair of bucket seats and a gas and oil tank bolted to the frame will get by very well, but they are not comfortable or very clean. The body shown on page 1031 is good, being neat in appearance; it can be made comfortable, and offers little resistance to the wind. While it is not drawn to scale, the proportions are near enough right to give the idea. There is a gas and oil tank in the rear compartment, with the spare being slung on the extreme rear. This body should cost you about $150 at the average body builders.

Don't forget your **hood straps,** and have them very substantial.

ANOTHER EXAMPLE OF INCREASING THE SPEED OF A FORD[1]

Cylinders

If the car has been driven over two or three years, it will be probably advisable to have the cylinders rebored to the Ford standard of 1/32″ oversize. While this will add only about one-half horsepower to the engine, on account of the larger bore, the fact that the cylinder casting will have aged sufficiently to attain its permanent set will have more influence on the power of the engine than is often supposed.

Compression[2]

It is, perhaps, not generally known that the cylinder heads on the Ford cars have not always been the same. The **cylinder heads** used a few years ago were not as deep as those used on the latest models. To obtain higher compression (which is necessary for high-speed work), it will be well to secure one of these old-style cylinder heads. They can be identified by comparing them with cylinders of the latest type, using a depth gauge as shown in Fig. 23.

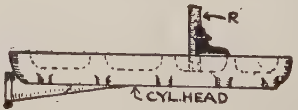

Fig. 23. Measuring depth of cylinder head.

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[1] From *Fordowner*, by Mr. Murray Fahnestock.

[2] In different Ford races there was not a car in which attempts had been made to increase compression by reducing compression space, and cast-iron pistons seemed to predominate. Gear ratios used were from 2¾ to 3 to 1. For long races radiators were fitted with tanks for extra water capacity.

These high-compression cylinder heads give more power, but they are harder on the bearings and make the engine more liable to knock, so that many owners are very glad to trade them for cylinder heads of the latest type, if the difference is pointed out to them.

It is true that different compressions affect the power of explosions, and that an **uneven compression ratio in different cylinders will, consequently, cause an engine to jerk.** If the compression is excessively high, it can keep the spark from jumping the gap in the plug.

If the old-style cylinder head cannot be obtained, it is possible to plane off about one-eighth inch from the bottom of the cylinder head and thus increase the compression of the engine to about 70 lbs. to the square inch. The work must be carefully done, so that a true surface is obtained, or water leaks and loss of compression will result. Good gaskets should be used between the cylinder head and the cylinder blocks, so that no compression will escape. By the use of Prussian blue and a scraper, it is possible to fit the cylinder head to the cylinder block without the use of a gasket, thus reducing the compression space about 1/32″.

Unless the compression is the same, the engine will not be in good balance, and loss of power will result. The power lost when one cylinder does not fire is far more than one-quarter, and this is due largely to a loss of balance.

Valve Springs

One of the most important features necessary to obtain increased power is good valve action. Valve springs are cheap, and it pays to install a new set of valve springs occasionally, even if the old ones do not seem to be worn out. Lively springs close the valves promptly and this is especially necessary if the engine is to be run at high speeds. If it is to be used for racing and the last ounce of power is desired, it may be advisable to use special valve springs that are stronger than the regular type, but which are more apt to break the valves and are more noisy.

It is, of course, understood that the engine will be kept free of carbon and the valves ground frequently, if used for speed work.

Valves and Cam Shaft[1]

In order to obtain the highest possible speed, it is necessary that the valves be timed differently from what is standard practice. For racing, it is necessary that the valves be given a greater lift, that is, that they open farther, and that the cams be so designed that the valves be opened and closed more quickly. Now these quick-action valve cams cause greater wear and tear and make more noise. It is also true that the engine will not run smoothly on high gear at speeds of less than 20 miles an hour, so these special cam shafts are only of value when the car is used for racing only.

For use as a speedster, on average roads, the regular cam shaft is probably the best. It is easy to set the timing gears one tooth ahead and so to open the valves earlier, but this also means that they close earlier, and so little is gained by this practice.

It is sometimes asserted that the speed of the Ford engine is purposely limited by the small size of the ports or valve openings. This is probably done so that careless drivers will not run the engine too fast, but if it is intelligently handled, it is true that greater power can be obtained by enlarging the ports or valve seats. A wide seating for the valves is not necessary and tends to restrict the flow of the gases. One thirty-second of an inch is wide enough, but requires more frequent grinding and valve adjustment than a wider seating, as it wears more quickly under the hammering action of the valves. Fig. 24 shows how the valve ports may be bored out larger, but great care should be taken not to break through the sides of the water jackets, as the walls are not always uniform in thickness, due to the displacement of the cores when the castings are made.

Muffler and Carburetion

Getting a large charge of fresh gas in the cylinders for each explosion is one of the essentials of maximum power. Of equal importance is the necessity of getting the old burned gases out quickly. For this reason, a muffler is often omitted from racing cars, although a car cannot lawfully be operated without a muffler on the roads of many states. However, a cutout is easily attached, and if used in moderation, serves the purpose very well. If no muffler is used, the end of the long exhaust pipe should be somewhat flattened, so that the sound waves will be somewhat broken up as they emerge. A number of small holes, and diagonal saw cuts will also aid in giving a free exhaust without undue noise. Or, it is possible to remove one of the baffle tubes from the muffler, or to bore additional holes in the muffler tubes, so that a comparatively free exhaust is secured without losing the muffling qualities altogether.

Carburetion: To obtain the maximum speed from the engine, a larger carburetor, say the 1¼″ size, can be used. This will not be economical of gasoline, and the engine will not run as smoothly at low speeds, but with a larger carburetor and a larger intake manifold, which should be smooth inside, the engine can draw in fuller charges at high speed.

Pistons and Piston Rings

The piston rings certainly create friction as they rub against the cylinder walls, and if the top ring is so well fitted that no compression will escape past it, the two lower rings are unnecessary, as they cannot stop any gases that do not reach them. Some owners prefer to fit special or patented piston rings at the top of each piston and claim that it makes the engine run more freely. However, if only one ring is used, greater care must be taken to keep that one ring in good condition.

If the rings are fitted on an old piston, they may be lapped in by using emery, and a more perfect fit will be obtained, and then they may be placed on the new pistons for actual use. If lapped on the new pistons, the grooves (for the rings) in the pistons are apt to be worn.

Pistons: For high-speed driving it is necessary that the pistons should be rather a loose fit in the cylinders, as otherwise they are apt to seize when the inevitable expansion due to heat occurs. This does not mean that it is not necessary to rebore cylinders or to fit new pistons on old cars, for in such cases the cylinders and pistons are apt to be worn oval, due to the thrust of the connecting rod and so do not have the proper clearance all around.

Obtaining Balance of Engine

Light pistons are certainly an advantage, and the use of aluminum has much to recommend it, especially if new pistons are to be fitted in any case, as then the additional cost will not be so much. In case the cast-iron pistons are used, they can be greatly lightened by careful drilling, care being taken not to weaken them too much. Most of the holes should be drilled near the ends of the piston pins, for if drilled on the sides, where the thrust occurs, they permit the oil to be squeezed out and thus to spoil the lubrication where it is most needed.

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[1] Sometimes the inlet valve is made to open slightly earlier for speed work. In this case the engine will not idle down very well.

Light reciprocating parts are the secret of high speed and power. If we consider structural iron work, we shall notice that beams are made very heavy along the edges where the strain occurs, and often the center is only a light lattice of thin steel strips (see Fig. 18, page 1026, for a drilled rod).

It is possible to balance the rotating masses of the engine, but it is not practicable to balance the reciprocating weights, except to a small extent. But by making the parts lighter, the unbalanced forces and power-absorbing vibrations are greatly reduced. It is more important to lighten the connecting rod at the piston end than at the crank-shaft end, because the piston end of the connecting rod has a reciprocating motion, while the big end bearing has a rotary motion.

Connecting rods: It is also important that the four connecting rods be of equal weight and that the four pistons have the same weight, so that they will tend to balance each other and to reduce vibration.

The **alignment of the connecting-rod bearings** is important. This can best be tested in special jigs which are part of the equipment of every branch of the Ford Motor Co. If one wishes to align these bearings, the piston pin can be placed in one end of the connecting rod, and a cylindrical pin, the size of the crank pin, placed in the other end of the connecting rod, and two steel squares used to make sure that the two bearings are in perfect alignment with each other (Fig. 25). This tests the alignment in one direction only and to test them in the other plane, it will be necessary to use the same tools and a perfectly flat surface, so that the distances from the pins to the plane surface can be measured and made equal on each side. See Index under "Alignment of pistons and connecting rods."

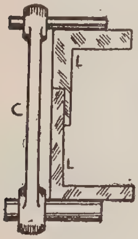

Fig. 25

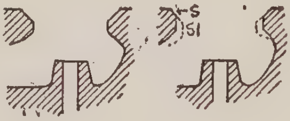

Fig. 24

Fig. 24. Increasing the port opening.
Fig. 25. Alignment of connecting rod.

Crank shaft: It is important that the crank shaft be in good running balance, which is different from being in balance when at rest. It can be tested by revolving the crank shaft at different rates of speed, between centers. The bearings of the crank shaft are also important, and, after they have been scraped to a good fit, the engine should be driven by an outside source of power until the bearings fit perfectly.

Flywheel: It hardly pays to reduce the weight of the flywheel, especially if the power of the engine is increased and a higher compression is used, but the flywheel alignment can be tested by holding a steel pointer near it when the engine is running, for a wobbly flywheel involves a loss of power.

Ignition and Lubrication

Ignition: For ordinary road use, the Ford ignition system will furnish about all the sparks required, but to obtain the very highest speeds, the more accurately timed sparks of the high-tension magneto are an advantage. If the Ford ignition system is used for high-speed work, the magnets and magneto-coil assemblies should be of the latest type and the vibrators should be adjusted more tightly, so that there will be less lag in the ignition. The spark can be advanced by bending the rod from the lower end of the steering column to the timer. It is also well to be sure that the timer is in good condition and that the spring holding the roller against the segments is strong and quick-acting. It may be even an advantage to fasten an additional spring beside the one already in place.

Lubrication: Adequate lubrication plays an important part in the maintenance of high engine speeds. A good quality of thin oil, which does not burn easily, should be used. Heavy oils exert a constant drag, and are not needed, if the engine is in good mechanical order. Oil holes can be drilled in the connecting-rod bearings and larger oil grooves can be cut in the bearings. It is also well to fit a much larger oil pipe and oil funnel. The oil pipe can be drilled with holes opposite each connecting rod, so as to supply a good oil bath.

RACING TYPE OF BODY

An example of a racing type of body for the Ford is shown below, together with dimensions.

As previously stated, one way of increasing the speed of the Ford car is by reducing the wind resistance, by taking off the top, mudguards, and windshield, and also, by the use of special racing bodies.

The radiator is designed especially for racing, and is high and narrow, thus reducing the wind resistance and improving the appearance. The radiating surface is of the patented bridge fin type, and the construction is of copper throughout.

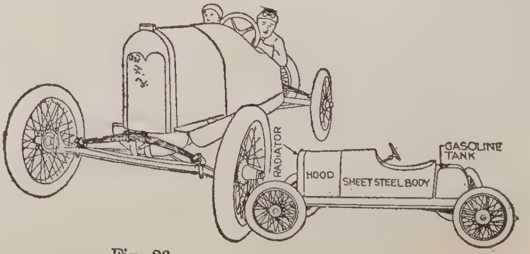

Fig. 26

Fig. 27

Figs. 26, 27. Front and side view of a racing type of body.

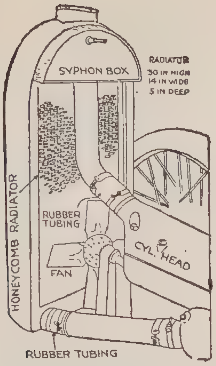

Fig. 28. The radiator is long and narrow: 30″ high; 14″ wide; and 5″ deep. Water capacity is 4½ gallons, including a tank at the top of the radiator.

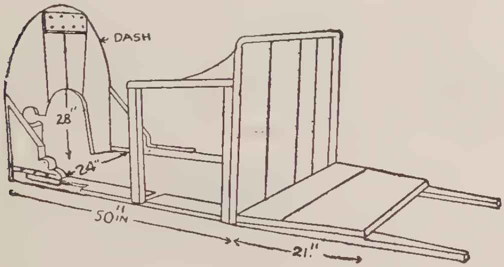

Fig. 29. The wood skeleton of frame of the body.

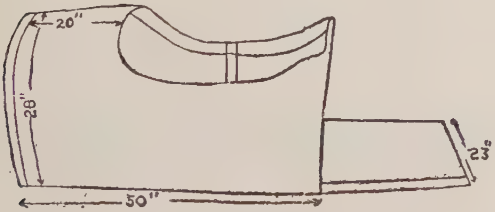

Fig. 30. Side view of metal body (18-gauge pressed steel) which is fitted over the wood skeleton (Fig. 29).

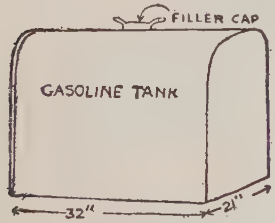

Fig. 31

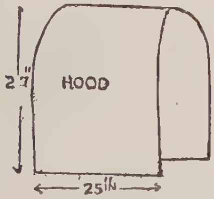

Fig. 32

Fig. 31. The gasoline tank of 35-gallon capacity which is made of 18-gauge steel with splash plates inside, anchored by steel straps. A large polished aluminum filler cap adds considerably to the appearance.

Fig. 32. Hood made of 18-gauge steel.

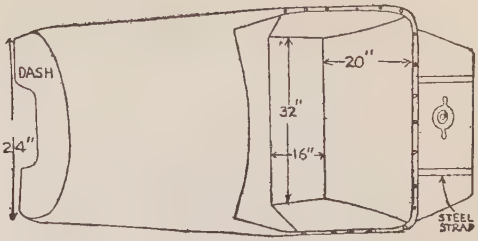

Fig. 33. Top view of body with gasoline tank in rear.

Fig. 34. **Bucket type of racing seats for the roadster, or** speedster. The shell is heavy gauge steel, attached and braced to wooden seat bottoms, and upholstered with substantial imitation leather, known as mule skin. (Can be secured of Am. Auto Accessories Co., Cincinnati, Ohio, Lehman Mfg. Co., Cannelton, Ind., and Laurel Motor Corpn., Anderson, Ind.)

Addresses of Body Builders

F. A. Ames Co., Owensboro, Ky.
Auto Remodeling Co., 1503 Michigan Ave., Chicago, Ill.
Champion Racing Body Co., 1920 So. Wabash Ave., Chicago, Ill.
O. T. Ford Speed and Power Equipment Mfg. Co., 250 W. 54th St., New York, N.Y.
Laurel Motors Corpn., Anderson, Ind.

Wires Wheels for Fords

Budd Wheel Corp'n., 22d. St., and Lehigh Ave., Philadelphia, Pa.
Dayton Wire Wheel Co., Dayton, Ohio.
Laurel Motor Corpn., Anderson, Ind.
Wire Wheel Corp'n. of America (Houk), 1700 Elmwood Ave., Buffalo, N.Y.

Disk Wheels for Fords

Brook-Steel Corp'n., 1010 Bergen St., Brooklyn, N.Y.
Dayton Automotive Wheel Co., Dayton, Ohio.
Detroit Press Steel Corp'n., 4815 Cabot Ave., Detroit, Mich.
Globe Machine and Stamping Co., 1200 W. 76th St., Cleveland, Ohio.
Laurel Motor Corpn., Anderson, Ind.

Racing Parts for Ford

A concern that makes a specialty of supplying parts for speeding up Fords for racing, etc., is the Laurel Motors Corpn., Anderson, Ind. They supply such parts as enumerated below:

Racing gears.
Racing radiators.
Racing carburetors.
Racing magnetos.
Steering gears; worm and gear type.
Cam shafts for high speed (see page 1033).
Counter-balances.
Parts for underslung chassis, etc.
Pistons: light weight.
Cylinder heads with 16 valves, etc.

MISCELLANEOUS SUGGESTIONS OR SPEED POINTERS[1]

Oiling a Ford for Speed

The oil reservoir (R) is placed at any convenient point from which oil is pumped by a **hand oil pump** (P) to the crank case (E) (Fig. 35). From here it is pumped by a small **piston oil pump** to the oil gage (G) on the dash; thence to the timing gears (T).

The oil pump is placed opposite the No. 4 exhaust cam by drilling a hole large enough to permit head (A) to pass through.

The pump parts are made of brass tube (B) screwed to flange (C) having four holes for cap screws. The crank case is tapped, and leather gaskets are inserted between. The piston of the pump is made of steel. Bushing (D) is fitted into (B) to which the remaining part of the pump is screwed. Check valves and parts are shown in the illustrations, Fig. 35.

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[1] This matter is collected from various authoritative sources. The writer has not personally tried out any of the devices.

The oil pipes are ¼″ copper tubing, using solderless connections. At (F) the pet cock is removed and a fitting is screwed into its place. Tubing (G) leads from this to the lower part of the oil pump. A hole is drilled at (T) and tapped to take the connection. (*Motor Age.*)

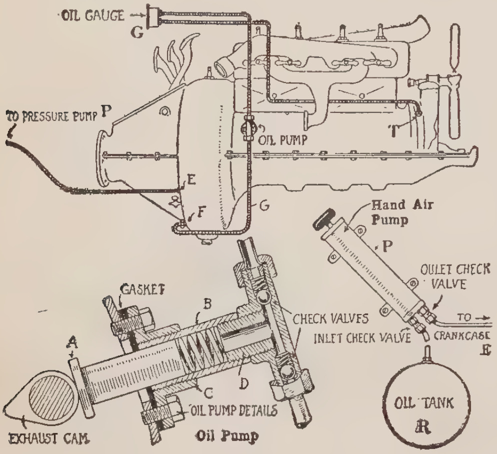

Fig. 35

Auxiliary Oiling (Another Example)

The present oil system in the Ford engine, while suitable for all ordinary purposes, is inadequate for high speed. The oil rotating with the flywheel is caught in a small funnel and is carried through a ⅜″ tubing to the timing-gears, flowing to the engine case, where it lubricates the moving parts of the engine. This funnel can hold only a certain amount of oil, and at any speed the tube can handle only a ⅜″ stream.

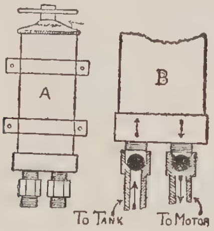

Fig. 36. Home made oil pump.

The funnel should be made larger, the long way, and higher to increase the weight there, and the tube should be replaced with one 7/16″ in diameter.

An auxiliary pump is frequently connected to the engine, as shown (Fig. 36). An old tire pump can be converted into a pump as follows:

An old tire pump is cut off about six inches below the handle. A metal handle is substituted for the wooden one, as shown in the drawing. The bottom of the pump is removed and carefully soldered, and the air outlet is soldered up. Two check valves, requiring no solder, are fitted to the bottom of the pump by drilling and tapping. The valves are, of course, inserted so that they will act in opposite directions. The valve allowing the oil to enter the engine allows the oil to be forced out of the pump, but will not allow it to re-enter. The other valve, working in the opposite direction, permits oil to come from the supply tank to the pump when the handle is pulled up. When the handle is pushed down, one valve closes while the other (the one permitting oil to enter the crank case) opens.

The supply tank may be located where most convenient, and is connected to the pump by copper tubing. The pump is placed under the front seat in a position where it can be operated easily.

Fenders

For fenders for Ford speed cars, we would suggest canvas guards, front and rear. They are easy to make and noiseless.

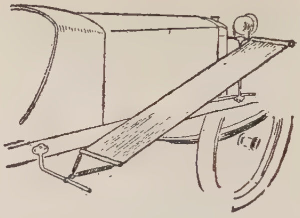

Fig. 37. **A canvas mudguard,** noiseless and easily made. The mudguard support also makes good lamp bracket.

Put a couple of coiled springs at the lower ends, and they will never sag. (*Newsabout Fords.*)

Lowering the Frame

The most important point in converting a Ford into a speedster is the lowering of the frame, because this car presents an awkward appearance with bucket seats and a big gasoline tank when high off the ground.

If semi-elliptic front springs are used, instead of the regular transverse spring, the semi-elliptic springs can be fastened under the axle by means of a U-shaped piece of flat steel (Fig. 38). Thus, the front of the car can be lowered several inches with but little change in the front axle itself. However, the frame will have to be changed, or special spring hangers must be fastened to the frame to form supports for the front ends of these semi-elliptic springs.

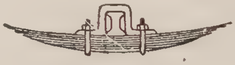

Fig. 38. One of the simple methods used to undersling Ford front springs.

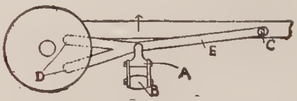

Fig. 39. **Underslung rear spring.** Forked rod (E) was anchored at the brake rods (D) and at the frame at (C). Spring (B) was shackled to the rod by (A).

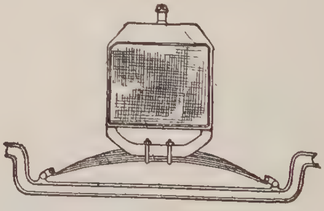

Fig. 40. This Ford front axle is a special forging with dropped ends.

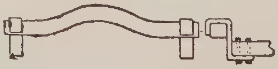

Fig. 41. Method of lowering rear spring 4 inches. The end of the panel was cut off and a gooseneck fitted as shown.

A special dropped front axle is shown in Fig. 40. It can be made to lower the front end of the car without making necessary inconvenient changes in the chassis frame.

The rear of the frame can be lowered by using the brake arm studs in the rear axle housing (Fig. 39) to fasten a forked steel bar from the axle to the frame. About two inches forward from the fork the spring shackles are bolted and the regular cross-spring is suspended from them. This gives about a 4-inch drop. (*Motor Age.*)

Another Method of Lowering the Frame

The work can be done by any good blacksmith, and will not cost more than $15. The principal changes in dropping the frame are in making the front and rear brackets which allow the frame to be hung 6″ lower, as shown in Fig. 42.

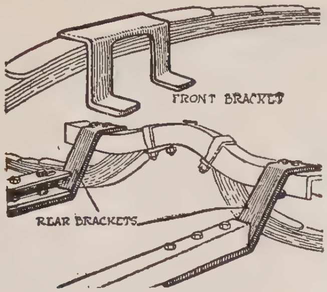

Fig. 42

The front bracket consists of a piece of iron, bent as shown, and made out of ½″ by 2″ stock. The method of attaching this is clearly indicated. The top is clamped over the spring, and the bottom ends are bolted to the cross-frame member.

The form of the rear bracket is also shown, and its attachment is even simpler than the front. The frame is sawed off, and the two brackets are bolted in place. Care should be taken in making the change not to alter the position of the axle relative to the frame backwards or forwards.

The attachment of the front bracket requires that the axle be pushed forward a certain amount—probably 3 inches. This must be compensated for by welding pieces in the radius rods running to the front axle.

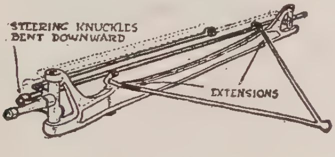

Fig. 43

The lower position of the crank case requires that the steering knuckles be bent downward, so that the tie rod will clear it. (*Newsabout Fords.*)

A Ford Racing Type Cam Shaft

A cam shaft designed to give more power and greater speed to a Ford is made by the Laurel Motor Corpn., Anderson, Ind., the installation instructions being as follows:

"The exhaust valve opens 55° before dead center and closes 10° past upper dead center. The intake opens 10° past top dead center and closes 55° past lower dead center. This is the same timing that was used on the Stutz 16-valve racing car.

"To remove the regular cam shaft, loosen the two set screws that hold the cam-shaft bushings in their place. Turn the motor over so that all the plunger pins can be inserted and so that they will not drop down into motor case. Remove the front cover plate and draw the cam shaft forward, and replace with a Laurel high-speed cam shaft. This is practically the same as changing any Ford cam shaft, excepting that you chisel a slight groove in the first and second bearing retainer, and 90° apart for clearance of the cam. The proper clearance between the valve stems and plungers should be about 10 one-thousandths of an inch. Set the cam-shaft gears to the Ford marks."

Ether, Picric Acid, and Gasoline

Q.: Can ether or picric acid be used for increasing power for racing?

Ans.: Yes, nitrous ether has been used, but is dangerous.

Nitrous ether is purchased in glass tubes and is put on ice at least 8 hours before the attempt to handle, as heat from the palm of the hand will explode it, and the shattered glass may put your eyes out. Mix one ounce to five gallons of gasoline, and you may have to add a little more gasoline or a little more ether to get the best results.

Ether bought in pound cans is suitable for easy starting in cold weather, if half ether and half gasoline is mixed and put in a small tank on the dash, using a small priming pump to squirt it in the intake pipe. This ether can be handled without danger, as long as it is kept away from a flame.

Picric acid: Put one pound of picric acid in a glass bottle and fill with gasoline or alcohol; keep in a cool place; stir twice a day for one week before using. The picric acid will not all dissolve, but pour out all the liquid, straining it through a fine sieve, and mix in the same proportion as you do ether. You can use both together by equally dividing them. There is one point to watch closely; do not get the mixture too rich. Picric acid is injurious to the engine, and will increase heat.

MOTOR BOAT AND MOTOR SLED

Ford Engine in a Boat

The length of boat suggested is 20 to 22 ft., by 5 ft. beam, and 1 ft. draft, the latter being for the hull only. The over-all draft, or water the boat draws, is determined by the size of the propeller. If there are obstructions in the water where the boat is to be used, it is better to fit some form of skeg or protection below the propeller.

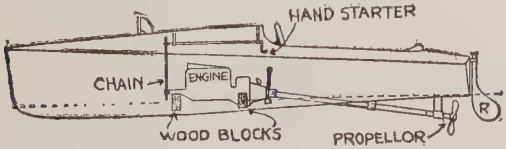

Fig. 44

In mounting the engine, fit strong oak cross-members in the engine compartment and fasten it in place with lag screws, using the same brackets fastened to the engine.

Leave the **transmission attached,** and mount the powerplant so that it will be level when the boat is in the water and under way. Boats rise out of the water when traveling fast, so you must make allowance for this. The engine will oil better when on a level. Proper adjustment can be made with shims under it.

The illustration (Fig. 44) shows a **cranking device,** by which the engine can be started from the seat. Arrange to drive a centrifugal or gear pump to force the cooling water around the jackets. Be careful not to get this pump too large, or the engine will be overcooled. Arrange to run some of the overflow water into the exhaust pipe, a foot or more from the engine, which will help to muffle the noise.

It is hard to give specific **propeller dimensions,** but if built somewhat after the design shown, one having a diameter of 15″, three blades, and a pitch of 22° would be about right. (*Motor Age.*)

A Motor Bob—Wheel Drive

Riding board 14″ wide x 1¼″ thick. Two 7″ strips may be used, but a single plank is best. Two 1″ x 3″ pieces strengthen it. Two **running boards** hung on steel brackets offer a foot rest for passengers. Sleds should be made of hardwood with steel runners.

The engine is of the motorcycle type, mounted in a frame of ⅜″ round stock (Fig. 47). The weight of the bob is not carried on the wheels; therefore two heavy coil springs force the wheel to the ground (Fig. 45), by pull on the frame.

Also note the **skid chain** on the motorcycle wheel, which is to give it traction. Steering is shown in Fig. 46.

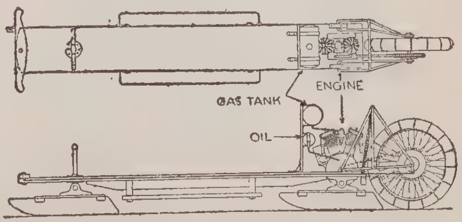

Fig. 45. Plan and elevation of the **wheel-driven** motor bobs. Note the trussed riding board and underslung foot rest. The brake is connected with the pivoted foot rest of the steersman

A Motor Bob—Propeller Drive

This is not recommended for narrow-gauge bobs. It has an advantage over the wheel in that the wheel has difficulty in obtaining traction in soft snow or on broken roads. If a propeller is used, it would be better to ask some aeroplane propeller manufacturer as to revolutions and size. (*Automobile.*)

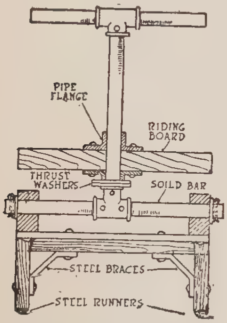

Fig. 46

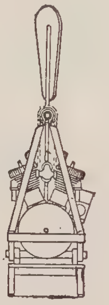

Fig. 47

Fig. 46. Detail of the front bob mounting, showing the steering mechanism.

Fig. 47. A simple method of mounting the propeller at the rear. The standards are made of 2-in. angle irons, rigidly braced.

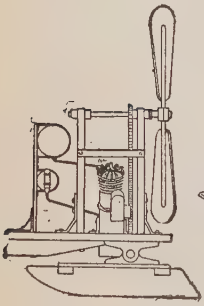

Fig. 48

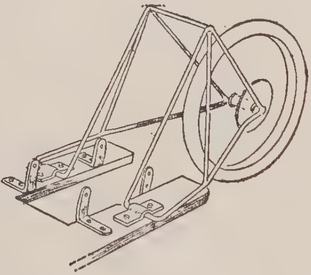

Fig. 49

Fig. 48. Side view of propeller.

Fig. 49. Detail of the motor mounting and the drive-wheel cradle.

Building a Motor Sled Using a Ford Engine

An idea of such a device is shown in Fig. 50. The narrower the job, the faster it will be, but it will require more efficient handling, particularly when making turns, where it will be necessary to slow down materially. The length will have to be worked out to suit the fittings. Because of the length required, there should be a truss under each side member, which can be made of a 3/16″ rod with about 3″ studs and a turn that goes to take up the slack. Besides having the front bob made to swivel to enable steering, there should be a step on each side upon which to brace the feet. The engine will set a little back of the middle, and this will about balance the weight of two passengers sitting ahead.

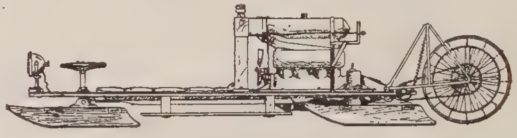

Fig. 50. A motor sled using a Ford engine.

To use a Ford engine, it will be necessary to fit a bevel gear to the end of the shaft, and a bevel gear on a cross-shaft, upon which is to be a driving sprocket, which can be the same as those used on motorcycles. Provide a truss bearing on the back of each bevel gear and, of course, the necessary oil holes in the bearing carrying the countershaft. The size of the shaft upon which the bevel gear should be, will depend upon the location of the drive wheel. It should be on the right side looking forward, as the flywheel of the engine should be set to the front, which will make the engine turn to the left when looking backward.

You can easily connect up the throttle, spark, and transmission levers to suit your needs in accordance with the position of the operator, who will sit in front. This can be arranged so that one can steer and one in the second seat can operate the levers; but this will be bad, in that one person could not manage the bob alone. The person in the second seat can operate the bob alone if an auxiliary steering arm is placed back and connected at right angles out to the side of the bob. We should recommend a mechanical starter as being a cheaper installation. The knob handle of the mechanical starter is shown at the rear of the gasoline tank. (*Motor Age.*)

MOTOR WHEEL AND AUTO-PED

The Smith Flyer (Fig. 51) is a light motor vehicle made from a four-wheeled buckboard with a Smith "**motor wheel**" attached to the rear.

This machine, though its entire weight is but 135 lbs.., is capable of running at 20 to 25 m.p.h., and runs from 50 to 60 miles on 1 gal. of gasoline.

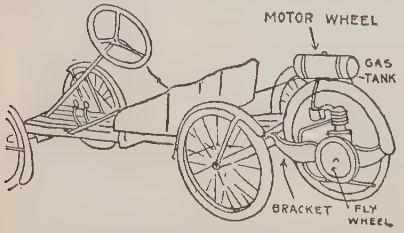

Fig. 51

The Auto-Ped, manufactured by the Auto-Ped Co. of America, Long Island City, N.Y., is shown in Fig. 52. To drive it, the operator is in a standing position. A 6-volt lighting generator is inclosed in the flywheel case.

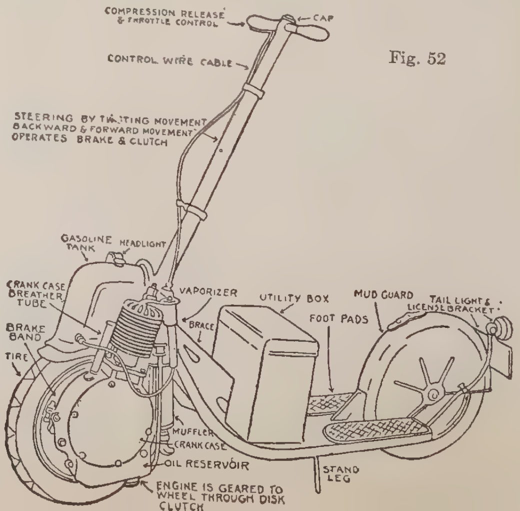
COMPRESSION RELEASE & THROTTLE CONTROL
CAP
CONTROL WIRE CABLE
STEERING BY TWISTING MOVEMENT BACKWARD & FORWARD MOVEMENT OPERATES BRAKE & CLUTCH
GASOLINE TANK
HEADLIGHT
CRANK CASE BREATHER TUBE
VAPORIZER
UTILITY BOX
MUD GUARD
TAIL LIGHT & LICENSE BRACKET
FOOT PADS
BRACE
BRAKE BAND
TIRE
MUFFLER
CRANK CASE
OIL RESERVOIR
STAND LEG
ENGINE IS GEARED TO WHEEL THROUGH DISK CLUTCH

Fig. 52

INSTRUCTION No. 82

USEFUL REPAIR HINTS AND SUGGESTIONS[1]

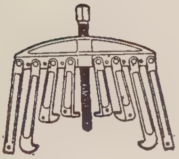

Fig. 1

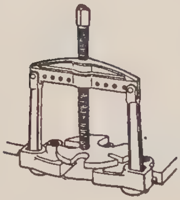

Fig. 2

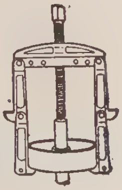

Fig. 3

Fig. 1. **Crane wheel pullers.** The complete outfit with various length attachments.

Fig. 2. A special attachment which makes an arbor press.

Fig. 3. Removing a flywheel.

All three of these are manufactured by the Crane Puller Co., Arlington, Mass.; also write to W. E. Prudden Hdw. Co., 864 8th Ave., New York, N.Y., for information on another type of wheel puller.

Pulling a wheel from a rusted axle is a bigger job than it appears. If the axle is greased before the wheel is put on, the probabilities are that it will come off readily; if not greased, it will, more than likely, be a task. A wheel puller can be bought of any auto supply house, or one can be made by a local blacksmith. Every repair shop needs a wheel puller.

A wheel puller can also be utilized for removing flywheels, transmissions, gears, collars, pulleys, couplings, marine propellers, etc.

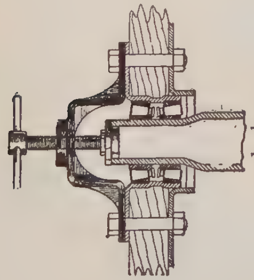

Fig. 4

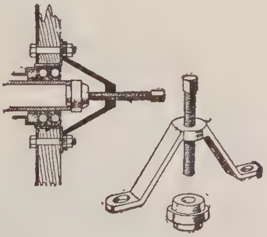

Fig. 5

Fig. 4. **Rear wheel puller.** This puller is used to remove the rear wheels of the Buick. The wheel flange and axle are removed and the puller bolted to the flange bolts. A steel button is then placed in the rear axle tube, and the pressure is applied by the central screw. By having several sizes of steel buttons, and making the flange bolt holes oval, this puller may be used on many cars.

Fig. 5. **A special puller is required for the removal of the Dodge rear wheel.** After the removal of the outside flange and the rear axle, the frame of the puller is bolted on to two of the flange bolts. The plunger on the end of the screw fits inside the rear axle housing, giving a leverage that permits the ready removal of the wheel. The frame is made of cast iron, reinforced by ribs; the screw is a ¾″ bolt.

Fig. 6. This **makeshift wheel puller** is made from two long bolts (B), with nuts, a short thick bolt (D), and three pieces of iron drilled as shown. These parts are applied to the wheel with the short pieces of iron behind the spokes of the wheel, and the bolt (D) communicating between the bar and the end of the axle shaft. By taking up evenly on the two nuts with the wrench (M) and occasionally striking the bar opposite the bolt (D) with a hammer, a very stubborn wheel can be easily removed.

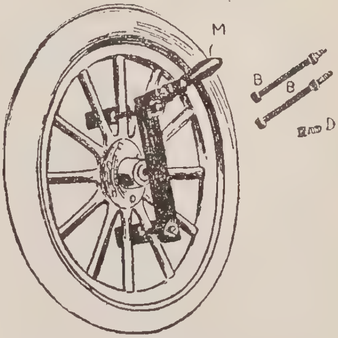

Fig. 6

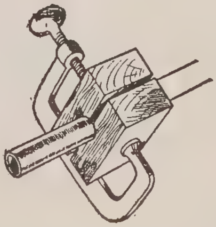

Fig. 7. **Steering-post puller.** Two wooden blocks clamped to the steering post by a heavy metal clamp offer a convenient brace for a jack, thus permitting the removal of the steering post. After applying a strain to the post by means of the jack, a few blows on the blocks with a heavy hammer so loosen the post that it may be drawn out without injury.

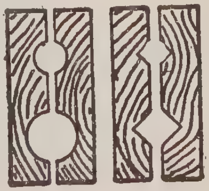

Fig. 8. **Vise clamps made of wood, ⅛″ sheet copper, and sometimes sheet lead.** These are useful and necessary where the material is to be clamped in a vise, which would mar its surface otherwise. When made of sheet copper or lead, use ⅛″ thick clamps cut to the size of the vise jaws, and bend over the top of the jaws to support them in place. When made of hardwood, bore holes through and then saw across, about ¼″ or more being cut away; or they can be cut to a V. These latter will take bars or pipes of various sizes without injury.

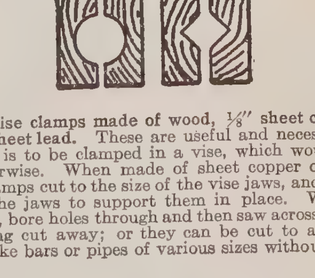

Fig. 9. **Vise clamps for working with tubing.** Note the spring tension which keeps clamps in vise when the jaws are opened.

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[1] From *Motor World* and *Motor Age*. See page 1041 relative to a book which gives 1,500 time and labor-saving kinks, methods, and devices.

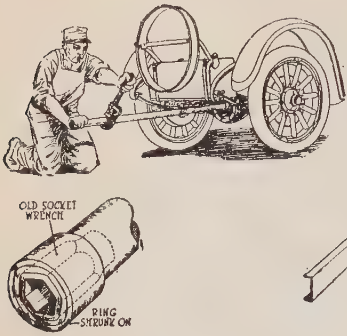

Fig. 10

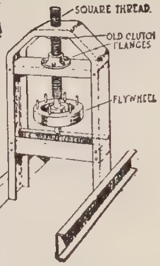

Fig. 11

Fig. 10. **Extension socket wrench.** By mounting a socket wrench head in the end of a 4 ft. length of 2" pipe, an extension wrench is made that facilitates the removal or replacement of the nut ~~on~~ the rear-axle drive pinion. A steel ring is first shrunk on the end of the pipe, to provide strength; the pipe is heated red, and the cold socket-wrench head is driven into the pipe. When cool, the head is firmly held in place. Because of the long handle, a pipe wrench may be used to get a leverage, and the workman may work from an uncramped position.

Fig. 11. **This home-made arbor press** is made of channel sections from an old frame. It comprises an inverted U-shaped member, supported in an upright position on the channel base as shown. The overall height is about 5½ ft. and the width 4 ft. The pressure screw is carried on two large nuts that are old clutch flanges tapped out, both the screw and the nuts having square threads. An old flywheel, keyed to the lower end of the pressure screw, serves as a hand wheel, and is provided with vertical pins so that a pinch bar may be used to increase the leverage.

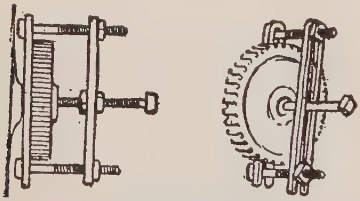

Fig. 12. **A gear puller** for removing tight gear wheels. The illustration explains its construction and action.

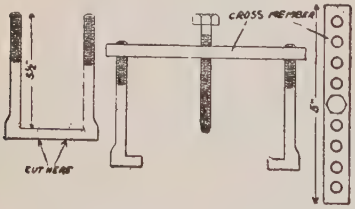

Fig. 13. **A home-made gear-wheel puller.** First get a piece of soft iron or steel. This piece must be 5" long and 1" square. Then find a long spring clip, the longer the better; cut the clip in two pieces at the bottom about ½" from the inside of the clip; then you have the arms completed.

To make the cross-member have a piece of iron or steel 1" square by 5" in length; drill a hole in the center and tap the threads for a ½" bolt. Next you can drill three or more smaller holes on each side of the large center hole, and tap these holes out to fit the threads on the spring clip; then you have an adjustment for three or more gears.

Fig. 14. **The brace rod from an old windshield may be made into an excellent wheel alignment tram.** After cutting the rod to a length about 2" less than the distance between the front wheels, a brass ferrule is soldered to one end. This ferrule is then drilled and tapped to carry a thumb screw in the manner shown. The adjustable part of the tram is a piece of ¼" drill rod, marked off into 1/16" divisions as shown, and placed within the tube.

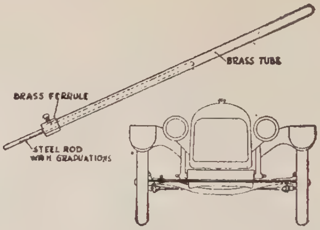

Fig. 14

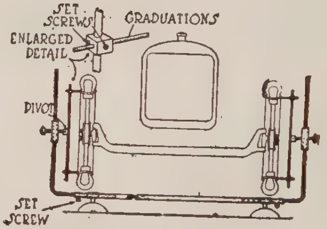

Fig. 15. **Wheel-aligning fixture.** The alignment of either the front or rear wheels may be tested by this fixture. The frame is made of wrought-iron pipe, and is adjustable by means of sliding joints. The feature of this fixture is that both sides of the wheel are tested at the same time; the camber and amount the wheel's toe-in can be readily determined. The front wheels should toe in from ¼" to ⅜".

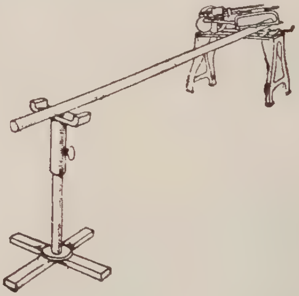

Fig. 16. **The saw stand** illustrated is useful in cutting off a long bar of stock in a power saw. Its construction is so simple that nothing further need be said.

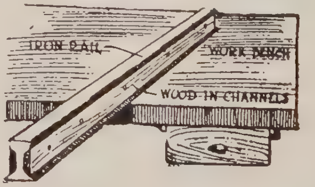

Fig. 17. **An iron rail is a useful device for any shop.**

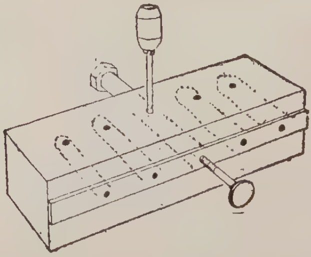

Fig. 18. **A jig for drilling cotter-pin holes in bolts and pins** may be made of a piece of square stock in which there are several transverse holes for receiving various sizes of pins. At right angles to each one of these is a hole through which the cotter-pin drill is inserted. The distance that the cotter hole is from the end of the pin is determined by the adjustment of a stop screw which is carried in a plate in the back.

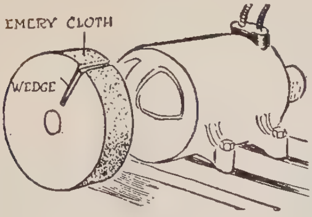

Fig. 19

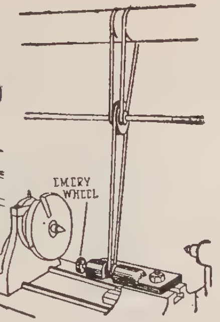

Fig. 20

Fig. 19. **A grinding wheel** for doing special work can be made by attaching a wooden wheel to the electric drill and wrapping a strip of emery paper around the periphery. The paper is fastened by cutting a notch in the wheel and holding the ends of the paper by driving a wedge into the notch.

Fig. 20. **A very small grinding wheel for mounting in a lathe** may be used for fine work. The wheel is approximately 1″ in diameter and runs several thousand revolutions per minute, this speed being obtained by a double belt reduction from the driving drum. The intermediate pulley really floats in the air, the shaft it slides on being merely to hold it in case one of the belts should break, thereby destroying its equilibrium.

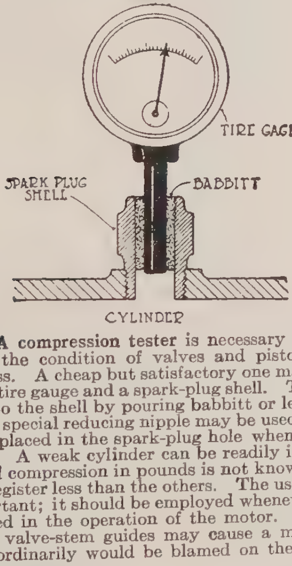

Fig. 21. **A compression tester** is necessary for accurately determining the condition of valves and pistons as regards their tightness. A cheap but satisfactory one may be made by combining a tire gauge and a spark-plug shell. The gauge may be fastened to the shell by pouring babbitt or lead in between the two, or a special reducing nipple may be used. The gauge, of course, is placed in the spark-plug hole when a cylinder is to be tested. A weak cylinder can be readily indicated, even if the normal compression in pounds is not known, by the fact that it will register less than the others. The use of this device is very important; it should be employed whenever any irregularity is noted in the operation of the motor. Leaky valves, pistons, and valve-stem guides may cause a miss or a jerky action that ordinarily would be blamed on the carburetor or ignition.

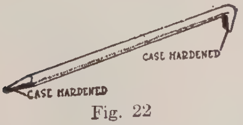

Fig. 22

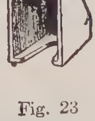

Fig. 23

Fig. 22. **A spanner wrench for facilitating the adjustment of the silent chain drive on the motor-generator of the Dodge car.** It consists of a piece of ½″ round stock about 9″ long, bent and formed in the manner shown. To adjust the chain, the chain-inspection plates are first removed from the motor gear cover. Then the set screw on the cylinder casting and the strap holding the motor to the hand-hole cover plate are loosened. By means of the spanner wrench the eccentric bushing is turned until the chain has the proper tension. When properly adjusted the chain should run without perceptible noise.

Fig. 23. **A puller for removing the generator gear on the Dodge car** is shown. The housing is made of cast iron, cut away at the base to engage the gear, and provided with a ¾″ set screw for obtaining a leverage on the generator shaft.

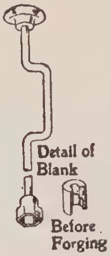

Fig. 24

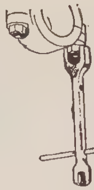

Fig. 25

Fig. 24. **Crank-case wrench.** The retaining nuts on the crank case may be quickly removed or replaced by the aid of this wrench. The handle is made of ½″ round stock bent in the form of a bit-stock, as shown. The upper end is fitted with a hand rest; the lower end with a socket for engaging the nut. A short piece of round stock, slightly larger in diameter than the nut eventually to be turned, is drilled, as illustrated in the smaller sketch. It is then heated and formed over the nut it is to fit, case-hardened, and secured to the handle by a pin.

Fig. 25. **Crank-shaft bearing wrench.** It is often difficult to get a socket wrench thin enough to fit between the nut and the bearing housing of the connecting-rod or crank-shaft bearing. Or if thin enough to do this, the wrench is too weak properly to tighten the nut. A solid S-wrench may be used, but is not as satisfactory as the socket for this purpose. A solid socket wrench, cut away in the manner illustrated, possesses the required strength and has all the advantages of the full-socket wrench. As the connecting-rod nuts are not the same size as the main bearing nuts, the wrench should be made double-ended and fitted with a removable handle.

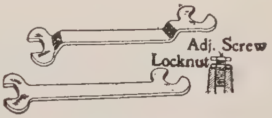

Fig. 26. **The valve tappets of the Maxwell may be readily adjusted by means of special wrenches provided for that purpose.** Two standard 626-X check-nut wrenches are purchased at any supply store, and bent, after heating, in the manner shown. After loosening the lock-nut the adjusting screw may be turned until a gage registers the proper clearance. This should be from .006″ to .009″.

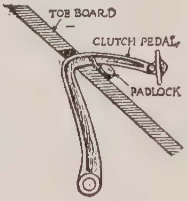

Fig. 27

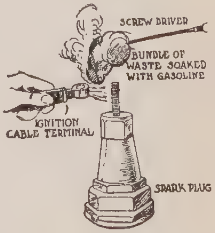

Fig. 28

Fig. 27. **One method of locking a car.** A hole is drilled in the clutch-pedal arm for the insertion of a padlock. It prevents the use of a clutch.

Fig. 28. **Substitute for a match.** A piece of waste or cloth dampened with gasoline is tied to a screwdriver. One of the ignition cables to a spark plug is removed and placed near enough to the electrode so that the spark jumps across. The cloth is introduced between the two, and the spark will ignite the gasoline.

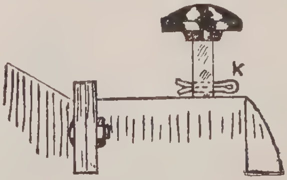

Fig. 29. **Silencing mechanical horns.** Car owners are often annoyed by small boys who persist in sounding the mechanical horn when the car is left unattended. A simple, but effective, method of discouraging this practice consists of drilling a small hole through the plunger rod and slipping a cotter pin through this hole when the car is left alone. The cotter pin may be easily removed when the owner of the car returns.

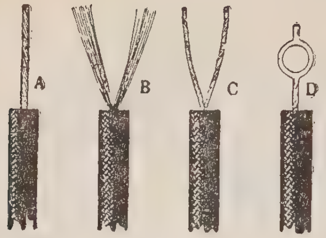

Fig. 30. Four steps in making a loop end: (A) insulation removed; (B) separating the strands; (C) twisting wires into two leads; and, (D) the looped end dipped in solder. (*Motor Age.*)

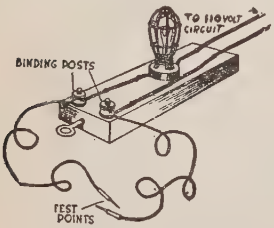

Fig. 31

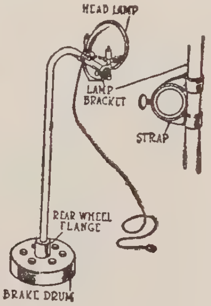

Fig. 32

Fig. 31. **This is a portable test lamp,** used in conjunction with a 110-volt lighting circuit, for testing lighting and ignition circuits on the car. It consists of a wooden base, on which is mounted a porcelain socket carrying a 16-candle-power lamp, connected to the lighting circuit as shown in the wiring diagram. The test points are connected to the binding post, and any metallic connection between the two causes the lamp to light. Hence if a wire is in proper condition, the lamp will light, when the test points are placed on each end of the wire. If there is an open circuit, it will not light. Similarly short circuits and grounds may be determined. By short-circuiting the two binding posts, the lamp may be used for inspection work.

Fig. 32. **This portable service lamp** was made both for night service in the shop, and for work on the road. A standard headlight, together with its bracket, is clamped to a pipe upright, bent as illustrated. This upright is fastened to a base that is an old rear-wheel flange bolted to a brake drum. Current is derived either from direct connection with the storage battery or by plugging into the dash lamp circuit. (*Motor World.*)

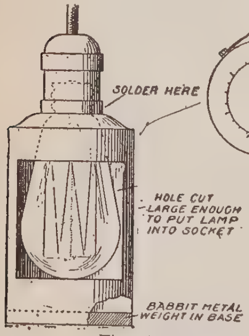
SOLDER HERE
HOLE CUT LARGE ENOUGH TO PUT LAMP INTO SOCKET
BABBIT METAL WEIGHT IN BASE

Fig. 33

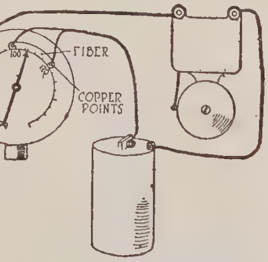

Fig. 34

Fig. 33. **A shop light,** made of a can, protects the globe and is not easily turned over.

Fig. 34. **It is a very simple matter to build a device which will cause a bell to ring when the pressure in the air tank reaches the desired maximum or minimum,** thus reminding the man in charge that the compressor should be turned off or on. The indicating hand on the air gauge completes a circuit by touching a metal pin when it moves to either extreme, and thus makes the bell ring. These pins are mounted in a small fiber block, which is riveted to the face of the gauge. The two pins are thus completely insulated from the gauge and are connected to one terminal of the bell. A short piece of wire runs from the other terminal to the battery and the return wire is attached to the casing of the gauge, so that current flows through the casing and the hand to one or the other of these metal points.

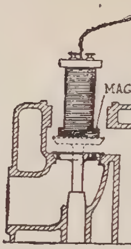

Fig. 35

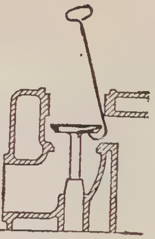

Fig. 36

Fig. 35. **A magnetic valve lifter.** Magnets have been used many times for picking up all sorts of iron and steel parts, but their use for pulling out valves is unusual. The magnet shown is approximately ¾″ x 3″, and is capable of exerting a pull of about 7 lbs., and will pull a valve out after the springs have been removed.

Fig. 36. **A simple tool which will be found of assistance for removing valves that stick badly, but may be raised slightly,** consists of a hook of Bessemer steel wire ⅛″ in diameter.

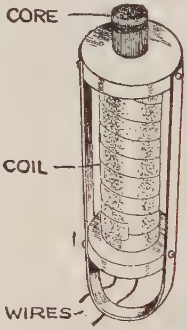

Fig. 37

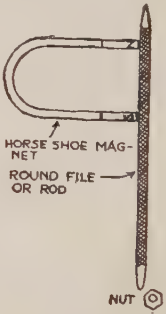

Fig. 38

Fig. 37. **Construction of the magnetic valve lifter.** An old make-and-break spark coil forms the basis of the device. The core is made of a bundle of coarse iron wires. The outside of the coil is covered with tape, and has a handle consisting of a strip of brass which extends down the sides of the coil to the end.

Fig. 38. **Another magnetic lifter,** which is useful for removing a nut which may have fallen into cylinder or other inaccessible place is shown. Simply touching the file with the magnet makes a magnet out of the file (a long rod may also be used instead).

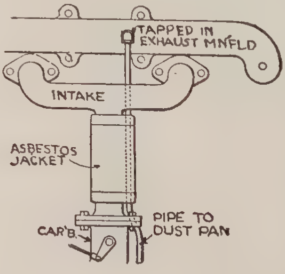

Fig. 39

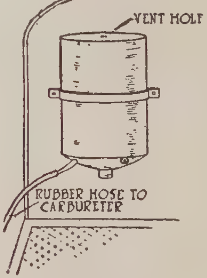

Fig. 40

Fig. 39. **Method of heating the carburetor mixture on old cars** that have a long inlet manifold. A ⅜″ or ½″ copper pipe is tapped to the exhaust manifold and run down along the intake manifold, being held away from the latter slightly by asbestos pads. Asbestos is then wrapped around the manifold and pipe, and the heat thus obtained will help to prevent the gases from condensing in the manifold at the point where it branches out to the cylinders.

Fig. 40. It is often desirable to determine the **exact consumption of a given car by determining how far it will run on a measured quantity of fuel.** A convenient means of doing this is to take an ordinary ½-gal. kerosene oil can and place in it a quart of gasoline. A rubber tube running to the carburetor is then attached to the spout, and the can is inverted and tied securely at some convenient place on the motor or dashboard.

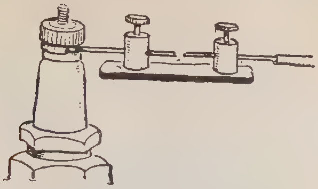

Fig. 41. **Ignition tester.** To find which cylinder is missing, a piece of fiber, ¾″ long, about ⅛″ thick, and ¾″ wide, is taken, and near the ends are inserted cable terminal posts. Through each post is passed a copper wire, the ends at the center being adjustable through lateral movement of the wires. One of the wires has a loop at the end for attachment to a plug. The ignition cable is attached to the other post. With one of these on each plug and the wires at a varying gap, it is possible, especially in a dim light or in darkness, to see the action of the plugs. See also page 237.

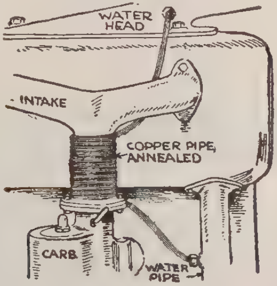

Fig. 42. **Method of heating a long inlet pipe.** Annealed soft copper pipe of small size is connected with the discharge pipe from the water pump, wrapped around manifold, and connected with the head.

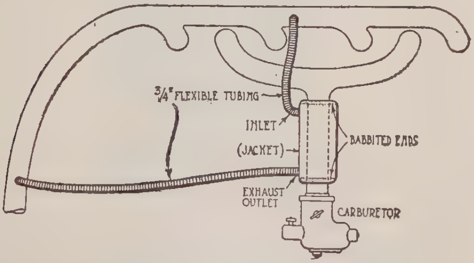

Fig. 43. **Heating the mixture on old carburetors:** Improving old-type carburetors which were designed for gasoline of higher vaporizing qualities and long inlet pipes.

Many of the old-model carburetors do not work well on the present low-grade gasoline. If a carburetor is too ancient, it is best to get a new model, but where it is in good condition, many of the older models can be improved by adding a hot-air jacket, as shown.

Use a pipe of some kind and slip over the intake manifold—about ¾ of its length. Weld it gas tight at each end (sheet iron can be made into a pipe), and pour a light layer of babbitt in each end to close up any holes or cracks.

A ⅜″, ½″, or ¾″ (the larger the better) flexible pipe is then attached to the top and bottom of the jacket to the exhaust pipe as shown, or the lower pipe can extend to the lower part of the engine.

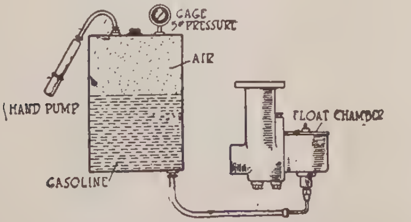

Fig. 44. **Float valve tester.** This illustration shows a device for determining whether the float valve of the carburetor leaks. It is designed particularly for pressure systems, although it may be used for the ordinary gravity system by simply removing the pressure. It consists of a tank partly filled with gasoline and provided with an air gauge and hand pump. The carburetor is attached, the pressure raised to the required amount, and then the carburetor is allowed to stand for several hours to determine whether any leakage takes place.

Float valves, which may not leak at all when tested under a small gravity head, will leak badly when put under a few pounds pressure.

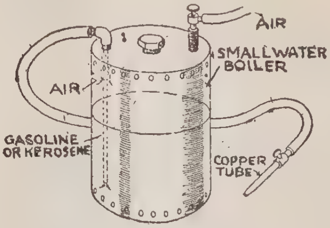

Fig. 45

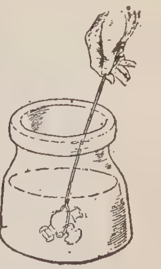

Fig. 46

Fig. 45. **This is a cleaning tank,** in which gasoline or kerosene is forced by air pressure in the form of a spray on to the part to be cleaned. The container is an old hot-water heater boiler. Air pressure is applied through a tire valve soldered to the tank, and the cleaning solution is drawn up through a small tube to the outlet pipe. A length of rubber hose, terminating in a copper tube, fitted with a valve, completes the outfit. Either gasoline or kerosene may be used as a cleaning solution, but the latter is preferable.

Fig. 46. **Cleaning brass parts.** Small brass parts, such as pet cocks, carburetor parts, etc., may be made to look like new by dipping them in the following bath: nitric acid, 75 parts; sulphuric acid, 100 parts; lampblack, 2 parts, and salt, 1 part. This solution should be mixed and kept in an earthenware or glass jar, and the parts should be thoroughly rinsed and dried after dipping. (See also Index.)

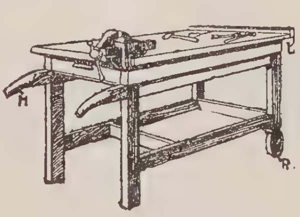

Fig. 47

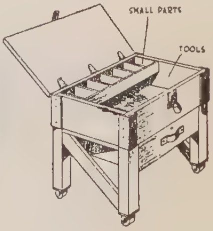

Fig. 48

Fig. 47. **A portable work bench.** An improvement would be to add shelves underneath for parts. Note the rollers (R) and handles (H).

Fig. 48. **This tool box** is made integral with its base, and is mounted on castors, so that it may be taken to the side of the car upon which the work is to be done. The tool box proper is shallow, and contains a space for the more common tools, in addition to several small compartments for miscellaneous parts. The more valuable, precise, and less frequently used tools are kept in a drawer beneath the box, which is locked unless in use. See also Fig. 52.

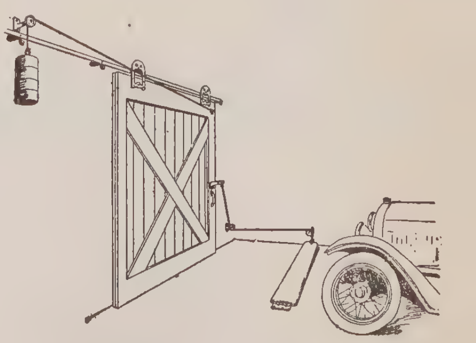

Fig. 49. **A self-opening repairshop door** is shown. The door is of the sliding type, hung on a horizontal track, but counter-balanced with weights swung over a pulley, so that it automatically opens when the catch is released. This catch is of the hook type, and connected with a hinged board placed across the roadway, the car itself releasing the catch and allowing the door to open. One of these hinged boards is placed both on the inside and the outside of the door, so that one entering or leaving has only to get out of the car once.

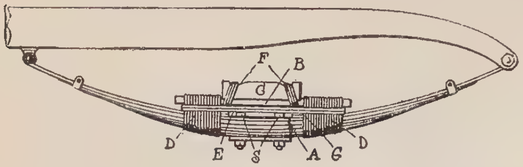

Fig. 50. **A temporary spring repair** was made upon a spring whose three lower leaves were broken on striking an apparently shallow hole in the road which was filled with water. After the break (**A**) occurred, the car was slowly driven to the next farmhouse, where some 2 x 4 blocks, a saw, and some baling wire were obtained. The short block (**E**) was cut off first, and two shallow grooves (**S**) were cut into one side of it so that it would clear the spring clips and rest flat on the central portion of the top spring leaf. The sides of these slots were cut with a saw and then finished up with a cold chisel carried in the tool kit of the car. The piece (**B**) then was cut off and nailed to the short piece (**E**), so that the sides were flush and its ends extended over the ends of the short block equally distant on either side. The top block (**C**) which was made just a trifle longer than the short bottom block, was cut off and slotted in the same manner as the under block, only the slots were not so wide and were farther apart, as designated by the letter (**F**). This block then was nailed to the long piece, centrally located with the slots up. The frame of the car was then jacked up so that the injured end of the spring was a little above its normal height, and the blocks were set in position as shown and securely bound into place with the wire (**D**). When this was done, a few strands were wound about the two top pieces, as at (**F**) to add to their security; then a few more strands were bound laterally around the whole, as at (G). This completed the temporary repair.

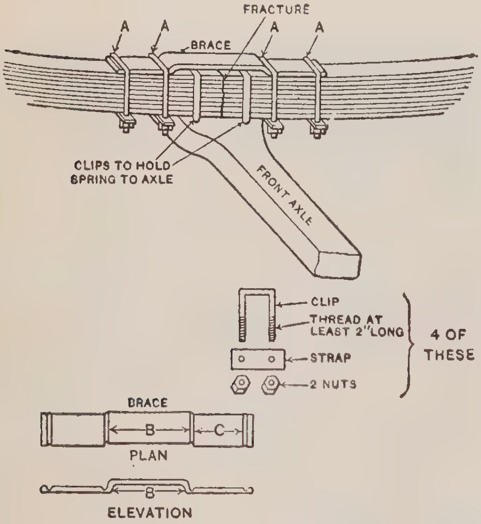

Fig. 51. **Another temporary repair on an automobile spring.** The width of the brace should be equal to the width of the spring and the part (**B**) long enough to lay over the clips holding the spring to the axle. The ends (**C**) should be about 3″ long. Such a brace will effectually repair either a front or rear spring.

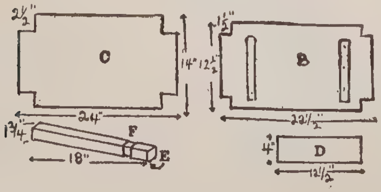

Fig. 52. **A portable tool stand.** Above illustration gives the dimensions and Fig. 52A shows stand completed. If you desire, the bins can be divided into smaller sections for cotter pins, washers, assorted bolts, nuts, etc.

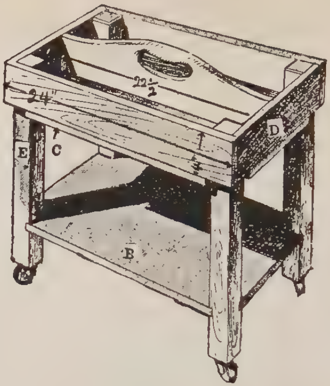

Fig. 52**A**. Portable tool stand completed.

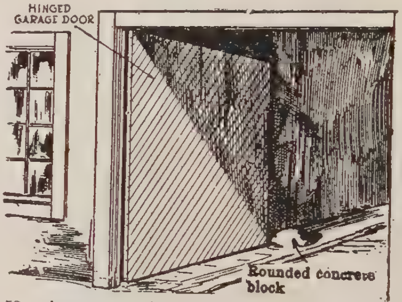

Fig. 53. **A concrete block** placed as shown will prevent driving and backing into the door.

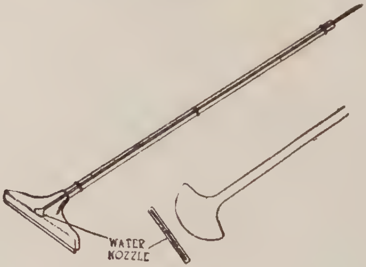

Fig. 54. **Window cleaner.** For removing dust from windows the ordinary rubber-edge window dryer combined with a nozzle which gives a flat spray the full length of the edge, may be used with a considerable saving of time. The nozzle is made from a piece of copper pipe, which is flattened and flared, as shown, and is then strapped to the handle. The water is turned on and the tool is rubbed up and down the window surface, thus removing all dust and dirt; then the water is shut off and the window is dried by scraping drops away.

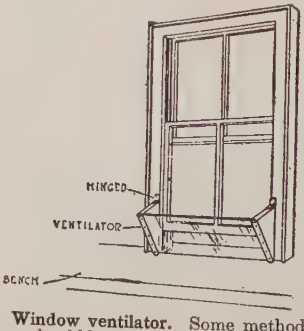

Fig. 55. **Window ventilator.** Some method of ventilating the repairshop should be provided, and a simple form of window ventilator is shown. It consists of a piece of an old windshield glass, held in an inclined position on the window sill by two triangular supports, and permits the window to be raised and the shop ventilated without causing a serious draught on the mechanic.

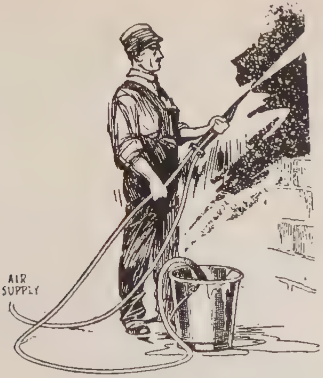

Fig. 56. **Rough surfaces, such as garage walls, may be painted or whitewashed** quickly and economically by the use of an air spray similar to that used for cleaning motors with kerosene. The paint or whitewash is placed in a bucket and the application of air pressure to the nozzle, whose construction is plainly shown, atomizes the liquid and sprays it against the walls. Valves are provided for regulating both air and liquid flow, and with a little experience it is easy to obtain an adjustment which will allow an even and economical application of paint. (*Popular Mechanics.*)

Fig. 57. **Automobile Repairshop Short Cuts.**[1] A book with over 1,500 time and labor-saving kinks, methods, and devices, from more than 1,000 of the best garages, service stations, and repairshops in the United States. Ideas that have been developed to save a good man's time, covering engine, clutch, gearset, running gear, and body repairs, managing and equipping the shop, etc. Collected and edited by *Motor World's* corps of experts. 256 pp., 9 x 12 in., 1,500 figs., cloth.

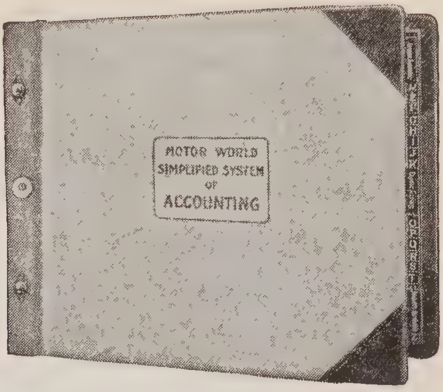

Fig. 58. **The "Motor World" Simplified System of Accounting.**[1] A simple method of keeping accurate records of what you pay out and take in, telling how much you made or lost on each department, and showing you how much you received, how much the stock and labor cost, how much your customers owe you, the amount of your overhead expenses, etc.

It is exclusively a garage and dealers' system and was prepared to meet every detail by an expert accountant who spent six months in both large and small garages and salesrooms applying it to the daily needs of the garageman and dealer. As a result the system is so simple that anyone can run it. 800 pp., 11½ x 15-in., leather index, heavy duck, leather corners.

Meaning of Some of the Words Used in Connection with the Auto

Cardan joint is the same as universal joint. **Pantasote** is an imitation leather used for upholstering and tops. The **bore of an engine cylinder** is the measurement across the circular space in which the piston moves; it is another term for the internal diameter of the cylinder. The **stroke** is the length of the path through which the piston moves in the cylinder, and is exactly equal to the diameter of the circle made by the crank pin. The purpose of an **accelerator** is to open the throttle by means of a pedal on the foot board independent of the hand throttle. It opens the throttle more quickly than the hand throttle, hence the term "accelerator."

Starter Out of Order and Crank Lost

To start engine if starting crank is lost, or starter fails to work: Jack the rear wheel, let clutch in, place gears in "high," and turn the wheel. Or let the clutch in and have someone push the car until the engine starts, and quickly throw out clutch when engine starts.

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[1] Can be obtained of A L. Dyke, Granite Bldg., St. Louis, Mo. Price of *Auto Repairshop Short Cuts*, $3.50; price of "*Motor World*" *Simplified System of Accounting*, $15.

INSTRUCTION No. 83

GENERAL DATA: Horsepower; Miscellaneous Data; Specifications; Insurance; Laws

METHODS OF COMPUTING HORSEPOWER

The S. A. E. or N. A. C. C. Horsepower Formula

The horsepower of a gasoline engine is dependent upon the following things: the number of cylinders, the area of piston heads, the average number of pounds per square inch exerted upon the piston during the strokes (mean effective pressure), and the revolutions per minute of the engine.

S. A. E. means Society of Automotive Engineers. This formula was originally adopted by the A. L. A. M. (American Licensed Automobile Manufacturers), later by the S. A. E., and now by the N. A. C. C. (National Automobile Chamber of Commerce).

It has been worked out upon the assumption that the piston speed is 1,000 ft. per min., and that the mean effective pressure is 90 lbs. per sq. in. and a certain percentage of developed power is lost in friction. Inasmuch as the piston speeds of modern engines run up as high as 1,500 to 2,000 ft. per min., and the mean effective pressures per sq. in. go up to 110 to 120 lbs., it will be seen that this formula is not altogether accurate as to the actual horsepower, which would be considerably more. However, it is used for estimating, and serves its purpose.

Piston Speed

When this S. A. E. formula was first adopted most engines developed their horsepower at 1,000 feet of piston travel per minute. Therefore it was worked out under the assumption that the piston speed is 1,000 feet per minute.

The factor of piston speed takes in both the length of the stroke and speed of the crank shaft in revolutions per minute.

The shorter the crank, the quicker it can be turned; the longer the crank, the more piston travel per stroke. Therefore the crank can travel more slowly and still the piston will travel the required distance.

As an example: Suppose that the stroke of an engine is 4 inches: it would have to make 3 strokes to travel 12 inches, or 1 foot, because each stroke is 4 inches in length. Take, on the other hand, an engine with a stroke of 6 inches: it would have but 2 strokes to make for each 12 inches or 1 foot of travel. Therefore it is evident that the shorter the stroke, the faster the crank must move to cause the piston to travel 1,000 feet in the specified time.

The table below gives the piston travel in feet per minute, of engines with different strokes with various crank-shaft speeds.

RPM	Stroke in Inches 3	3¼	3½	3¾	4	4¼	4½	4¾	5	5¼	5½	5¾	6
200..	100	108	116	125	133	141	150	158	166	175	183	191	200
400......	200	217	233	250	267	283	300	317	333	350	367	383	400
600......	300	325	350	375	400	425	450	475	500	525	550	575	600
800......	400	434	466	500	534	566	600	634	666	700	734	766	800
1000......	500	542	584	625	676	708	750	792	834	875	917	958	1000
1200.....	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200
1400......	700	766	816	875	934	992	1100	1108	1165	1225	1282	1342	1400
1600......	800	868	932	1000	1068	1132	1200	1268	1332	1400	1468	1532	1600
1800......	900	975	1050	1125	1200	1275	1350	1425	1500	1575	1650	1725	1800
2000......	1000	1084	1168	1250	1352	1416	1500	1584	1668	1750	1852	1916	2000

Example: How many feet would a piston travel in an engine with a 3-inch stroke when the crank shaft was turning 200 revolutions per minute (r.p.m.)?

Ans.: The piston goes down 3 inches and up 3 inches to one revolution of the crank shaft. Therefore 3 inches down and 3 inches up would be 6 inches of travel of the piston to one revolution of the crank shaft. With 200 revolutions of the crank shaft, the piston would travel $200 \times 6 = 1{,}200$ inches. As there are 12 inches to a foot, then we should have $1{,}200 \div 12 = 100$ feet of piston travel per minute to 200 revolutions of the crank shaft.

This formula would be: $P = \frac{S \times 2 \times R}{12}$. P, is piston travel per minute which equals the stroke S, $\times 2$, $\times R$ (the revolutions per minute of the crank shaft) divided by 12.

How to Figure the S. A. E. Formula

This formula is used by all leading manufacturers and by the license offices in different cities. The formula is expressed as follows:

$$\text{Horsepower} = \frac{(\text{Diam. in inches})^2 \times \text{number of cylinders}}{2.5}$$

For example: What is the S. A. E. horsepower of a four-cylinder engine which has a 4-inch bore?

By referring to the table below, one 4-inch bore cylinder is 6.4 and 4 cylinders of 4-in. bore is 25.6 h.p.

This is arrived at as follows: $\text{h.p.} = \frac{D^2\ N}{2.5}$.

D^2 (diameter squared) $4 \times 4 = 16$.

N (number of cylinders) $16 \times 4 = 64$.

2.5 (constant) $64 \div 2.5 = 25.6$ h.p.

It will be noted that the stroke of the cylinder was not taken into consideration at all.

S.A.E. Horsepower Table

Inches	Millimeters	1 Cylinder	2 Cylinders	4 Cylinders	6 Cylinders	8 Cylinders	12 Cylinders
2½	64	2.5	5.0	10.00	15.00	20.00	30.00
⅝	68	2.8	5.5	11.23	16.85	22.46	33.70
¾	70	3.0	6.0	12.08	18.13	24.16	36.23
⅞	73	3.3	6.6	13.37	20.00	26.74	40.00
3-	76	3.6	7.2	14.40	21.60	28.80	43,20
⅛	79	3.9	7.8	15.64	23.50	31.28	47.00
¼	83	4.2	8.4	16.92	25.39	33.84	50.78
⅜	85	4.6	9.1	18.21	27.30	36.42	54.60
3½	89	4.9	9.8	19.61	29.45	39.22	58.90
⅝	92	5.3	10.5	21.08	31.57	42.16	63.14
¾	95	5.6	11.2	22.50	33.75	45.00	67.50
⅞	99	6.0	12.0	24.22	36.32	48.44	72.64
4-	102	6.4	12.8	25.60	38.40	51.20	76.80
⅛	105	6.8	13.6	27.20	40.80	54.40	81.60
¼	108	7.2	14.4	29.00	43.50	58.00	87.00
⅜	111	7.7	15.3	30.65	46.00	61.30	92.00
4½	114	8.1	16.2	32.40	48.60	64.80	97.20
⅝	118	8.6	17.1	34.28	51.41	69.56	102.81
¾	121	9.0	18.0	36.15	54.20	72.30	108.40
⅞	124	9.5	19.0	38.25	57.21	76.50	114.42
5-	127	10.0	20.0	10.00	60.00	80.00	120.00
⅛	130	10.5	21.0	42.20	63.20	84.40	126.40
¼	133	11.0	22.0	44.20	66.40	88.40	132.80
⅜	137	11.6	23.1	46.34	69.50	92.68	139.00
5½	140	12.1	24.2	48.48	72.72	96.96	145.44
⅝	143	12.7	25.3	50.80	76.10	101.60	152.20
¾	146	13.2	26.4	53.00	79.50	106.00	159.00
⅞	149	13.8	27.6	55.28	83.88	110.56	167.76
6-	152	14.4	28.8	57.70	86.64	115.40	173.28

POWER, WORK, HORSEPOWER, AND TORQUE; MEANING OF

Now that we know one method of computing horsepower, we will get down to fundamentals, so that we may have a clear understanding of this subject.

Power: In order to understand power, one must consider that its definition is the **rate (speed) of doing work.**

Work is a force acting through a distance. For example, if we lift 10 lbs. through 2 feet, we accomplish an amount of work equal to 10 lbs. × 2 ft., or 20 foot lbs.

The next factor is the rate (speed) of doing this work. For example, suppose we lift 10 lbs. through 2 feet in 10 minutes, our power is 10 lbs. × 2 ft.÷ 10 min., or **2 foot pounds per minute.**

Horsepower (h.p.) is, then, a unit of power, namely the accomplishment of 33,000 ft. lbs. of work in 1 minute, expressed as 1 horsepower (1 h.p.).

The horsepower unit is used in motor work as a standard rate of doing mechanical work, equal to 33,000 pounds (or weight) raised through a height of 1 foot in 1 minute; or any factors which multiplied together equal 33,000 ft. lbs. in the same time, is also equal to 1 horsepower. The horsepower has nothing to do whatever with the power developed by a horse—but in the days of Watt and early engineers (of the eighteenth century) the work in ft. lbs. capable of being done by an average draught horse in 1 minute was taken as the unit of power. The French horsepower equals 32,549 ft. lbs. of work in one minute, expressed as 1 horsepower, and is thus less than the English standard.

Torque is the product of force multiplied by the distance at which it is exerted from the center of rotation. For example, suppose we have a 1-foot pipe wrench and we apply a force of 40 lbs. on the end of that wrench, we shall then exert a torque of 40 lbs. × 1 foot, or 40 ft. lbs. of torque. On the other hand, if we had a 2-foot pipe wrench and exerted 40 lbs. on the end of it, we should exert a torque of 40 lbs. × 2 feet, or 80 foot lbs. of torque. This explains why it is easier to unscrew a pipe coupling with a 2-foot wrench than it is with a 1-foot wrench—the torque is greater.

When we say an engine develops 83 ft. lbs. torque, we mean that at a distance of 1 foot from the center of the crank shaft the engine would exert a force of 83 lbs., or at a distance of 83 feet from the center of the crank shaft the engine would exert a force of 1 lb. For instance, suppose we wished to stop an engine which exerted 83 ft. lbs. torque, by means of a pipe wrench. If a 1-foot wrench was used, by exerting a force of 83 lbs. on the end of the wrench, it would stop the engine. Or if an 83-foot wrench were used, a force of 1 lb. exerted at the end of the wrench, would stop the engine.

On the Ford engine the torque at 900 r.p.m. (see illustration of curve, Fig. 1), is 83 ft. lbs., and the h.p. is 14.2, whereas at 1,600 r.p.m., the torque is only 65 ft. lbs., and the h.p. is 20. Also note that the torque increases up to 900 r.p.m., and then falls off, and also note that the horsepower increases up to 1,600 r.p.m., and then falls off. To the layman it would appear that the greatest pull or force exerted would be at 1,600 r.p.m., but such is not the case. The greatest pull on this particular engine is at 900 r.p.m.

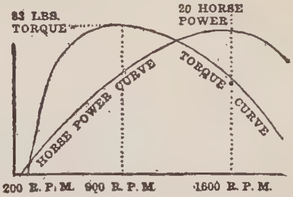

Fig. 1

The reason why greater horsepower can be developed with less torque is the factor of speed, which we have already seen is one of the items affecting power.

For example, the engine at 900 r.p.m. is like Tom, who can carry 150 lbs. of bricks (we will term the carrying capacity of Tom "torque"), **at a speed of 4 miles per hour.** Suppose the bricks had to be moved one mile. Tom could move 4 × 150=600 lbs. of brick in 1 hour.

The engine, while running at 1,600 r.p.m., is like Philip, who can carry only 125 lbs. of bricks, but can run at a speed of 6 miles per hour. Philip could then move the bricks a mile at the following rate of speed: 6 × 125=750 lbs. of brick in 1 hour. Thus, while Philip develops less torque, he develops greater power.

Therefore, at 900 r.p.m. the load carried (torque) is greater, but the speed is less, and the rate of doing the work is less. At 1,600 r.p.m. the load carried (torque) is less, but the speed and rate of doing the work (h.p.) are greater.

The reason why the engine develops less torque at 1,600 r.p.m. than at 900 r.p.m. is the fact that the cylinder receives a smaller charge of gas per stroke at 1,600 than at 900 r.p.m., because of the inertia and the friction of the gases passing through the manifold and valve. At the lower speed, the effect of inertia and friction is small, allowing a considerable quantity of gas to be introduced into the cylinder at each inlet stroke; on the other hand, at 1,600 r.p.m., the high velocity of the gas causes a considerable amount of friction, and the effect of inertia (tendency to move slower) is greater, which decreases the charge of gas entering the cylinder. This also accounts for the great decrease of torque and consequent falling off of power (h.p.) after 1,600 r.p.m. Therefore this engine exerts its greatest pull at 900 r.p.m., and the futility of racing an engine when attempting to pull out of a hole is apparent.

A given amount of power can be developed in cylinders of either large or small diameter. Thus there is the example of the stationary gas engine. To obtain, for example, 10 h.p. from this type of engine, a very large cylinder and comparatively slow speed would be employed, with a maximum speed of perhaps 300 to 600 r.p.m. A modern 10 h.p. automobile engine, on the other hand, has four very small cylinders, but a high speed, say 1,500 to 2,000 revolutions per minute. The individual power impulses are very much weaker than those of the large slow-speed engine, and consequently its parts can be made much lighter and smaller, as the shocks and stresses that have to be sustained are proportionately much less.

The Dodge engine, which has larger cylinders and valves, exerts its greatest pull (torque) at from 1,100 to 1,400 r.p.m., whereas its greatest speed and horsepower are at 2,200 r.p.m.

Power and Pressure and Other Terms

Brake horsepower (b.h.p.): Power delivered at the crank shaft.

Indicated horsepower (i.h.p.): Power delivered by the gas inside the cylinder to the piston.

If an engine develops 10 indicated horsepower, and it takes 3 horsepower to drive itself, the crank shaft would deliver 7 h.p., and the rating of the engine would be **7 brake** horsepower, or **10 indicated** horsepower.

To estimate the horsepower of an engine within a reasonable degree of accuracy, the following may be used.

Another H.P. Formula (not the S. A. E.)

The following formula takes into consideration the stroke as well as the bore, and also the speed.

H. P. Formula: $\frac{D^2 \times N \times L \times R}{C}$ = horsepower

This means, square the diameter or bore of the cylinder (**D^2**) and multiply the result by the number of cylinders (**N**); multiply this result by the length of stroke (**L**), and multiply this result by the revolutions (**R**) per minute of the crank shaft; then divide this total result by the "constant" (**C**) below.

The "constant" for a 4-cycle engine is 13,000.
The "constant" for a 2-cycle engine is 10,000.

Example: Suppose we have a 4-cylinder engine, 4-inch bore (diameter), and 5-inch stroke, and 1,000 revolutions per minute, what is the horsepower?

4 × 4 equals 16 (squaring the diameter **D^2**).
16 × 4 equals 64 (result multiplied by number cylinders **N**).
64 × 5 equals 320 (result multiplied by length of stroke **L**).
320 × 1,000 equals 320,000 (result multiplied by number of revolutions **R**).
320,000 divided by the "constant" 13,000, will give us 24.6 h.p. for a 4-cycle engine.
320,000 divided by 10,000 will give us 32 h.p. for a 2-cycle engine.

The "constant" is a figure arrived at by the founder of the formula. You will note there is a difference of 1 h.p. between the horsepower figured with this formula and the S.A.E. formula. There is usually a difference with all formulas.

To calculate the horsepower delivered by the crank shaft, the brake test must be made with a mechanical machine, such as a "prony brake test" (page 1045) or "dynamometer test" below; the result is the **b.h.p.**

Thermal efficiency of an engine: See dictionary, page 1078.

Mechanical efficiency of an engine: See dictionary, page 1077.

Compression pressure is the pressure of the gas after being drawn into the cylinder and compressed in the combustion chamber by the up compression stroke of the piston. This varies with the quantity of gas drawn into the cylinder, the speed of the piston, the size of the combustion chamber, and the condition of the valves, and rings, and the tightness of the parts. See also page 116.

The expansion pressure (often termed explosion pressure) would be the maximum or greatest pressure immediately following the combustion or burning of the gases. This pressure is many times greater than compression pressure. This expansion pressure (gas expands when ignited and heated) continues, but diminishes throughout the entire power stroke.

Mean effective pressure (**m.e.p.**): During the entire cycle of a gas engine, the cylinder is subjected to many variations of pressure. We have seen that during the power stroke, the pressure decreases as the piston proceeds along its stroke. All of this pressure causes the engine to deliver power. In the same way, during the compression stroke the pressure gradually increases as the piston travels upward. All of this pressure hinders the engine from delivering power, and should therefore be considered as a negative power. Now, if we average up all the pressures during a cycle and subtract those which hinder the engine from those which help it (the power stroke is the only stroke which helps), we shall arrive at the m.e.p., that is, the **average or mean pressure which is effective in producing power.**

B.H.P., meaning of: See dictionary, page 1074.

B.T.U. (British Thermal Unit): See dictionary.

Calorific value: See dictionary.

E.H.P., E.P.M., meaning of: See dictionary.

Heat units, meaning of: See dictionary.

M.E.P., meaning of: See dictionary.

Wind resistance increases in proportion to the "square" of the speed: thus at 20 miles per hour it is four times what it is at 10 miles, and at 30 miles per hour nine times, and so on.

METHODS OF MEASURING B. H. P.

There are several methods for measuring the b.h.p. of an engine, as, for instance, with a fan dynamometer, an electrical dynamometer, and by means of a prony brake test.

The Fan Dynamometer

This consists of a fan, driven by the engine. The power required to turn the fan increases with the speed, and at all times bears a definite relation to the speed. Hence, knowing the speed, it is possible to determine the horsepower being developed—see the r.p.m. (revolutions per minute) and h.p. table on the next page.

The speed is shown by means of a speedometer, driven from the fan shaft, but registering revolutions per minute instead of miles per hour.

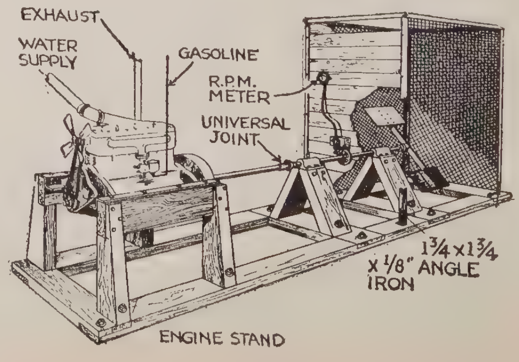

Fig. 2

The engine is bolted to a frame. The drive shaft is shown. The fan shaft is carried on two heavy pillow blocks bolted to wooden supports with ball or roller type bearings, if possible. The **fan arm** should be of solid bar nickel steel, 3″ x 3/8″ by 5/16″ long. The hub should also be of nickel steel.

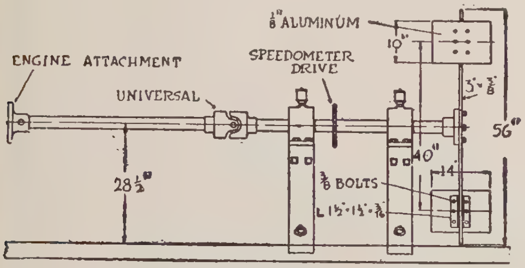

Fig. 3

Fan blades are of heavy sheet aluminum, placed 40″ apart on the centers, and bolted to the fan arm by means of angle-iron strips that are riveted back to back on the aluminum blades. To avoid accident the fan is enclosed in a cage of mesh wire netting.

R.P M.	H.P.
400	1
600	2½
800	6
1,000	12
1,200	20
1,300	25
1,400	37
1,500	40
1,600	48
1,700	60
1,800	70

Electrical Dynamometer

The method for testing the horsepower of a gasoline engine with an electrical dynamometer is as follows: The engine is belted or (preferably) coupled direct to a dynamo machine. Connected up with the dynamo are two specially accurate electrical measuring instruments, one a voltmeter and the other an amperemeter. The current which the dynamo produces when driven is used up, by either a group of lamps or a set of wire or liquid resistances. The amount of work the dynamo will do, such as lighting lamps, etc., depends on the power put into it from the engine.

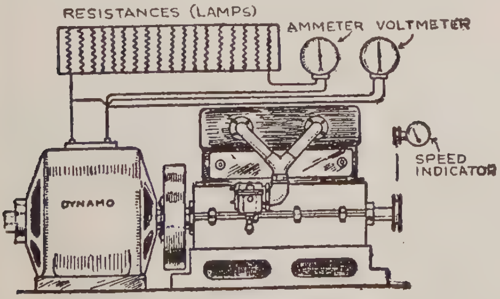

Fig. 4

It is easy to convert electrical power units into mechanical units. Thus: amperes multiplied by volts equals watts; there are 746 watts to a horsepower, so that by simply taking the readings of the voltmeter and ammeter, the amount of power the dynamo is giving out is at once calculated. The dynamo, of course, does not transform the whole of the power put into it into electricity, but it may transform somewhere near 90 per cent of it.

Certain mechanical and electrical losses occur in the dynamo, but these are calculated beforehand. Hence, knowing exactly how much of the power put into the dynamo is lost or wasted, and the maximum amount given out, the power actually produced by the engine will be the result.

Prony Brake Test

This is one method of testing the brake horsepower and torque of an engine.

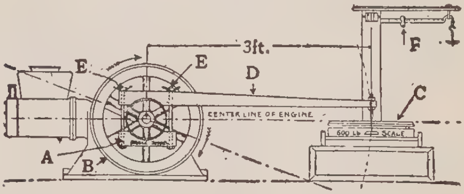

Fig. 5

One horsepower is defined as the power that will raise 550 lbs. 1 ft. high in 1 second, or, as the case may be, 33,000 lbs. 1 ft. high in 1 minute. The power that will do one will exactly do the other if the gearing is suitably arranged.

Torque is the product of force multiplied by distance at which it is exerted from the center of rotation. If arm (**D**) is 3 ft., and 30 lbs. pull is shown at (**F**) at 1,500 r.p.m., then the torque would be 30 lbs. × 3 = 90 **foot pounds torque.**

To find the h.p. at, say, 1,500 r.p.m., we start up the engine (having first rigged up to some convenient part a speed counter), open the throttle fully, tighten down the clamp by the screws (**E**) until the engine is slowed to the required speed, namely, 1,500 r.p.m. The number of pounds pull on arm (**D**) is now read off at (**F**).

Observe now the calculation. We first measure the distance from the central point of the flywheel to the point of the arm which rests on the scale. Assume this to be 3 ft., and the number of lbs. indicated on the scale to be 30, and we have all the necessary information.

This 3 ft. arm (**D**) is virtually the radius of an imaginary flywheel 6 ft. in diameter, which exerts at its rim., i.e., at the point resting on the scale, a pull of 30 lbs.

Now a flywheel having a diameter of 6 ft. has, roughly, a circumference of 19 ft., therefore during one revolution of the flywheel, the force of 30 lbs. will act through a distance of 19 ft., and if its speed is to be 1,500 r.p.m., we have here a rim speed of 28,500 ft. per minute, exerting a pull of 30 lbs., or in other words, 855,000 ft. lbs. per minute. But, as we have seen, 33,000 ft. lbs. per minute is 1 h.p.; therefore it requires but a simple division (855,000 ÷ 33,000) to find that the engine is developing nearly 26 h.p.

In actual practice, rather more elaboration is necessary to cope with secondary considerations. A suitable method of dealing with the friction on the flywheel, for instance, must be found, as well as a proper lining for the braking clamp, so that the drag on the flywheel is constant, free from jerks, etc.

Horsepower and revolutions. The gasoline engine, within certain limits, is dependent upon engine revolutions for power. If the revolutions are not maintained to a certain speed, especially on 1, 2, and 4-cylinder engines, the power is not sufficient to start a car or to climb hills. It is for this reason that transmission gears are necessary.

Relation of Speed of Engine to Road Wheels

If you do not know the ratio between the speed of the engine and the speed of the car, there is a way of arriving at this ratio approximately. Jack up both the rear wheels as shown in Fig. 6, and then, after throwing the car into low gear, crank the engine slowly by hand, counting the number of times the engine has to be completely turned over to one complete revolution of both rear wheels or two complete revolutions of one rear wheel.

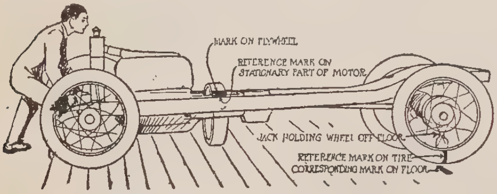
MARK ON FLYWHEEL
REFERENCE MARK ON STATIONARY PART OF MOTOR
JACK HOLDING WHEEL OFF FLOOR
REFERENCE MARK ON TIRE
CORRESPONDING MARK ON FLOOR

Fig. 6

First make a reference mark on the flywheel, or take one of the timing marks as a reference, and after bringing this directly under the pointer, if there is one, or some other reference point on the flywheel housing, make a mark on the tire and another directly below this on the floor. **Now turn the engine slowly,** and when the rear wheel is again in line with its floor mark, count the number of times the flywheel has turned. If it has taken 20 revolutions of the engine, the ratio is 20 to 1, and so on.

Test the intermediate and high gear in the same manner. See page 8 for the meaning of "ratio" and page 9 for the ratio of different cars.

McCullough Formula for Finding the Speed of a Car

Engine speed per minute × diameter in inches of the rear wheel × .002975÷ratio.

The ratio of the drive, for example, is 4 to 1; which means that the engine crank shaft turns four times to one of the rear axle. Therefore the figure to be used to divide by would be four. The same holds good in all speeds, no matter if in first, second, third, or fourth speed.

Example: 1,000 (rev. of engine) × 30 (diameter in inches of wheel) × .002975, divided by 4 (4 to 1 ratio) equals 22.31, plus miles per hour.

PISTON DISPLACEMENT[1]

Piston displacement means the volume of gas displaced during one stroke of the piston. For example, when the piston is at top dead center, there is a certain volume in the combustion space above the piston, say, 10 cubic inches. When the piston is at the bottom of stroke, there is a greater volume above the piston, say, 63 cubic inches. The piston displacement in this case would be 53 cubic inches (63−10=53) for one cylinder, or 53×4=212 cu. in. displacement for a 4-cylinder engine.

To compensate for inferior quality of gasoline, some manufacturers have reduced the area of combustion chamber, so as to give a high compression. (See tables[1] of Piston Displacement on next page.)

How to find piston displacement: The formula would be designated thus: $D^2 \times .7854 \times S \times N =$ piston displacement. D^2 means diameter or bore squared or multiplied by itself, as 5×5. This result is then multiplied by the constant .7854 (the area of a cylinder 1 inch in diameter), this result by **S**, the stroke in inches, and this result by **N**, the number of cylinders.

Example: What is the piston displacement of four cylinders, 4-inch bore and 5½-inch stroke? Procedure: 4×4=16×.7854 =12.566×5½ (or 5.5)=69.115×4=276.5 cubic inches.

Example: What is the piston displacement of four cylinders 3⅛-inch bore and 4⅝-inch stroke? Procedure: 3⅛ × 3⅛ × .7854×4⅝×4=141.9 cubic-inch piston displacement.

GRADES

The general assumption is that a grade of 100 per cent would be vertical, or at a 90° angle, as in line (**D**) (Fig. 7); but this is incorrect.

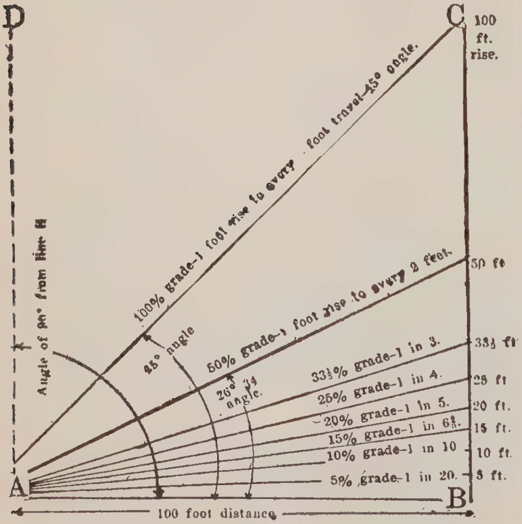

Fig. 7

A grade is expressed in terms of percentage, and means so many feet rise or fall in a given distance measured in a horizontal direction. This given distance may, for convenience, be 100, 500, 1,000 feet, etc.

A rise of 100 feet in the same distance measured horizontally is a 100 per cent grade; however, the included angle is 45°, and not 90°. Fig. 7 shows the grade percentage, which is based on a horizontal distance, line (**B**) of 100 feet.

Assume that line (**B**) is a straight line, 100 feet long and perfectly level. Therefore from (**A**) to (**B**) there would be no grade. If from (**A**) to (**B**) there was a rise of 1 foot in every 20 feet, when we reached line (**B**) we should be 5 feet higher than at (**A**). Therefore this would be a 5 per cent grade. It is not necessary, however, to travel the full distance. Just as long as there is a rise of 1 foot to every 20 feet, it is a 5 per cent grade at any point.

If the grade or steepness increased to 1 foot rise in 10 feet, then it would be a 10 per cent grade, and we should be 10 feet higher at line (**B**) than at (**A**). 1 in 6 2/3 is a 1 foot rise in 6 2/3 feet, and a 15 per cent grade, and so on up to 100 per cent grade, which would be a rise of 1 foot in 1 foot, as the slope from (**A**) to (**C**).

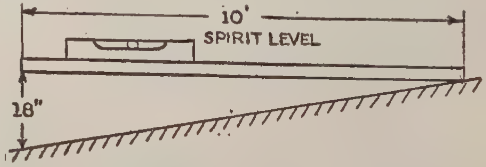

Fig. 8

To ascertain the percentage of a grade without the use of any special instruments: Secure a spirit level and a ten-foot stick (Fig. 8). Rest one end of the stick on the road surface and find its level position with a spirit level, by placing this on the stick and raising o lowering the stick until the bubble is in the center

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[1] The tables of Piston Displacement on the next page are taken from the instruction book of the Stromberg Motor Devices Co. (carburetor manufacturers).

Then measure the perpendicular distance between the end of the stick and road surface, and multiply by 10, which will give the rise in feet in proportion to one hundred feet.

For example: Assume that the perpendicular distance measured 18 inches; this multiplied by 10 gives 180 inches, and reduced to feet gives 15 feet as the rise in 100 feet, or a 15 per cent grade.

The average of such measurements taken on grades will give fairly accurate results.

Per cent		Angle
100	1′ in 1′	45°
50	1′ in 2′	26° 34′
25	1′ in 4′	14° 2′
20	1′ in 5′	11° 19′
15	1′ in 6 2/3′	8° 32′
10	1′ in 10′	5° 43′
5	1′ in 20′	2° 52′

The affix to the figures in the center column, as 1′, means 1 foot; whereas in the right-hand column, as 34′, it means 34 minutes.

A 66 2/3 per cent grade is as steep as a car could possibly climb, as **gravity overcomes traction** at this angle.

PISTON DISPLACEMENTS IN CUBIC INCHES AND RATED HORSE-POWER FOR 4-CYLINDER MOTORS

FOR 8-CYLINDER MOTORS, MULTIPLY GIVEN DISPLACEMENT BY 2

Cylinder Bore in Inches	STROKE IN INCHES																																	S.A.E. Rating H.P.
	3	3⅛	3¼	3⅜	3½	3⅝	3¾	3⅞	4	4⅛	4¼	4⅜	4½	4⅝	4¾	4⅞	5	5⅛	5¼	5⅜	5½	5⅝	5¾	5⅞	6	6¼	6½	6¾	7	7¼	7½	7¾	8	
2½	59	61	64	66	69	71	74	76	79	81	83	86	88	91	93	96	98	101	103	106	108	110	113	115	118	123	128	132	138	142	148	152	157	10.0
2⅝	65	68	70	73	76	79	81	84	87	89	92	95	97	100	102	106	108	111	114	116	119	122	124	127	130	135	140	146	152	157	162	168	173	11.05
2¾	71	74	77	80	83	86	89	92	95	98	101	104	107	110	113	116	119	122	125	128	131	134	137	140	143	148	154	160	166	172	178	184	190	12.1
2⅞	78	81	84	88	91	94	97	101	104	107	110	114	117	120	123	126	130	133	136	140	143	146	149	152	156	162	169	175	182	188	195	201	208	13.2
3	85	89	92	95	99	103	106	110	113	117	120	124	127	131	134	138	141	145	148	152	156	159	163	166	170	177	184	191	198	205	212	219	226	14.5
3⅛	92	96	100	104	107	111	115	119	123	127	130	134	138	142	146	150	153	157	161	165	169	173	176	180	184	192	199	207	214	222	230	238	245	15.65
3¼	100	104	108	112	116	120	124	128	133	137	141	145	149	153	158	162	166	170	174	178	183	187	191	195	199	207	216	224	232	240	249	257	266	16.9
3⅜	107	112	116	121	125	130	134	139	143	148	152	157	161	165	170	175	179	183	188	192	197	201	206	210	215	224	233	242	251	260	268	277	286	18.25
3½	115	120	125	130	135	140	144	149	154	159	164	168	173	178	183	188	192	197	202	207	212	217	221	226	231	241	250	260	269	279	289	298	308	19.6
3⅝	124	129	134	139	145	150	155	160	165	170	176	181	186	191	195	201	206	211	217	222	227	232	237	243	248	258	268	279	289	299	310	320	330	21.0
3¾	133	138	144	149	156	160	166	171	177	182	188	193	199	204	210	215	221	226	232	237	243	249	254	260	265	276	287	298	309	320	331	342	353	22.5
3⅞	142	147	153	159	165	171	177	183	189	195	200	206	212	218	224	229	236	242	248	253	260	265	271	277	283	295	307	318	330	342	354	366	377	24.0
4	151	157	163	170	176	182	189	195	201	207	214	220	226	233	239	245	251	258	264	270	277	283	289	295	302	314	327	339	352	364	377	300	402	25.6
4⅛	160	167	174	180	187	194	201	207	214	221	227	234	241	247	254	261	267	274	281	287	294	301	307	314	321	334	348	361	374	388	401	414	428	27.2
4¼	170	177	184	191	199	206	213	220	227	234	241	248	255	262	269	277	284	291	298	305	312	319	326	333	340	355	360	383	397	411	426	440	454	28.9
4⅜	180	188	195	203	211	218	226	233	241	248	256	263	271	278	286	293	301	308	316	323	331	338	346	353	361	376	391	406	421	436	451	466	481	30.6
4½	191	199	207	215	223	231	239	247	255	262	270	278	286	294	302	310	318	326	334	342	350	358	366	374	382	398	414	429	445	461	477	493	509	32.4
4⅝	202	210	218	227	235	244	252	260	269	277	286	294	302	311	319	328	336	344	353	361	370	378	386	395	403	420	437	454	470	487	504	521	538	34.2
4¾	213	222	230	239	248	257	266	275	284	292	301	310	319	328	337	346	354	363	372	381	390	399	408	416	425	443	461	478	496	514	532	549	567	36.1
4⅞	224	233	243	252	261	271	280	289	299	308	317	327	336	345	355	364	373	383	392	401	411	420	429	439	448	467	485	504	523	541	560	579	597	38.0
5	236	245	255	265	275	285	295	304	314	324	334	344	353	363	373	383	393	403	412	422	432	442	452	461	471	491	511	530	550	569	589	609	628	40.0
5⅛	248	258	268	279	289	299	309	320	330	340	351	361	371	382	392	402	413	423	433	444	454	464	475	485	495	516	536	557	578	598	619	640	660	42.0
5¼	260	271	281	292	303	314	325	336	346	357	368	379	390	400	411	422	433	444	455	465	476	487	498	509	520	541	563	584	606	628	649	671	693	44.1
5⅜	272	284	295	306	318	329	340	352	363	374	386	397	409	420	431	443	454	465	477	488	499	511	522	533	545	567	590	613	635	658	681	703	726	46.2
5½	285	297	309	321	333	345	356	368	380	393	404	416	428	440	451	463	475	487	499	511	523	535	546	558	570	594	618	641	665	689	713	736	760	48.4
5⅝	298	311	323	336	348	360	373	385	398	410	422	435	447	460	472	485	497	509	522	534	547	559	572	584	596	621	646	671	696	721	746	770	795	50.6
5¾	312	325	338	351	364	377	390	403	416	429	441	454	467	480	494	506	519	532	545	558	571	583	597	610	623	649	675	701	727	753	779	805	831	52.8
5⅞	325	339	352	366	380	393	407	420	434	448	461	474	488	502	515	529	540	556	569	583	596	610	623	637	651	678	705	732	759	786	813	840	867	55.1
6	339	354	368	382	396	410	424	438	452	467	481	495	509	523	537	551	566	580	594	608	622	636	650	664	679	707	735	763	792	820	848	876	905	57.6
6¼	368	384	390	414	430	445	460	476	491	506	522	537	552	568	583	598	614	629	644	660	675	690	706	721	736	767	798	828	859	890	920	951	982	62.5
6½	398	415	431	448	465	481	498	514	531	548	564	581	597	614	630	647	664	680	697	713	730	747	763	780	796	829	863	896	929	962	995	1029	1062	67.5
6¾	429	447	465	483	501	519	537	555	573	590	608	626	644	662	680	698	716	734	752	769	787	805	823	841	859	895	930	966	1002	1038	1074	1109	1145	72.7
7	462	481	500	520	540	559	578	597	616	635	653	672	692	711	731	750	770	789	809	828	847	867	886	904	923	962	1001	1040	1079	1118	1156	1194	1232	78.4
7¼	495	516	537	558	579	599	620	640	661	681	702	723	743	768	785	806	827	848	868	889	910	930	950	970	991	1016	1067	1118	1159	1199	1240	1280	1321	84.1
7½	530	552	574	507	619	640	662	685	707	729	750	772	795	818	840	862	884	908	929	950	972	994	1017	1040	1060	1104	1153	1196	1240	1283	1326	1372	1418	89.9
7¾	566	590	613	636	660	683	707	730	754	778	801	825	849	873	897	920	943	968	900	1017	1039	1062	1084	1107	1132	1179	1224	1272	1320	1368	1414	1460	1506	96.1
Factor "A"	.500	.521	.542	.563	.583	.604	.625	.646	.667	.688	708	.729	.750	771	792	813	.833	854	875	896	.917	938	.958	979	1 00	1 042	1.083	1.125	1.167	1 208	1.250	1.292	1.333	

NOTE:—S. A. E. Horse-Power Rating is based on *1000 feet per minute piston speed.*
To find equivalent horse-power at *1000 revolutions per minute* multiply S. A. E. Rating for Given Bore by Factor "A" for Given Stroke.

PISTON DISPLACEMENTS IN CUBIC INCHES AND RATED HORSE-POWER FOR 6-CYLINDER MOTORS

FOR 12-CYLINDER MOTORS, MULTIPLY GIVEN DISPLACEMENT BY 2

Cylinder Bore in Inches	STROKE IN INCHES																																	S.A.E. Rating H.P.
	3	3⅛	3¼	3⅜	3½	3⅝	3¾	3⅞	4	4⅛	4¼	4⅜	4½	4⅝	4¾	4⅞	5	5⅛	5¼	5⅜	5½	5⅝	5¾	5⅞	6	6¼	6½	6¾	7	7¼	7½	7¾	8	
2½	88	92	96	99	103	107	110	114	118	122	125	129	133	136	140	144	147	151	155	158	162	166	169	173	177	184	191	199	206	214	221	228	235	15.0
2⅝	97	102	106	110	114	118	122	126	130	134	138	142	146	150	154	158	162	166	171	175	179	183	187	191	195	203	211	219	227	235	244	251	260	16.54
2¾	107	111	116	120	125	129	134	138	143	147	152	156	160	165	169	174	178	183	187	192	196	201	205	209	214	223	232	241	249	258	267	276	285	18.14
2⅞	117	122	127	131	136	141	146	151	156	161	166	170	175	180	185	190	195	200	205	209	214	219	224	229	234	243	253	263	273	283	293	302	312	19.82
3	127	132	138	143	148	154	159	164	170	175	180	186	191	196	201	207	212	217	223	328	233	239	244	249	254	265	276	286	297	308	318	329	340	21.6
3⅛	138	144	150	156	161	167	173	178	184	190	196	201	207	213	219	224	230	236	242	247	253	258	265	270	276	288	299	311	322	334	345	356	368	23.45
3¼	149	155	162	168	174	180	186	193	199	205	212	218	224	230	236	243	249	255	261	268	274	280	286	292	299	311	324	336	348	360	373	385	398	25 35
3⅜	161	168	174	181	188	194	201	208	215	221	228	235	242	248	255	262	268	275	282	289	295	302	309	315	322	336	349	362	376	389	403	416	430	27.3
3½	173	180	188	195	202	209	216	224	231	238	245	253	260	267	274	281	289	296	303	310	317	325	332	339	346	361	375	390	404	418	433	447	461	29.4
3⅝	186	194	201	209	216	224	232	240	247	255	263	271	278	286	294	302	309	317	325	333	340	348	356	364	371	387	402	418	433	449	465	480	495	31.5
3¾	199	207	215	224	232	240	248	256	265	273	282	290	298	307	315	323	331	340	348	356	365	373	381	389	398	414	431	447	464	480	496	513	530	33.7
3⅞	212	221	230	239	248	257	266	274	283	292	301	310	318	327	336	345	354	363	371	380	389	398	407	416	425	442	460	478	495	514	531	549	567	36.0
4	226	236	245	254	264	274	283	292	302	311	320	329	339	319	358	368	377	386	396	405	415	424	434	443	452	471	490	509	528	546	565	585	604	38.4
4⅛	241	251	261	271	281	201	301	311	321	331	341	351	361	371	381	391	401	411	421	431	441	451	461	471	481	501	521	541	561	581	601	621	641	40 9
4¼	255	266	276	287	298	308	319	330	341	351	362	372	353	394	404	415	426	436	447	458	468	479	490	500	511	532	553	575	596	617	638	659	680	43 4
4⅜	271	282	293	305	316	327	338	330	361	372	383	395	406	417	428	440	451	462	474	485	496	507	519	530	541	564	586	609	631	653	677	700	722	45.0
4½	286	298	310	322	334	346	358	370	382	394	406	418	429	441	453	465	477	489	501	513	525	537	549	561	573	596	620	644	668	692	716	740	764	48.6
4⅝	302	315	328	340	353	365	378	391	403	416	428	441	454	466	479	491	504	517	529	542	554	567	580	592	605	630	655	680	706	730	756	781	806	51 3
4¾	319	332	346	359	372	386	[illegible]	412	425	439	452	465	479	492	505	518	532	545	558	572	585	598	611	625	[illegible]	665	691	718	744	770	79[illegible]	825	851	54.2
4⅞	336	350	364	378	392	406	420	434	448	462	476	490	504	518	532	546	560	574	588	602	616	630	644	658	672	700	728	756	784	812	840	868	896	57.0
5	353	368	383	398	412	427	442	457	471	486	501	515	530	545	560	574	589	604	619	633	648	663	677	692	707	736	765	795	825	854	884	913	942	60.0
5⅛	371	387	402	418	433	449	464	480	495	511	526	542	557	573	588	603	619	634	650	665	681	696	712	727	743	774	805	836	806	897	928	959	990	63.1
5¼	390	406	422	439	455	471	487	504	520	536	552	568	585	601	617	633	649	666	682	698	714	731	747	763	779	812	844	877	909	941	975	1008	1040	66.2
5⅜	409	426	443	459	476	494	510	527	545	562	579	596	613	630	647	664	681	698	715	732	749	766	783	800	817	851	885	919	953	987	1021	1056	1090	69.4
5½	428	445	464	481	499	516	535	553	570	588	606	624	641	659	677	695	713	731	748	766	784	802	820	838	855	801	927	962	908	1033	1069	1105	1141	72.7
5⅝	448	466	485	504	523	540	559	578	597	615	634	653	671	600	709	728	746	765	784	802	821	839	858	876	893	932	970	1007	1044	1082	1119	1156	1193	75.9
5¾	468	487	506	526	546	565	585	604	624	643	662	682	702	721	740	760	780	799	819	838	857	877	890	916	935	974	1013	1052	1092	1130	1170	1209	1248	79.4
5⅞	488	509	529	550	570	590	610	631	651	671	692	712	732	753	773	794	814	835	855	875	896	916	936	957	977	1018	1059	1099	1140	1180	1211	1261	1302	82.8
6	509	530	552	573	595	615	636	658	679	700	722	743	764	785	806	828	849	870	891	912	934	955	976	998	1019	1060	1101	1142	1184	1226	1270	1314	1358	86 4
6¼	553	575	598	621	645	667	690	713	736	760	782	805	828	852	875	897	920	944	967	990	1014	1038	1060	1084	1106	1152	1199	1245	1292	1339	1384	1429	1474	93.8
6½	598	623	647	672	697	722	647	772	796	821	846	871	896	921	946	971	996	1020	1044	1068	1093	1118	1143	1160	1195	1246	1298	1346	1395	1445	1495	1544	1594	101.4
6¾	644	670	696	724	750	777	804	831	858	885	911	938	965	992	1020	1047	1075	1101	1128	1155	1182	1209	1236	1263	1289	1342	1398	1452	1505	1558	1612	1666	1720	109.3
7	693	722	751	780	809	837	866	895	924	953	981	1011	1041	1070	1099	1128	1157	1286	1214	1243	1272	1301	1330	1359	1388	1446	1504	1562	1620	1678	1736	1794	1848	117.7
7¼	744	774	805	836	867	898	929	960	991	1022	1053	1084	1116	1147	1178	1209	1240	1271	1303	1333	1364	1395	1426	1457	1488	1550	1614	1676	1737	1799	1860	1921	1982	126.2
7½	796	829	862	895	928	961	995	1028	1061	1094	1127	1160	1193	1227	1260	1293	1326	1359	1392	1425	1458	1491	1524	1557	1592	1658	1725	1791	1858	1925	1991	2058	2124	135.0
7¾	850	886	921	957	992	1027	1062	1098	1133	1169	1204	1240	1275	1311	1346	1382	1417	1453	1488	1524	1559	1595	1630	1665	1700	1771	1841	1912	1983	2054	2125	2196	2267	144 2
Factor "A"	.500	.521	.542	.563	.583	604	.625	646	667	688	.708	.729	750	.771	.792	813	.833	854	875	.896	917	.938	.958	.979	1.00	1 042	1 083	1 125	1.167	1 208	1 250	1.292	1.333	

NOTE:—S. A. E. Horse-power rating is based on *1000 feet per minute piston speed.*
To find equivalent horse-power in *1000 revolutions per minute,* multiply rating, for given bore, by factor "A" for given stroke.

MISCELLANEOUS TABLES, DATA, AND INFORMATION

Miscellaneous Computations

Atmospheric pressure equals 14.7 lbs. per square inch at sea level.

To find the circumference of a circle, multiply the diameter by 3.1416.

To find the diameter of a circle, multiply the circumference by .31831.

To find the area of a circle, multiply the square of the diameter by .7854.

To find the area of a triangle, multiply the base by one-half the perpendicular height.

To find the surface of a ball, multiply the square of the diameter by 3.1416.

To find the solidity of a sphere, multiply the cube of the diameter by .5236.

To find the cubic inches in a ball multiply the cube of the diameter by .5236.

Doubling the diameter of a pipe increases its capacity four times.

A cubic foot of water contains 7½ gallons, 1728 cubic in., and weighs 62½ lbs.

To convert gallons of water to pounds, multiply by 8.345

Centigrade to Fahrenheit

Deg. Cent.	Deg. Fahr	Deg. Cent.	Deg. Fahr	Deg. Cent	Deg. Fahr	Deg. Cent.	Deg. Fahr.	Deg Cent.	Deg. Fahr	Deg. Cent.	Deg Fahr.
—10	14	22	71.6	53	127.4	84	183.2	175	347	460	860
— 9	15.8	23	73.4	54	129.2	85	185	180	356	470	878
— 8	17.6	24	75 2	55	131	86	186.8	185	365	480	896
— 7	19.4	25	77	56	132.8	87	188.6	190	374	490	914
— 6	21.2	26	78.8	57	134.6	88	190.4	195	383	500	932
— 5	23	27	80.6	58	136.4	89	192.2	200	892	525	977
— 4	24.8	28	82.4	59	138.2	90	194	210	410	550	1022
— 3	26.6	29	84.2	60	140	91	195.8	220	428	575	1067
— 2	28.4	30	86	61	141.8	92	197.6	230	446	600	1112
— 1	30.2	31	87.8	62	143.6	93	199.4	240	464	625	1157
0	32	32	89.6	63	145.4	94	201.2	250	482	650	1202
1	33.8	33	91.4	64	147.2	95	203	260	500	675	1247
2	35.6	34	93.2	65	149	96	204.8	270	518	700	1292
3	37.4	35	95	66	150.8	97	206.6	280	536	725	1337
4	39.2	36	96.8	67	152.6	98	208.4	290	554	750	1382
5	41	37	98.6	68	154.4	99	210.2	300	572	775	1427
6	42.8	38	100.4	69	156.2	100	212	310	590	800	1472
7	44.6	39	102.2	70	158	105	221	320	608	825	1517
8	46.4	40	104	71	159.8	110	230	330	626	850	1562
9	48.2	41	105.8	72	161.6	115	239	340	644	875	1607
10	50	42	107.6	73	163.4	120	248	350	662	900	1652
11	51.8	43	109.4	74	165.2	125	257	360	680	925	1697
12	53.6	44	111.2	75	167	130	266	370	698	950	1742
13	55.4	45	113	76	168.8	135	275	380	716	975	1787
14	57.2	46	114.8	77	170.6	140	284	390	734	1000	1832
15	59	47	116.6	78	172.4	145	293	400	752	1025	1877
16	60.8	48	118.4	79	174.2	150	302	410	770	1050	1922
17	62.6	49	120.2	80	176	155	311	420	788	1075	1967
18	64.4	50	122	81	177.8	160	320	430	806	1100	2012
19	66 2	51	123.8	82	179.6	165	329	440	824	1125	2057
20	68	52	125.6	83	181.4	170	338	450	842	1150	2102
21	69.8										

Melting Points of Various Materials

	Fahrenheit Degrees	Centigrade Degrees
ALUMINUM	1216	658
ANTIMONY	1166	630
Arsenic	1472	800
Bismuth	518	270
CADMIUM	610	321
Calcium	1481	805
Chromium	2741	1505
COBALT	2714	1490
COPPER	1981	1083
GOLD	1945	1063
Iridium (?)	4172	2300
IRON	2768	1520
LEAD	621	327
Magnesium	1204	651
Manganese	2237	1225
MERCURY	—38	—39
Molybdenum (?)	4532	2500
GLASS	1832	1000
GLASS, LEAD FREE	2192	1200
DELTA METAL	1742	950
BARIUM CHLORIDE	1635	891
POTASSIUM FERRO-CYANIDE	1145	618
POTASSI'M CHLORIDE	1325	718
SODIUM CHLORIDE	1472	800
NICKEL	2642	1450
PALLADIUM	2822	1550
Phosphorus	111	44
PLATINUM	3191	1755
POTASSIUM	144	62
Rhodium (?)	3452	1900
Silicon	2588	1420
SILVER	1762	961
SODIUM	207	97
Tantalum (?)	5252	2900
TIN	450	232
Titanium (?)	3362	1850
TUNGSTEN	5432	3000
Uranium	4352	2400
Vanadium (?)	3182	1750
ZINC	786	419
Sulphur	237 248	114 120
Fusible Metals:		
1 Tin, 2 Lead	361	[illegible]
1 Tin, 1 Lead	304	151
3 Tin, 2 Lead	275	135
4 Tin, 4 Lead, 1 Bismuth	263	128
3 Tin, 5 Lead, 8 Bismuth	212	100

Decimal Equivalent of Fractional Parts of an Inch

In using this table it is not necessary to carry out all of the fraction. As a rule, three figures to the right of the decimal point is close enough for all practical purposes—which would be, of course, read in thousandths, as .015 (fifteen one-thousandths).

8ths

⅛=.125
¼=.250
⅜=.375
½=.500
⅝=.625
¾=.750
⅞=.875

16ths

1/16=.0625
3/16=.1875
5/16=.3125
7/16=.4375
9/16=.5625
11/16=.6875
13/16=.8125
15/16=.9375

32ds

1/32=.03125
3/32=.09375
5/32=.15625
7/32=.21875
9/32=.28125
11/32=.34375
13/32=.40625
15/32=.46875
17/32=.53125
19/32=.59375
21/32=.65625
23/32=.71875
25/32=.78125
27/32=.84375
29/32=.90625
31/32=.96875

64ths

1/64=.015625
3/64=.046875
5/64=.078125
7/64=.109375
9/64=.140625
11/64=.171875
13/64=.203125
15/64=.234375
17/64=.265625
19/64=.296875
21/64=.328125
23/64=.359375
25/64=.390625
27/64=.421875
29/64=.453125
31/64=.484375
33/64=.515625
35/64=.546875
37/64=.578125
39/64=.609375
41/64=.640625
43/64=.671875
45/64=.703125
47/64=.734375
49/64=.765625
51/64=.796875
53/64=.828125
55/64=.859375
57/64=.890625
59/64=.921875
61/64=.953125
63/64=.984375

.015 is approximately 1/64″; .025 is 1/40″.

The one-thousandth part of an inch is explained elsewhere. See page 701.

Hundredths of an inch to sixty-fourths of an inch are explained elsewhere. See page 68.

Metric System[1]

The metric system, called the French standard, is used quite extensively abroad and is also referred to quite often in this book. Therefore a conversion of those figures most generally used is given. See tables below.

m is the designation of meter; **cm,** centimeter; **mm** or **m/m** millimeter.

1 millimeter is approximately 1/25″, and is exactly .03937″.

1 centimeter is approximately 13/32″, and is exactly .3937″.

1 meter is approximately 39¼″, and is exactly 39.37″, or 1.0936 yards.

1 kilometer is approximately ⅝ mile, and is exactly .6213 mile.

1 kilogram is approximately 2¼ lbs., and is exactly 2.21 lbs.

1 liter is approximately 2 1/9 pints, and is exactly 2.11 pints

10 mm. = 1 centimeter = 0.3937″
10 cm. = 1 decimeter = 3.937 ″
10 dm. = 1 meter = 39.37″
25.4 mm. = 1 English inch.

To convert inches to centimeters, multiply by 2.54

To convert meters to yards, multiply by 70 and divide by 64.

To convert kilometers to miles, multiply by 5 and divide by 8 (approx.).

To convert cubic inches to cubic centimeters, multiply by 16.39.

To convert cubic meters to cubic feet, multiply by 35.32.

To convert grams to ounces, multiply by 567 and divide by 20.

To convert liters to U.S. pints, multiply by 95 and divide by 45.

See page 595 (tires) for metric conversions.

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[1] See Index under "Tires, metric sizes."

Millimeters to Inches (decimal)

Mm.	Inches	Mm.	Inches
2=	07874	14=	.55118
3=	11811	15=	.59055
4=	.15748	16=	.62992
5=	.19685	17=	.66929
6=	.23622	18=	.70866
7=	.27559	19=	74803
8=	.31496	20=	78740
9=	.35433	21=	.82677
10=	.39370	22=	.86614
11=	.43307	23=	90551
12=	.47244	24=	.94488
13=	.51181	25=	.98425
		26=	1.02362

Tenths of Millimeters

.2 (2/10ths) of a mm. is approx. .008″
.3 (3/10ths) of a mm. is approx. .012″
.4 (4/10ths) of a mm. is approx. .016″
.5 (5/10ths) of a mm. is approx. .019″

Millimeters to Fractions of an Inch

1 mm. is approximately	3/64″
2 mm. is approximately	5/64″
3 mm. is approximately	7/64″
4 mm. is approximately	5/32″
5 mm. is approximately	12/64″
6 mm. is approximately	15/64″ or ¼″
7 mm. is approximately	17/64″
8 mm. is approximately	20/64″ or 10/32″ or 5/16″
9 mm. is approximately	22/64″
10 mm. is approximately	25/64″
12 mm. is approximately	15/32″
15 mm. is approximately	19/32″
16 mm. is approximately	⅝″
18 mm. is approximately	23/32″
20 mm. is approximately	25/32″
22 mm. is approximately	55/64″
24 mm. is approximately	15/16″
25 mm. is approximately	63/64″

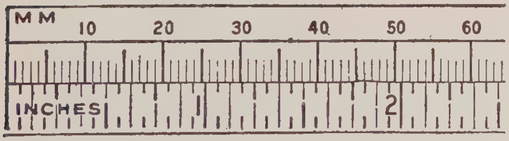

Fig. 9. Comparative difference between millimeters and inches with a rule 2½″ long.

Table of Cylinder Bores and Strokes in Millimeters and Inches

The following figures are approximate, and intended only as a rough guide for comparison. For accurate measurements a sliding calliper with inches and metric scales should be used.

A Cylinder	Equals in Inches	A Cylinder	Equals in Inches
66 by 70 millimetres	2 9/16 by 2¾	84 by 90 millimetres	3 5/16 by 3 9/16
67 ,, 70 ,,	2⅝ ,, 2¾	90 ,, 90 ,,	3 9/16 ,, 3 9/16
67 ,, 73 ,,	2⅝ ,, 2⅞	90 ,, 110 ,,	3 9/16 ,, 4 5/16
67 ,, 77 ,,	2⅝ ,, 3	95 ,, 115 ,,	3¾ ,, 4 9/16
70 ,, 70 ,,	2¾ ,, 2¾	100 ,, 115 ,,	3 15/16 ,, 4 9/16
70 ,, 73 ,,	2¾ ,, 2⅞	105 ,, 118 ,,	4⅛ ,, 4⅝
70 ,, 77 ,,	2¾ ,, 3	108 ,, 120 ,,	4¼ ,, 4¾
72 ,, 77 ,,	2 13/16 ,, 3	110 ,, 125 ,,	4 5/16 ,, 4 15/16
73 ,, 73 ,,	2⅞ ,, 2⅞	112 ,, 128 ,,	4 7/16 ,, 5 1/16
73 ,, 80 ,,	2⅞ ,, 3⅛	114 ,, 130 ,,	4½ ,, 5⅛
77 ,, 77 ,,	3 ,, 3	116 ,, 134 ,,	4 9/16 ,, 5 5/16
77 ,, 80 ,,	3 ,, 3⅛	118 ,, 138 ,,	4⅝ ,, 5 7/16
77 ,, 83 ,,	3 ,, 3¼	120 ,, 140 ,,	4¾ ,, 5½
78 ,, 78 ,,	3 1/16 ,, 3 1/16	122 ,, 143 ,,	4 13/16 ,, 5⅝
80 ,, 80 ,,	3⅛ ,, 3⅛	124 ,, 146 ,,	4⅞ ,, 5¾
80 ,, 86 ,,	3⅛ ,, 3⅜	126 ,, 148 ,,	4 15/16 ,, 5 13/16
83 ,, 83 ,,	3¼ ,, 3¼	128 ,, 150 ,,	5 1/16 ,, 5 15/16
83 ,, 86 ,,	3¼ ,, 3⅜	130 ,, 152 ,,	5⅛ ,, 6
86 ,, 86 ,,	3⅜ ,, 3⅜	140 ,, 160 ,,	5½ ,, 6⅜

Time per Mile Expressed in Miles per Hour

There are 3,600 seconds in an hour, and, to find the speed in miles per hour, divide 3,600 by the time in seconds it takes to make 1 mile.

Time for one mile Min.	Sec.		Miles Per hour	Time for one mile. Min.	Sec.		Miles Per hour	Time for one mile Min.	Sec.		Miles Per hour
0	36	=	100.00	1	12	=	50.00	1	47	=	33.64
0	37	=	97.30	1	13	=	49.31	1	48	=	33.33
0	38	=	94.74	1	14	=	48.65	1	49	=	33.03
0	39	=	92.31	1	15	=	48.00	1	50	=	32.72
0	40	=	90.00	1	16	=	47.37	1	51	=	32.43
0	41	=	87.80	1	17	=	46.75	1	52	=	32.14
0	42	=	85.71	1	18	=	46.15	1	53	=	31.86
0	43	=	83.72	1	19	=	45.57	1	54	=	31.58
0	44	=	81.82	1	20	=	45.00	1	55	=	31.30
0	45	=	80.00	1	21	=	44.44	1	56	=	31.03
0	46	=	78.26	1	22	=	43.90	1	57	=	30.77
0	47	=	76.60	1	23	=	43.37	1	58	=	30.50
0	48	=	75.00	1	24	=	42.86	1	59	=	30.25
0	49	=	73.47	1	25	=	42.35	2	0	=	30.00
0	50	=	72.00	1	26	=	41.86	2	3	=	29.26
0	51	=	70.59	1	27	=	41.38	2	6	=	28.57
0	52	=	69.23	1	28	=	40.91	2	9	=	27.90
0	53	=	67.92	1	29	=	40.45	2	12	=	27.27
0	54	=	66.67	1	30	=	40.00	2	15	=	26.66
0	55	=	65.45	1	31	=	39.56	2	18	=	26.08
0	56	=	64.29	1	32	=	39.13	2	21	=	25.53
0	57	=	63.16	1	33	=	38.71	2	24	=	25.00
0	58	=	62.07	1	34	=	38.30	2	27	=	24.49
0	59	=	61.02	1	35	=	37.89	2	30	=	24.00
1	0	=	60.00	1	36	=	37.50	2	33	=	23.53
1	1	=	59.02	1	37	=	37.11	2	36	=	23.07
1	2	=	58.06	1	38	=	36.73	2	39	=	22.64
1	3	=	57.14	1	39	=	36.36	2	42	=	22.22
1	4	=	56.25	1	40	=	36.00	2	45	=	21.81
1	5	=	55.38	1	41	=	35.64	2	48	=	21.42
1	6	=	54.55	1	42	=	35.29	2	51	=	21.05
1	7	=	53.73	1	43	=	34.95	2	54	=	20.69
1	8	=	52.94	1	44	=	34.61	3	0	=	20.00
1	9	=	52.17	1	45	=	34.28	..	..		....
1	10	=	51.42	1	46	=	33.96				
1	11	=	50.70								

Miles and Kilometers

Kilo.	Miles.	Kilo.	Miles.	Kilo.	Miles.	Kilo.	Miles.
1	⅝	20	12⅜	38	23⅝	56	34¾
2	1¼	21	13	39	24¼	57	35⅜
3	1⅞	22	13⅝	40	24⅞	58	36
4	2½	23	14¼	41	25½	59	36⅝
5	3⅛	24	14⅞	42	26⅛	60	37¼
6	3¾	25	15½	43	26¾	70	43½
7	4⅜	26	16⅛	44	27⅜	80	49¾
8	5	27	16¾	45	28	90	55⅞
9	5⅝	28	17⅜	46	28⅝	100	62⅛
10	6¼	29	18	47	29¼	200	124¼
11	6⅞	30	18⅝	48	29⅞	300	186⅜
12	7½	31	19¼	49	30½	400	248½
13	8⅛	32	19⅞	50	31⅛	500	310¾
14	8¾	33	20½	51	31¾	600	372⅞
15	9⅜	34	21⅛	52	32¼	700	435
16	10	35	21¾	53	32⅞	800	497⅛
17	10⅝	36	22⅜	54	33½	900	559¼
18	11¼	37	23	55	34⅛	1000	621⅜
19	11⅞						

Kilometers and Miles per Hour

A Kilometre in Min.	Sec.	Miles per Hour	A Kilometre in Sec.	Miles per Hour.
0	55	40.65	16	139.79
0	56	39.93	18	124.26
0	57	39.23	20	111.83
0	58	38.55	21	106.50
0	59	37.89	22	101.66
1	0	37.26	23	97.24
1	1	36.65	24	93.19
1	2	36. 6	25	89.54
1	3	35.49	26	86.02
1	4	34.93	27	82 83
1	5	34.40	28	78.88
1	6	33 88	30	74.53
1	7	33.37	31	72.13
1	8	32.88	32	69.87
1	9	32.41	33	67.76
1	10	31.94	34	65.76
1	11	31.49	35	63.88
1	12	31.05	36	62.11
1	13	30.63	37	60.43
1	14	30.21	38	58.85
1	15	29.81	39	57.33
1	16	29.42	40	55.99
1	17	29 03	41	54.53
1	18	28 66	42	53.24
1	19	28.30	43	52 00
1	20	27 95	44	50.82
1	21	27.60	45	49 69
1	22	27.26	46	48.61
1	23	26.94	47	47.57
1	24	26.62	48	46.58
1	25	26.30	49	45.63
1	26	26.00	50	44.72
1	27	25.70	51	43.84
1	28	25.41	52	43.00
1	29	25.12	53	42.19
1	30	24.84	54	41.40

Wheel and Engine Speeds

This table gives the number of revolutions that a tire of given size makes in going a mile.

TIRE SIZE	WHEEL R.P.M.	ENGINE REVOLUTIONS PER MILE WITH VARIOUS GEAR RATIOS		
		3 to 1	3½ to 1	4 to 1
30	672.2	2016.6	2352.7	2688.8
32	631.7	1895.1	2210.9	2526.8
33	611.1	1833.3	2138.8	2444.4
34	593.2	1779.6	2075.2	2372.8
35	576.2	1728.6	2016.7	2304.8
36	560.2	1680.6	1960.7	2240.8
40	504.2	1512.6	1764.6	2016.8
SIZE	R.P.M.	4½ to 1	5 to 1	5½ to 1
30	672.2	3024.9	3361.0	3697.1
32	631.7	2842.6	3158.5	3474.3
33	611.1	2749.9	3055.5	3361.0
34	593.2	2669.4	2966.0	3262.6
35	576.2	2592.9	2881.0	3169.1
36	560.2	2528.9	2801.0	3081.1
40	504.2	2268.8	2520.0	2773.1

How to Find Degrees with a Protractor

A degree is a unit employed in measuring angles, and is the ninetieth part of a right angle or one three-hundred and sixtieth part of a circle.

The degree explanation is given on page 60. See also pages 68 and 299, "Converting degrees into inches."

A protractor is used for dividing circles into any number of equal parts or degrees, and for determining angles.

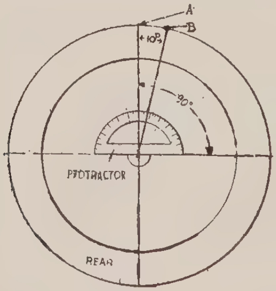

Fig. 10

For instance, to find the number of degrees in a circle with a protractor, say, of a flywheel of an engine: Place the protractor as shown. From the center line (A) to (B) is 10°; from (A) to the extreme right, the lower part of the protractor—if a line was drawn—you would have a right angle, or 90°. The number of degrees from the extreme left to the extreme right of the protractor would be 180°, or half a circle. The entire circle would be 360°. In other words, the circle is divided into 360 equal parts called degrees, and designated by the symbol °.

We can divide each degree into 60 parts, called **"minutes,"** and each minute can be divided into 60 parts called **"seconds."** One minute would be designated thus (1′), and one second thus (1″).

Signs or Symbols of Inches, Feet, Minutes, and Seconds

The sign for inches or seconds is (″), as 6″.

The sign for feet or minutes is (′), as 6′.

It will be observed that the same symbols are used for inches and seconds, and also for feet and minutes.

Freezing and Boiling Point and Specific Gravity of Water, Alcohol, Kerosene and Gasoline

Mercury freezes at 38.7° below zero, and **boils** or gives off gas at 357° above zero, Fahrenheit.

Constants	Water	Wood Alcohol	Ethyl Alcohol	Denatured Alcohol Formula #1	Kerosene	Gasoline
Freezing Point	+32°F 0°C	—144°F —98°C	—202°F —130°C	—200°F —129°C	Does not have a definite point Solidifies about —50°C	—202°F —130°C
Boiling Point	+212°F +100°C	153°F 67°C	173°F 78.4°C	171°F 77.4°C	387°F 197°C	173°F 78.5°C
Specific Gravity	1.000 at 0/4°C	.789 at 0°C	.8002 at 0°C	.8164 at 15°C	.815 at 15°C	728 at 15°C

1 lb. of gasoline of 58 specific gravity is approximately 8/10 of a pint. **A gallon of gasoline** (58 s.g.) weighs approximately 6.6 lbs. See page 1078, under "Thermal efficiency," for the number of B.T.U.'s to a pound of gasoline.

Capacity of Cylindrical Tanks

The formula for computing the capacity of a cylindrical tank is as follows:

$$C = \frac{D^2 \times L}{293.3}$$

C is the capacity in gallons.
D is the diameter of the tank in inches.
L is length in inches.

Example: What is the capacity of a tank 10″ in diameter and 12″ long?

C is the capacity of the tank, which we desire to know, and is equal to the diameter squared (**D**²) or multiplied by itself, as 10 × 10=100 × by (**L**), the length, or 12 inches =1,200. The line under **D**² × **L** means that the total of **D**² × **L**, which is 1,200, is divided by a constant 293.3=4.09 gallons.

The table gives the capacity of tanks in gallons for given sizes.

Length	12 in.	16 in.	20 in.	24 in.	28 in.	32 in.	36 in.
Diameter	Gal.	Gal.	Gal.	Gal.	Gal.	Gal.	Gal.
10 in.	4.09	5.45	6.81	8.17	9.53	10.89	12.25
15 in.	9.20	12.27	15.34	18.40	21.47	24.54	27.61
20 in.	16.36	21.80	27.24	32.68	38.12	43.56	49.00
25 in.	25.56	34.08	42.60	51.12	59.64	68.16	76.68
30 in.	36.81	49.05	61.29	73.53	85.77	98.01	110.25
35 in.	50.15	66.87	83.59	100.31	117.02	133.74	150.46

S.A.E. Recommended Sizes of Carburetor Flanges (Two-Bolt Type)

The following data give the **opening in carburetor** flange (A); thus one can **tell the size of a carburetor** by measuring this opening. See also page 109.

If a **carburetor flange** on the inlet manifold or on the carburetor is **to be repaired,** such as welding, etc., the **diameter and distance apart of bolt holes,** as well as of the threads are given.

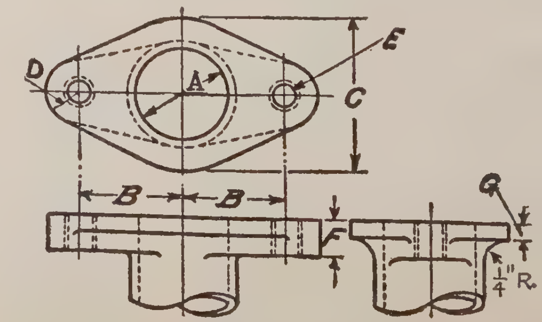

Fig. 11. S. A. E. Carburetor flange dimensions. See table, page 1051, giving the dimensions of A to G above on different sizes of carburetors.

Nom. Carburetor Size	A	B	C	D	E*		F†	G†
					Diam.	Threads per Inch		
½	13/16	29/32	1 7/16	9/32	1/4	20	5/16	3/32
⅝	13/16	29/32	1 7/16	9/32	1/4	20	5/16	3/32
¾	1 1/16	1 1/8	1 3/4	11/32	5/16	18	3/8	1/8
⅞	1 1/16	1 1/8	1 3/4	11/32	5/16	18	3/8	1/8
1	1 3/16	1 3/16	1 7/8	11/32	5/16	18	13/32	5/32
1¼	1 7/16	1 11/32	2 3/16	13/32	3/8	16	15/32	3/16
1½	1 11/16	1 15/32	2 1/2	13/32	3/8	16	15/32	3/16
1¾	1 15/16	1 21/32	2 13/16	15/32	7/16	14	9/16	7/32
2	2 3/16	1 25/32	3 1/8	15/32	7/16	14	9/16	7/32

* **U.S. standard thread.** All dimensions in inches.

† **Cast-iron carburetor flanges:** Flange dimensions (F) and (G) shall be increased ⅛″ for cast-iron carburetors.

Side-outlet carburetor flanges: The standard flange dimensions shall be used with the long diameter of the flange in a vertical plane when attaching carburetors of the side-outlet type.

Localities Where Cars Are Owned

The following is an analysis of present ownership of registered automotive vehicles, published by the National Automobile Chamber of Commerce, based on a survey made by J. M. Gunn, president of the U.S. Tire Co.

In towns of 1,000 and under 33 per cent
In towns of 1,000 to 5,000 20 per cent
In towns of 5,000 to 50,000 16 per cent
In cities of 500,000 or over 9 per cent

Location of Numbers and Weight of Cars (S.A.E. Standard)

The standard location for the engine number shall be on the crank case proper, at the front end, as near the middle as practicable crosswise, and on top, if possible. Consideration should be given to accessibility in the completely assembled car. If it is not possible to locate the number near the center at the front, that position should be approximated, preference being given to the right-hand side. The number should be deeply indented in the crank case in characters at least ¼″ high.

The standard location for the maker's identification number on car, chassis, or frame (whichever is used for identification) shall be on the outside flat of the right-hand frame member, as far forward as possible. Such number shall be heavily indented in the frame side-member in characters not less than ¼″ high. Where this location is inaccessible, it should be approximated.

The use of attached plates in lieu of numbers stamped as specified is discouraged, because of the ease with which a plate can be removed.

The standard weight of a car shall be the actual scale weight with complete catalog equipment, less fuel and water.

Example of location of serial numbers on a car (Reo): The location is shown on the illustration above (Fig. 12). The numbers vary on different cars. The part number of the spring and date of manufacture are to be found on short leaf.

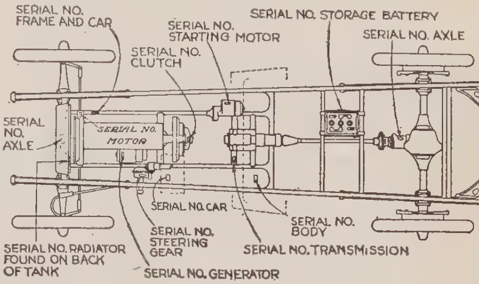

Fig. 12

Exhaust Pipe Diameters of 1920 and 1921 Automobile Passenger-Car Engines[1]

Name and Model	1920	1921
	In Inches	
Ace, AL	....	2¼″
Allen, 43	2″	2″
American, C	2¼″	2¼″
American Beauty	2¼″	2¼″
Anderson, S-40	2¼″	2¼″
Apperson, 821	1¾″	1¾″
Argonne	2½″	....
Auburn	2″	2¼″
Beggs, 20T & 21T	2¼	2¼″
Bell	....	2½″
Biddle	2¼″	....
Bour-Davis	2¼″	....
Brewster	2¾″	2½″
Briscoe, 434	....	1 13/16
Buick	1¾″	1¾″
Cadillac, 59	1¾″	1¾″
Cameron, 6-35	....	2¾″
Case	2¼″	....
Chalmers, 35 B & C	2⅜″	2⅜″
Champion	5″	....
Chandler	2″	2″
Chevrolet, 490	1½″	2″
Chevrolet, FB	2″	2″
Cleveland, 41	2″	2″
Climber, S	2¼″	2¼″
Cole, Aero 8	2⅝″	2⅝″
Columbia Six	2″	2¼″
Comet	2½″	....
Commonwealth	2½″	2¼″
Crawford, 21-6-40	2¼″	2¼″
Crow Elkhart	2¼″	....
Cunningham	2¼″	2¼″
Daniels, D19	1⅞″	1⅞″
Davis	....	....
Dispatch	....	....
Dodge Bros	2″	2″
Dort, 15	2¼″	2¼″
Dixie, HS-7000	2⅜″	1⅜″
Dorris, 680	2½″	2½″
Dupont, A	....	2½″
Elcar, D, H, G, K	2⅜″	2¼″
Elgin	2″	....
Essex, A	2′	2″
Economy	....	....
Ferris, C21	....	2¼
Franklin, 9B	1½″	1½″
Ford, T	1½″	1½″
Gardner, G	....	2¼″
Geronimo, 6-E-45	2¼″	2¼″
Grant	2″	2″
Hanson, 54-60	....	2¼″
Harrow	....	....
Harvard	....	....
Halladay, MS	....	....
Hatfield, A-42	2″	2″
Haynes, L. Six	2⅜″	2⅜″
Haynes, L. Twelve	....	1¾″
H. C. S	....	....
Hollier	2½″	....
Holmes, 1921	....	2″
Hudson, O	2¼″	2¼″
Huffman, HS	....	2¼″
Hupmobile, R-5	1¾″	1⅞″
Jackson	....	....
Jones	....	....
Jordan, M	2¼″	2¼″
King	1¾″	....
Kissel	2¾″	....
Kline Kar, SK	2″	2¼″
La Fayette, 134	....	1¾″
Leach	....	2″
Lexington, S	....	2″
Liberty, 10C	2″	2″
Lincoln	....	....
Locomobile	2½″	2½″
Lorraine, 21T	....	2″
Madison	....	....
Maibohm, B	2″	2″
Marmon, 34	3″	3″
Maxwell, 25	1⅝″	1 15/16
McFarlan, 147	3¼″	3¼″
Mercer, Series 5	3″	3″
Meteor, R & RR	....	2½″
Metz, M. Six	2 3/16″	2¼″
Mitchell	2¼″	....
Monitor	....	....
Moon, 6-48	2¼″	2¼″
Monroe, S-9-10	....	1¾″
Nash, 681-7	2″	2″
National, Sextet	2½″	2½″
Nelson	1½″	1½″
Noma, 1D	....	1¼″
Norwalk, 430-KS	....	2⅜″
Oakland, 34C	2¼″	2¼″
Ogren	....	....
Oldsmobile, 46	1¾″	1¾″
Oldsmobile, 45B & 37A	1¾″	....
Olympian, 45	1¼″	1¾″
Overland, 4	2″	2″
Owen Magnetic	2⅝″	...
Packard, 335	2¼″	2¼″
Paige, 642	2″	2″
Paige, 666	2¼″	2½″
Paterson, 650	....	2¼″
Peerless, 56-56	1⅞″	1⅞″
Phianna	....	....
Piedmont, 6-40	....	2¼″
Pierce Arrow	....	....
Pan, A	....	2¼″
Pilgrim	....	....
Pilot	2¼″	....
Porter, 46	....	2⅝″
Premier	....	2″
Ranger, B	....	2″
Reo, T6	2½″	2½″
Revere, Series F	3″	3″
Roamer	2¼″	....
Rock Falls No. 11	....	2¼″
R. & V. Knight-J	2½″	2½″
R. & V. Knight-R	2½″	2½″
Saxon, 125	....	2″
Sayers Six, DP	2″	2¼″
Scripps Booth	2¼″	....
Seneca, RS & T21	1½″	1½″
Severin	....	....
Skelton, 35	....	2¼″
Spacke, 21	....	1½″
Standard, I	1⅝″	1⅝″
Stearns	2¼″	....
Sevens, Duryea, E	....	2½″
Stephens, 80	2¼″	2¼″
Studebaker	....	....
Studebaker	....	....
Studebaker	....	....
Stutz	....	....
Templar	2″	....
Texan, A38-B38	....	2¼″
Tulsa	....	....
Velie, 34	2″	2″
Velie, 38	2¼″	2¼″
Westcott, D38	....	2¼″
Willys Knight, 20	....	....
Winther, 61	....	2¼″
Winton, 25	2½″	2½″
Wasp, 2011	....	2½″

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[1] From *Motor Age.*

VALVE TIMING, VALVE CLEARANCE AND VALVE DIMENSIONS, 1920 AND 1921 PASSENGER CAR ENGINES

The tables on pages 1052, 1053 give the valve setting in degrees and minutes for 1920 and 1921 cars. For example, the intake closes "46-40" on the Cadillac; meaning 46 degrees and 40 minutes.

The tables also give the valve clearance and the diameter and length of the valve, as taken from *Motor Age*.

Average Valve Setting

If the timing of an engine is not known, and you desire to set the valves, here is a plan to follow:

The pitch of the timing gears is generally coarse enough to allow of only one proper setting, and when

—*continued on page 1053*

NAME AND MODEL	VALVE TIMING Measured in Degrees and Minutes				Valve Clearance		Valve Diameter	Valve Stems	
	Intake		Exhaust		Intake	Exhaust		Diameter	Length
	Opens After Upper Dead Center	Closes After Lower Dead Center	Opens Before Bottom Dead Center	Closes After Top Dead Center					
Ace, TL	...	....	...	....	....	....	....	....	....
Allen, 43	10	44	48	10	.004	.004	1.625	.375	6.0625
American, C 6	*8	45	45	8	.003	.004	1.75	.434	8.25
American Beauty, C-55	12	40	40	8	.004	.006	1.812	.4375	5.687
Anderson, 30	12	40	40	8	.004	.006	1.5	.3725	5.625
Apperson, 821-S	15	45	55	10	.004	.004	1.5625	.375	7.375
Apperson, Anniversary	....	....	....	....	....	....	....	....	....
Auburn, 639 H-K	12	40	40	8	.3125	....	1.6718	.390	5.6875
Argonne, 1920	7	57	50	11	.006	.008	2.125	.375	6.
Bour-Davis, 21S	10	28	40	2.5	.004	.006	1.5312	.3723	6.0469
Brewster, 1920	10	50	45	....	Sleeve Vl.	Sleeve Vl.	Sleeve Vl.	Sleeve Vl.	Sleeve Vl.
Briscoe, 4-34	13	35	45	8	.004	.004	1.75	.3725	6.609 6.593
Buick, K 6-45	15-10	38-40	12-40	12-10	.010	.010	1.625 1.25	.3730 .3710	4.843
Buick, K 6-49	...	....	....	....	....	....	....	....	....
Bell	....	....	....	....	....	....	....	....	....
Cadillac, 59	...	46-40	46-40	.. .	.002	.002	1.6875	.375	7.156
Case, V	10	28	40	...	.003	.003	1.53125	.375	6.
Chalmers, 6-30	...	50	50	10	.004	.004	1.60	.3125	6.25
Champion, C-4	5	38	47	10	.003	.004	1.5	.375	5.5
Chandler, 27	16	36	46	9	.004	.004	1.3125	.375	6.25
Cleveland, 40	12	40	50	10	.002	.003	1.3125	.3125	4.156
Chevrolet, 490	. .	...	....	....	....	....	....	....	....
Chevrolet, FB	....	....	...	...	....	....	....	....	....
Cole, 870	15	38	45	10	.006	.006	1.5	.375	4.875
Columbia, D-C & CS	12	40	40	8	.004	.006	1.812	.437	5.687
Comet, C-53	...	..	....	....	....	....	....	....	....
Commonwealth	5	38	47	10	.003	.004	1.5	.375	5.5
Crow-Elkhart, L-53-55	8	33	40	4	.002	.003	1.68	.4375	5.375
Crow-Elkhart, H-53-55	..	...	....	...	....	....	....	....	....
Cunningham, V-4	5	45	55	5	....	....	1.75	.432	6.125
Daniels, D	10	50	45	10	.003	.003	1.4375	.34375	7.5
Davis, 51-55	12	40	40	8	.004	.606	1.5	.3725	5.625
Dispatch, G	....	...	....	....	....	....	....	....	....
Dixie Flyer, HS-70	....	....	....	....	...	....	....	....	....
Dodge Brothers	10	35	45	8	.004	.004	1.6875	.370	6.531
Dorris, 6-80	10	45	45	10	.34375	.34375	1.875	.4375	5.0625
Dort, 15	5	38	47	10	.003	.003	1.6562	.3735	6.0312
Douglas, G-18	10	....	...	5	....	....	1.625	.4375	6.0
Du Pont, A	....	40	45	10	.003	.006	1.75	.375	6.8125
Economy, 6-46	....	....	....	...	....	....	....	....	....
Elcar, 4	5	38	47	10	.003	.004	1.5	.375	5.5
Elcar, 6	12	40	40	8	.004	.006	1.5	.3725	5.625
Elgin, K	13	42	45	10	.003	.003	1.375	.310	4.5312
Essex, A	7	42	55	8	.006	.008	1.875	.373	5.5625
Ferris	10	28	40	2-30	.004	.006	1.218	.3720	6.046
Ford, T	.0625	.5625	.3125	....	.025	.025	1.2656	.3105	4.974
Franklin, 9-B	....	57	43-5	25	.010	.010	1.3125	.338	4.7187
Grant, HX	13	42	.45	10	.004	.004	1.5	.310	4.6875
Gardner	.	...	....	....	....	....	....	....	....
Geronimo	15	50	45	10	.004	.004	1.4375	.312	5.375
Halladay	15	50	45	10	.003	.003	1.4375	.3125	5.375
Hanson, 54	...	..	.. .	....	....	....	....	....	....
Harroun, AA-2		...	..	...	....	....	....	....	....
Haynes, 45	5	35	47	2	.004	.006	1.5625	.4375	5.625
Haynes, 47	15	33	50	15	.035	.035	1.875	.372	3.75
Huffman, R	12	40	40	8	.004	.006	1.5	.3725	5.625
H. C. S.	..	. .	..	. .	...	....	....	....	....
Hollier, 206-B	...	..	...	....	....	....	....	....	....
Holmes	15	33	50	15	.3125	.3125	1.625	.371 .3085	3.75 3.25
Hudson	7	42	55	8	.004	.006	1.8125	.370	6.75
Hupmobile, R	12	44	44	12	.004	.004	1.625	.375	5.5625
Jackson, 638	8	40	40	12	.004	.006	1.5	.3725	5.625
Jones, 28	10	28	40	2.5	.002	.003	1.6875	.375	5.875
Jordan, F		..	..	....	....	....	....	....	....
Jordan, M	12	40	40	8	.004	.006	1.5	.3725	5.625
King, H	.	35	45	6	.0075	.0075	1.6875	.3125	6.2187
Kissel, 45	5	35	45	....	.004	.004	1.812	.3735	5.75
Klinekar, 6-55-J	10	33	67	8	.004	.004	1.625	.375	5.875
LaFayette	..	46	46	...	.003	.005	1.75	....	....
Leach, B-W	10	28	40	2.5	.004	.006	1.531	.3723	6.046
Lexington, S20	12	40	40	8	.004	.006	1.5	.3725	5.625
Liberty, 10-C	8	40	45	6	.002	.003	1.5	.3125	5.5
Locomobile, 48	14	50	50	....	.002	.004	2.125	.433	8.281

[*concluded on next page*

—*continued from page 1052*

the proper position is almost reached, the tooth of the cam-shaft gear, which should mesh between the two teeth on the crank-shaft gear, will be so close that less than the width of one tooth will be between that and the exact position.

The following is an average setting of 114 cars, as given by *Motor Age*. The intake opens 9.5° late and closes 37° late. The exhaust valve opens 50° before bottom, and closes 9° late. It is not necessary to pay any attention to more than one of these dimensions; for instance, set the exhaust closing with the cam shaft, since most engines are of the L-type, with all cams on one shaft.

After making this setting you can determine if the setting is wrong, as it will probably be out only one tooth on the cam-shaft gear, one way or the other.

NAME AND MODEL	VALVE TIMING Measured in Degrees and Minutes						Valve Diameter	Valve Stems	
	Intake		Exhaust		Valve Clearance				
	Opens After Upper Dead Center	Closes After Lower Dead Center	Opens Before Bottom Dead Center	Closes After Top Dead Center	Intake	Exhaust		Diameter	Length
Lorraine	....	....	....	....	....	....	....	....	....
Madison	15	50	45	10	.004	.004	.3125	....	....
Maibohm, B	13	42	45	10	....	....	1.375	.312	4.5312
Marmon, 34B	19	35	45	12	.008	.008	2.	.375	5.
Maxwell, 1920	5	40	35	....	.265	.265	1.5	.3725	4.39062
McFarlan	10	40	55	5	.003	.004	2.18	.403	8.24
Mercer, Series 5	5	55	70	15	.0055	.0055	2.37	.370	9.6562
Meteor, K & R	....	....	....	....	....	....	....	....	....
Metz, M6	15	50	45	10	.003	.003	1.3125	.3125	4.8125
Mitchell, F-40	10	35	41	4	.003	.003	1.5625	.3715	5.625
Monitor, S-3	12	40	40	8	.004	.006	1.812	.437	5.687
Monroe, S-9 & S-10	5	49	49	5	.378	.378	1.75	.375	5.5
Moon, 6-48	12	40	40	8	.004	.006	1.5	.3725	5.625
Moon, 6-68	10	28	40	2.5	.004	.006	1.531	.3723	6.046
Moore, 30G	....	....	....	....	.004	.005	1.75	.375	6.875
Nash, 681-2-3-4-5-6	15	38	45	10	.008	.008	1.5937	.372	5.625
National Sextet, BB	7	55	52	7	.003	.003	1.7812	.371	5.8125
Nelson, D	10	30	45	5	.005	.005	1.25	.3125	5.375
Noma, 1B	....	....	....	....	....	....	....	....	....
Norwalk, A 30 K	....	....	....	....	....	....	....	....	....
Oakland, 34-C	17.5	36	42.5	7.5	.008	.008	1.125	.3125	4.875
Ogren, 6-30	10	40	50	4	.004	.006	1.6875	.375	3.5
Oldsmobile, 45-B	15	38	45	10	.006	.008	1.4375	.309	4.633
Oldsmobile, 37-A	17.5	38	42.5	7.5	.010	.010	1.2812	.309	4.890
Olympian, 45	4	51	45	....	.003	.003	1,75	.374	5.25
Overland, 4	97	2.83	3.64	.81	.004	.004	....	....	....
Owen Magnetic, 60	....	....	....	....	....	....	....	....	....
Packard, 335	9	42	47	4	.004	.004	1.6562	.3405	6.7812
Paige, 6-42	15	50	45	10	.003	.003	1.4375	.3115	7.
Paige, 6-55	15	50	45	10	.003	.004	1.551	.3723	6.125
Pan, A	....	41	50	2	.005	.003	1.75	.375	4.375
Paterson, 6-47	12	45	55	12	.004	.004	1.625	.375	5.25
Peerless, 57	22	70	70	22	.008	.008	1.5625	.371	5.5
Piedmont, 6-30	....	....	....	....	....	....	....	....	....
Piedmont, 6-40	....	33	67	....	.004	.004	1.375	.3125	4.75
Pierce-Arrow, 31	5	45	45	5	.003	.003	1.620	.406	7.3745
Pierce-Arrow, 51	5	45	45	5	....	....	....	....	....
Pilot, 6-45	10	30	45	10	.004	.006	1.5625	.3725	6.937
Porter, 45	....	....	....	....	.002	.004	1.8125	.374	6.656
Premier, 6-D	15	38	45	10	.0135	.0135	1.5	.372	5.1875
R. & V. Knight, R	18	50	50	5	....	....	....	....	....
R. & V. Knight, J	15	40	50	6	Sleeve Vl.	Sleeve Vl.	Sleeve Vl.	Sleeve Vl.	Sleeve Vl.
Reo, T-6	17	45	54	10	.002	.002	2.125	.4375 .375	4.1562 6.125
Revere, C	7	57	50	11	.004	.004	2.187	.437	5,781
Roamer, C-6-56	....	....	....	....	....	....	....	....	....
Roamer, D-4-75	....	....	....	....	....	....	....	....	....
Saxon, 125	....	....	....	....	....	....	....	....	....
Sayers, SP	12	45	55	12	.003	.004	1.5	.310	4.656
Scripps-Booth, B	17½	38	42½	7.5	.008	.008	1.125	.310	4.937
Seneca, L 20	10	24	45	5	.004	.006	1.625	.3125	5.
Severin	10	28	40	2.5	.004	.006	1.531	.3723	6.046
Singer, 20	....	....	....	....	....	....	....	....	....
Skelton, 35	....	....	....	....	....	....	....	....	....
Spacke, S 20	6	53	42½	18½	.004	.006	1.625	.370	1.718
Standard, I	8	45	45	8	.005	.005	1.4375	.4375	7.
Stanley Steamer	....	....	....	....	....	....	....	....	....
Stearns, S K L 4	....	....	....	....	....	....	....	....	....
Stephens, 80	5	49	49	5	.003	.004	1.75	.3125	5.5
Studebaker, E J-40	....	....	....	....	....	....	....	....	....
Studebaker, E H-50	7-30	37-30	47	11	.008	.008	1.875	.375	6.125
Studebaker, E G-60	....	....	....	....	....	....	....	....	....
Stutz, H	....	....	....	....	....	....	....	....	....
Templar	1.18	4.24	5.88	1.18	.002	.003	1.75	.374	3.9375
Texan	5	37	47	10	.003	.004	1.875	.375	..
Tulsa, E-1	8	45	45	8	.003	.004	1.5625	.4375	8.25
Velie, 48	12	40	40	8	.004	.006	1.6	.3725	5.625
Velie, 34	....	....	....	....	....	....	....	....	..
Vogue, 655	....	....	....	....	....	....	....	....	....
Vogue, 666	....	....	....	....	....	....	....	....	....
Westcott, C-48	10	28	40	2-30	.002	.002	1.6875	.372	6.2343
Westcott, C-38	12	40	40	8	.003	.003	1.6718	.372	5.7656
Willys-Knight, 20	15	20	50	80	Sleeve Vl.	Sleeve Vl.	Sleeve Vl.	Sleeve Vl.	Sleeve Vl.
Winther, 61	8	45	45	8	.002	.004	1.75	.4375	6.375
Winton, 25	13	45	54	8	.006	.006	1.9375	.4375	8.5
Wasp	15	45	45	10	.004	.006	2.5	.4375	6.25

*American intake valve opens before upper dead center.

VALVE TIMING, VALVE CLEARANCE, AND VALVE DIMENSIONS 1919 CAR ENGINES[1]

	Intake		Exhaust		Valve Clearance		Valve Diameter	Valve Stems	
	Opens After Upper Dead Center	Closes After Lower Dead Center	Opens Before Bottom Dead Center	Closes After Top Dead Center	Install	Exhaust		Diameter	Length
Apperson 8-19	15	45	55	10	.343	.343	1.5625	.37375	6 5/16
Auburn 6-39-H	0	33	67	0	.003	.005	1.5625	.310	4 17/32
Auburn 6-39-K	0	33	67	0	.003	.005	1.5625	.310	4 17/32
Bour-Davis 18-B	10	28	40	2-30	—	—	—	—	—
Bour-Davis 20	0	33	67	0	—	—	—	—	—
Briscoe 4-24	13	35	45	8	.004	.004	1.625	.3720	5 31/32
Cadillac 57	0	46-40	46-40	0	.002-.003	.002-.003	1.6875	.375	7 1/8
Case U	10	28	40	0-38	.004	.004	1.53125	.375	6 3/64
Chalmers 35-C & 6-30	0	50	50	10	.003	.003	1.6875 1.5625	.3125	6 1/4
Champion KO	5	40	45	5	.003	.006	1.625	.375	—
Chevrolet 490	16	52	40	16	.002	.002	1.5	.309-.311	4 5/8
Chevrolet FB	1-30	54-30	44-30	11-30	.002	.002	1.5	.309-.311	4 5/8
Chevrolet D	0	56	46	10	.002	.002	1.5	.309-.311	4 5/8
Cole 870	15	38	45	10	.3437	.3437	1.5	.373	4 7/8
Columbia EFG	0	33	67	0	.004	.004	1.5625	.3125	4 5/8
Comet	12	32	34-6	4.93	.003	.004	—	1.6875	6 3/16
Crawford 9-N	10	28	40	†2-30	.003	.005	1.6875	.372	6 3/16
Crow-Elkhart K-36	5	37	47	10	.003	.004	1.5	.375	5 1/2
Davis 6-H	0	33	67	0	—	—	—	—	—
Davis 6-J	10	28	40	2-30	.003	.005	—	—	—
Dixie Flyer	‡8	45	45	8	.004	.004	1.75	.4375	6 9/32
Dodge	10	35	¶45	8	.004	.004	1.6875	.372	6 17/32
Dorris	10	45	45	10	—	—	1.84375	.4375	4 3/8
Dort 9	5	37-42	47-18	10	3	3	1.65625	.375	5 27/32
Elcar	5	37	47	10	—	—	1.5	—	—
Elcar	0	33	67	0	—	—	—	—	—
Elgin H	13	42	45	10	.282	.282	1.375	.3125	4 17/32
Essex A	7	42	55	8	4	6	1.875 1.715	.375	5 21/32 6
Ford	12-40	50-49	37-52	0	.025	.025	1.421875	.311	.4975
Franklin 9-B	†8	49	51-30	17	.010	.010	1.5	.338	4 7/8
Geronimo 6-A-45	15	50	45	10	.002	.003	1.3125	.3125	5 3/8
Glide 6-40	15	50	45	10	.002	.003	1.3125	.3125	5 3/8
Hanson	0	33	67	0	—	—	—	—	—
Haynes 45 & 46	5	35	47	2	—	—	1.5625	.4375	6 5/8
Haynes 46	5	35	47	2	—	—	1.375	.3125	4 5/8
Holmes I	15	33	50	15	.035	.035	1.25 1.875	.3125 .375	4 1/2 4 15/32
Hudson O	7	42	55	8	4	6	1.8125	.375	6 7/8
Hupmobile R	12	44	44	12	.003	.003	1.625	.375	5 11/16
Jones 28	10	28	40	2-30	.002	.003	1.6875	.375	5 7/8
Jordan F	10	28	40	2-30	.004	.004	1.6875	.372	5 43/64
Kissel	5	35	45	0	.004	.004	1.8125	.375	5 7/8
Klinekar 6-42-H	12	45	55	12	.004	.004	1.5625	.3125	5
Lexington 6-R	0	33	67	0	.004	.004	1.375	.310	5 1/8
Locomobile 38	0	*5/8	*3/4	1/8	—	—	2.5	.433	7 3/8
Locomobile 48	*3/32	*3/4	*3/4	0	—	—	2.125	.433	8 9/32
Maibohm B	13	42	45	10	.004	.006	1 25	.3125	4 3/8
Marmon 34	19	35	45	12	.003	.003	1.9375	.375	5 17/32
Maxwell 25	5	40	35	0	—	—	—	—	—
McFarlan X	10	40	55	5	*	*	—	—	—
Mercer	5	55	70	15	.003	.004	2.125	.370	9
Mitchell E-40 & E-42	10	35	41	4	.004	.004	1.5625	.375	6 1/16
Monitor M & O	0	33	67	0	—	—	—	—	—
National AL	10	28	40	2 1/2	.003	.003	1.53125	.372	6 1/8
National AM	6	43	42	2 1/2	.004	.004	1.4375	.356	5 1/8
Nelson D	15	35	45	10	.005	.005	1.25	.3125	5 1/4
Oakland 34-B	17 1/2	38	42-30	7-30	.3446	.3446	1.125	.3125	5
Oldsmobile 45-A	15	38	45	10	.004	.004	1.125	.309-.311	4 9/16
Oldsmobile 37-A	17-30	38	42-30	7-30	.008 .010	.008 .010	1.125	.309-.311	4 13/16
Olympian 45	0	62	65	5	.003	.012	1.5625	1.71875	6 11/16
Overland 90 & 90-B	5	38	46	15	.012	.003	1.75	.3735	5 1/4
Owen Magnetic W-42	5	50	45	0	.005	.005	1.8125	.434	5.078
Packard	9	42-30	47-30	4	.0025	.004	1.65625	.359	6 41/64
Paterson	12	45	55	12	—	—	1.5625	.3125	4 3/4
Peerless 56	†22	70	70	22	—	—	1.75	.371	6 9/32
Phianna R	0	45	55	20	.004	.004	1.8125	.372	8
Pilot 6-45	10	50	45	5	.004	.004	1.5625	.372	6 15/16
Premier 6-C	15	38	45	10	.0135	.0135	1.5	.372	5 3/16
Revere	7	11	50	7	.362	.362	2.25	.4375	5 25/32
Roamer C-6-54	10	28	40	2-30	.003	.005	1.6875	.372	6 3/16
Sayers B	12	45	55	12	.003	.004	1.5625	.310	4 21/32
Scripps-Booth	17-30	38	42-30	17-30	—	—	1.2825	.309 .311	4 7/16
Seneca H	10	24	45	5	.004	.006	1.625	.3125	5 1/16
Standard H	8	45	45	8	.003	.003	1.625	.435	6 1/4
Stephens 80	5	49	49	12	—	—	—	.3125	5 3/8
Templar	10	36	50	10	.003	.005	1.75	.375	4 1/4
Tulsa	5	37-42	47-18	10	.003	.003	1.5	.374	5 1/2
Velie 38	0	33	67	0	.025	.025	1.375	.310	5 5/32
Velie 39	10	28	40	2-30	.025	.025	1.53125	.372	6 15/64
Westcott A-38	0	33	67	0	.250	.250	1.375	.310	5 1/8
Westcott A-48	10	28	40	2-30	.3055	.337	1.59375	.372	6 15/64
Winton 24	21	45	54	12	8	8	2.4375 2,1875	.498	8 15/16
Willys-Knight 88-4	8	37	48	5					
Willys-Knight 88-8	15	40	50	8					
Willys Six 89	10	28	40	2-30	.002	.002	1.546	1.6875	6 3/16

ECIFICATIONS FOR REPLACEMENTS, ACCESSORIES, INTERCHANGEABLE PARTS, EQUIPMENT, AND STOCK GOODS ON 1923 PASSENGER CARS—See Pages 1058–1063 FOR GENERAL SPECIFICATIONS OF 1923 PASSENGER CARS.

The specifications on pages 1055 to 1063 are from "Automobile Trade Journal" (Chilton Co., Philadelphia) by permission

Name and Model	ENGINE						CHASSIS															BATTERY				LENS	LAMP BULBS											
	Piston Rings*		Piston Pin Diameter	Spark Plug Size	Carbureter		Exhaust Pipe Size	Upper Hose		Lower Hose		Fan Belt		Tubing Outer Diam. Copper		Brake Lining Service			Brake Lining Emergency			Make	Type	Voltage	Amp. H.	Head-light	Head			Dim			Dash			Tail		
	No. per Cyl.	Width			Outlet Diameter	Vertical or Horizontal		Length	Inner Diam	Length	Inner Diam.	Length	Width	Gas	Oil	Length	Width	Thickness	Length	Width	Thickness					Diameter	C. P.	Voltage	Contact	C. P.	Voltage	Contact	C. P.	Voltage	Contact	C. P.	Voltage	Contact
e L.	3	¼	⅞	⅞	1¼	H	2¼	12½	1½	14	1½	34	1⅛	¼	¼	40	2¼	3/16	32	2	3/16	USL	HDN311X	6	100	9¼	21	6	S	..	..	...	2	6	D	2	6	S
e F.	3	¼	1	⅞	1	H	2	8	2½	16	2½	34	1⅛	¼	¼	40	2¼	3/16	36	2	3/16	USL	HDN311X	6	100	9¼	21	6	S	..	..	...	2	6	D	2	6	S
nerican D–66	3	3/16	⅞	⅞	1½	H	2¼	17	1½	7	1¼	33¾	1	5/16	¼	43	2	3/16	42	2	3/16	W	SJR 15	7	96	8⅞	21	7	S	4	5	S	2	7	D	2	7	S
nderson 50	3	3/16	11/16	⅞	1¼	V	2⅛	10	1¼	9½	1¼	32⅞	1¼	5/16	5/16	43½	2	3/16	41⅞	2	3/32	W	SJRN 4	6	111	8¾	21	7	S	..	..	...	2	7	S	2	7	S
nderson 41	3	3/16	47/64	⅞	1	V	2	13½	1½	3	1¼	38	1	5/16	5/16	37	2	3/16	22	2	3/32	W	SJRN 4	6	111	9	21	7	S	..	..	...	2	7	S	2	7	S
pperson 8–22 & 23	3	3/16	11/16	⅞	1 1/16	V	1¾	12	3	16¾	2	40	⅝	5/16	5/16	48½	2¼	3/16	44¾	2	3/16	E	3XC	6	104	9⅝	18	6	S	4	6	S	2	6	D	2	6	S
uburn 6–63	3	3/32	⅞	⅞	1¼	V	2¼	4¾	1½	6	1¼	35¾	⅝	5/16	¼	44¼	2	3/32	21¼	2	3/16	E	3XC15	6	105	......	21	6	S	2	6	S	2	6	S	2	6	S
uburn 643–	3	3/16	⅞	⅞	1	V	2	12¾	1½	5	1¼	40¼	1	5/16	¼	36⅜	2	5/32	21¼	2	3/32	E	3XC13	6	90	8	21	6	S	2	6	S	2	6	S	2	6	S
arley 6–50	...	....	....	⅞	1	V	2	11	1½	9½	1¼	39⅝	1	5/16	5/16	....	...	..	....	...	..	P	611SHC	6	.....	......	21	6	S	4	6	...	2	6	D	2	6	S
ay State 1	3	3/16	⅞	⅞	1 1/16	V	2¼	5	1¼	7½	1¼	30	1¼	5/16	¼	49	2½	5/32	47	2¼	5/32	E	3XC15–1	6	105	9⅛	21	6	S	2	6	S	2	6	S	2	6	S
ddle B1–B5	3	3/16	1 1/16	⅞	.....	H	2¼	4½	2⅛	5	1⅜	36	1	¼	....	44	2	⅛	17	2	⅛	W	SJRN–4	6	.....	9⅜	17	6	D	5	6	D	2	6	S	2	6	D
our-Davis 21–S	3	3/16	1 3/16	⅞	1⅞	H	2¼	9¾	1½	8½	1¼	37	1¼	5/16	¼	45	2	3/16	43	2	3/16	W	....	6	115	9⅜	21	6	S	4	6	S	4	6	S	2	6	S
rewster 91	4	⅛	1¼	⅞	1¾	V	2¾	....	1 1/32	9	1 1/32	....	...	¼	¼	18	2	¼	11½	1¾	3/16	USL	....	12	80	......	21	12	D	5	12	D	5	6	D	5	6	D
uick 44–50	3	3/16	21/32	⅞	1¼	H	1¾	8	1¼	15	1¼	29⅞	1¼	5/16	....	40	2	3/16	....	1¾	3/16	E	....	6	80	8½	21	6	S	4	6	S	2	6	S	2	6	S
adillac 61	3	3/16	¾	⅞	2	H	1¾	8	1¼	4⅞	1¼	....	...	¼	.31	54	2½	3/16	51	2½	3/16	E	3 LXRV-15-2	6	130	9¼	21	6	S	..	..	...	2	4	S	2	4	S
ase X	3	3/16	⅞	⅞	1¼	V	2¼	5	1¼	10¾	1¼	32½	1⅛	5/16	¼	48	2½	5/32	46⅝	2¼	5/32	W	SJRG–4	6	118	8½	21	6	S	4	6	S	2	6	S	2	6	S
ase W	3	3/16	1⅛	⅞	1½	V	2½	5	1¼	9	1¼	44 5/16	9/16	5/16	5/16	48	2½	5/32	46⅝	2¼	5/32	W	SJRG–5	6	133	9⅜	21	6	S	4	6	S	2	6	S	2	6	S
halmers 1922	3	⅛	11/16	⅞	1¼	V	2⅜	5¼	2½	....	2¼	37¾	1¾	¼	⅜	43½	2	3/16	41¾	1½	3/16	USL	CDX313X	6	106	8⅝	21	6	S	..	..	...	2	6	S	2	6	S
handler 6	3	⅛	21/32	⅞	1¼	V	2¼	6⅝	1⅜	7¾	1⅜	35 11/16	⅝	5/16	¼	45½	2	3/16	23¾	1¾	5/32	P	613RHN	6	105	8¾	21	6	S	4	6	S	2	6	S	2	6	S
hevrolet Superior	3	3/16	.849	⅞	1	V	2⅛	9½	1¼	4	1¼	29¾	21/32	5/16	....	27½	1¼	5/32	26½	1¾	5/32	W	XW–13	6	90	7¾	21	6	S	..	..	...	2	6	S	2	6	S
leveland 6–42	3	3/16	27/32	⅞	1	H	2	3½	1¼	6½	1¼	42	⅝	5/16	¼	41	2	5/32	22	1½	5/32	P	611RHN	6	94	8½	21	6	S	4	6	S	2	6	S	2	6	S
ole 890	4	3/16	⅞	⅞	1½	V	2⅝	22½	1½	3¾	1½	44	¾	5/16	5/16	48	2½	5/32	46⅝	2¼	5/32	W	SJRN 5	6	125	9½	21	7	S	4	6	S	4	6	S	4	6	S
olumbia Six	3	⅛	.750	⅞	1	V	2	12½	1½	3⅜	1¼	40½	1	5/16	⅜	20⅝	1¾	3/16	22¼	2	3/16	USL	CDX313X	6	106	8	15	6	S	..	..	...	2	6	D	2	6	S
olumbia Elite	3	3/16	.859	⅞	1¼	V	2¼	3⅜	1¼	13	1¼	32	1¼	5/16	⅜	20 3/16	1¾	3/16	42½	1½	3/16	P	611RHN	6	80	8⅝	15	6	S	4	6	S	2	6	D	2	6	S
omet C–53–2	4	3/16	1⅛	⅞	1¼	V	1¼	7¼	1½	10½	1½	41½	¾	3/16	3/16	44½	2	3/16	41	2	3/16	W	2JRN4	6	100	10	20	6	...	6	6	S	6	6	S	2	6	S
ourier	3	⅛	.74	⅞	1	H	2	9	2¼	11	2¼	42	1	5/16	¼	43⅞	2	5/32	39	1¾	5/32	USL	HDX311	6	94	8⅛	21	6	S	2	6	S	2	6	S	2	6	S
rawford 23–6–70	3	3/16	....	⅞	1¾	V	2½	6	1⅛	10	1⅛	46	⅝	¼	¼	42	2 3/16	3/16	36	2	3/16	W	SJRG 4	6	115	9¼	15	6	S	4	6	S	2	6	D	2	6	S
unningham V–4	3	3/16	....	⅞	1½	V	2¼	....	...	....	...	.....	...	5/16	5/16	54	2½	3/16	54	2½	3/16	W	SJRN 5	6	110	11	21	6	S	4	6	S	2	6	S	2	6	S
agmar 23–6–70	3	3/16	....	⅞	1¾	V	2½	6	1⅛	10	1⅛	46	⅝	¼	¼	42	2 3/16	3/16	36	2	3/16	W	SJRG4	6	115	10	15	6	S	4	6	S	2	6	D	2	6	S
aniels 8–D	3	3/16	11/16	⅞	......	V	1⅞	6	1¾	8⅝	1¾	43½	¾	5/16	5/16	50⅛	2½	3/16	46 3/16	2½	3/16	W	SJRN5	7	140	9	21	6	S	4	6	S	2	6	D	2	6	S
odge Brothers	4	⅛	11/16	⅞	1⅛	V	2	9	1½	7¼	1 3/16	34½	1	¼	⅜	19¼	2¼	3/16	14⅜	1¾	3/16	W	SJR26	12	50	8⅜	21	12	...	..	..	S	2	12	S	2	12	S
orris 6–80	3	¼	1 1/32	⅞	1½	V	2½	2¼	1½	6¼	1¼	41 1/16	1¼	¼	⅜	47½	2½	3/16	46½	2½	3/16	W	SJRG–5	6	139	9½	21	6	S	4	6	S	2	6	S	2	6	S
ort 18 and 23	3	3/16	⅞	⅞	1	H	2¼	6	2¼	14¼	2¼	32½	1	Opt	¼	35½	1¾	5/32	36	1¾	5/32	U	HDN311X	6	94	8⅛	21	6	S	..	..	...	2	6	S	4	6	S
ort 20 and 25	3	⅛	¾	⅞	1	H	2	8½	2¼	12	2¼	42	1¼	¼	¼	35½	1¾	5/32	36	1¾	5/32	U	HDN311X	6	94	8⅛	21	6	S	..	..	...	2	6	S	4	6	S
uesenberg S	4	⅛	¾	M	1½	V	2⅜	8	1½	....	1½	....	39/64	⅜	5/16	58½	2¼	¼	14	2¼	¼	W	SJR5	6	125	9½	21	6	S	4	6	S	2	6	S	2	6	S
uPont C	3	3/16	⅞	⅞	.....	H	2	5¾	1½	4¾	1½	40	1	5/16	⅝	47¼	2½	3/16	47¼	2¼	3/16	E	3XC15-3-1	6	105	9½	21	6	S	4	6	S	2	6	S	2	6	S

* See footnote on page 1057.

[Continued on next page.]

REPLACEMENT TABLE—*Continued*

Name and Model	ENGINE						CHASSIS															BATTERY				LENS	LAMP BULBS											
	Piston Rings*				Carburetor			Upper Hose		Lower Hose		Fan Belt		Tubing Outer Diam. Copper		Brake Lining Service			Brake Lining Emergency							Head-light	Head			Dim			Dash			Tail		
	No. per Cyl.	Width	Piston Pin Diameter	Spark Plug Size	Outlet Diameter	Vertical or Horizontal	Exhaust Pipe Size	Length	Inner Diam.	Length	Inner Diam.	Length	Width	Gas	Oil	Length	Width	Thickness	Length	Width	Thickness	Make	Type	Voltage	Amp. H.	Diameter	C. P.	Voltage	Contact	C. P.	Voltage	Contact	C. P.	Voltage	Contact	C. P.	Voltage	Contact
Earl 40	3	.188	1	⅞	1	H	1¾	5	1 11/16	5	1 11/16	34¼	1	¼	5/16	40¾	2	9/64	21½	2	9/64	USL	CDN313X	6	106	8¾	21	6	S	..	..	...	2	6	D	2	6	S
Elcar 4 cyl.	3	3/16	1⅛	⅞	1	V	2¼	10	2¼	21	2¼	35 11/16	1¼	5/16	¼	35	2	3/16	24	2	3/16	W	....	6	90	11	15	7	S	4	7	S	2	7	S	2	7	S
Elcar 6 cyl.	3	⅛	⅞	⅞	1¼	V	2¼	6½	1¼	12½	1¼	33½	1¼	3/16	¼	43½	2	3/16	42	2	3/16	W	....	6	90	11	15	7	S	4	7	S	2	7	S	2	7	S
Elgin K-1	3	3/16	¾	⅞	1	H	2	7½	1⅞	15⅝	1⅞	39	⅞	5/16	¼	43⅞	2	5/32	39	1¾	5/32	USL	HDX313X	6	90	9¼	21	6	S	4	6	S	2	6	S	2	6	S
Essex A	3	⅛	.874	M	1 1/16	H	1¾	4	2½	14½	2¼	41½	1	5/16	5/16	40	1¾	3/16	42½	1½	3/16	E	3DX13-1	7	90	8⅛	21	6	S	..	..	...	2	3	S	2	3	S
Flint	3	3/16	⅞	⅞	1¼	V	2¼	8	1½	12¼	1¼	12⅝	⅝	5/16	⅜	42⅜	2	5/32	40⅞	1¾	5/32	USL	CDN313X	6	117	9½	21	6	S	2	6	S	2	6	D	2	6	S
Ford T	3	¼	.740	½	1⅛	H	...	4	2	2¾	1¾	27	1⅛	¼	⅜	23⅜	1⅛	3/16	....	...	..	E	3XC-13	6	80	8⅛	21	6	D	2	6	D	..	...	...	2	6	S
Fox	3	....	⅞	....	1¼	V	2¾	....	...	....	...	....	...	5/16	¼	48	2½	⅛	42	2½	⅛	E	3XC17-1	6	120	......	21	6	S	4	6	S	2	6	D	4	6	S
Franklin Series 10	3	3/16	⅞	⅞	1	V	1½	....	...	....	...	....	...	¼	¼	23⅞	3½	3/16	28	2⅝	5/32	W	SJR 5	6	136	9	21	6	S	4	6	S	2	3	S	2	3	S
Gardner Series 5	4	⅛	1⅛	⅞	1	V	2¼	8¼	2¼	15	2¼	36	1¼	¼	¼	34	1¾	5/32	20¾	1¾	5/32	W	SW 4	6	94	8⅛	21	6	S	..	..	...	2	6	S	2	6	S
Grant 6-HX	4	⅛	⅞	⅞	1	V	2	8	2¼	4⅞	2¼	41½	1¼	5/16	¼	38⅝	1¾	5/32	34	1¾	5/32	P	RHN613	6	105	9	21	6	S	4	6	S	2	6	S	2	6	S
Gray N	3	3/16	.740	⅞	1⅛	H	1¾	9	2¼	2¾	1¾	34¼	1	¼	½	28	1¼	5/32	19½	1¼	⅛	USL	CDX311X	6	84	8⅛	21	6	S	..	..	S	2	6	S	2	6	S
Hanson 66	3	3/16	....	⅞	1¼	V	2¼	9½	1¼	12½	1¼	30	1¼	5/16	¼	41	1¾	3/16	41	2	3/32	P	613RHN	6	100	11	21	6	S	16	6	S	2	6	S	2	6	S
Haynes 57	4	⅛	1⅛	⅞	1¼	H	2⅜	14¼	1¼	12½	1½	34½	¾	5/16	5/16	42	2½	3/16	25¼	2½	3/16	P	615SHC	6	125	8½	21	6	S	..	..	...	2	6	S	2	6	S
Haynes 77	4	⅛	1⅛	⅞	1½	V	2½	8⅞	1¼	10¾	1½	32	⅝	5/16	5/16	49	2½	3/16	47⅜	2¼	3/16	P	615SHC	6	125	9½	21	6	S	5	6	S	2	6	S	2	6	S
Holmes	2	3/16	⅞	⅞	1	V	2	....	..	....	...	....	...	5/16	¼	28⅞	3	¼	40½	2½	¼	W	SJR 27	12	70	9¼	21	12	S	4	12	S	2	12	D	2	12	D
Hudson O	3	⅛	1.093	M	1¾	H	2¼	7	1½	5¾	1½	34⅞	1	5/16	5/16	40	2½	3/16	40	2½	3/16	E	3XC15-1	7	105	9	21	6	S	..	..	...	2	3	S	2	3	S
Huffman 6	3	3/16	⅞	⅞	1¼	H	2¼	14	1¼	14	1¼	30	¾	⅛	⅛	18	2	3/16	18	2	3/16	W	SJR 3	6	....	9½	16	6	S	8	6	S	4	6	S	8	6	S
Hupmobile R	4	⅛	⅞	⅞	1	V	1¾	5½	2½	9 1/16	2¼	24⅞	⅝	5/16	½	33⅛	2	5/32	13¾	1¾	⅛	W	SJRG 4	6	117½	8¼	21	6	S	..	...	...	2	6	S	2	6	S
Jordan MX & H	3	3/16	⅞	⅞	1¼	V	2¼	9½	1¼	12½	1¼	44½	9/16	5/16	¼	43¼	2	3/16	44	1¾	5/16	W	XR 15	6	113	8¾	21	6	S	4	6	S	2	6	S	2	6	S
Kelsey 1922	3	3/16	1	⅞	1	V	2	4	2⅜	18	2⅜	38	1¼	¼	¼	37⅜	2	3/16	24	2¾	3/16	E	3XC15-3-1	6	105	8½	20	6	S	2	6	S	2	6	S	2	6	S
Kelsey Gear 1922	3	3/16	1	⅞	1	V	2	4	2⅜	18	2⅜	38	1¼	¼	¼	36	1¾	3/16	31	1¾	3/16	E	3XC15-3-1	6	105	8½	20	6	S	2	6	S	2	6	S	2	6	S
Kelsey Gear 1923	4	⅛	1⅛	⅞	1	V	2	7½	2⅜	17	2⅜	36	1¼	¼	¼	36⅜	2	3/16	22⅞	2	3/16	W	6C 13	6	105	8½	20	6	S	2	6	S	2	6	S	2	6	S
King 8-K	2	3/16	⅞	⅞	1¼	V	2 1/16	6	2¼	3⅜	1¾	30	1 3/16	5/16	¼	48	2½	5/32	46⅝	2¼	5/32	P	615WHN	6	120	8½	15	7	S	5	7	S	2	7	S	2	7	S
Kissel Custom 45	3	3/16	11/16	⅞	1¼	H	2¾	8⅝	1¼	10 11/16	1¾	34 9/16	...	5/16	3/16	43½	2	3/16	43½	2	3/16	W	SJRN 5	6	139	8	21	6	S	12	6	S	2	6	D	2	6	S
Kissel 55	6	3/16	.938	⅞	1¼	H	2¼	....	1¾	....	1¾	34 9/16	⅞	5/16	5/16	45¼	2	3/16	42½	2	3/16	W	SJRN 4	6	117½	8¾	21	6	S	2	6	S	2	6	D	2	6	S
Kline 6-60-L	3	3/16	⅞	⅞	1¼	V	2¼	7½	1¼	16	1¼	35	1¼	5/16	¼	17	1¾	3/16	41	1¾	3/16	P	RHN	6	100	8¾	21	6	S	..	..	...	2	6	S	2	6	S
Kurtz	3	3/16	....	⅞	1¼	H	2¼	8	1½	11½	1¼	33	1	5/16	5/16	43½	2	3/16	42	2	5/32	P	613SHC	6	120	......	21	6	S	4	6	S	2	6	S	2	6	S
La Fayette	4	3/16	¾	⅞	2	V	1¾	6	1⅛	Opt	1¼	....	...	5/16	¼	54	2½	3/16	51 11/16	2½	3/16	E	3LXRV15-2	6	130	9⅛	21	6	S	4	6	S	2	3	S	2	3	S
Leach 999	3	3/16	1 5/32	⅞	1½	V	3	6½	1½	6½	1¼	....	...	5/16	¼	....	2½	3/16	....	2¼	5/32	P	617SC	6	180	8¾	21	6	S	5	6	S	5	6	S	2	6	S
Lexington 23	2	3/16	⅞	⅞	1½	H	2	6½	1¼	4½	1¼	42 11/16	9/16	5/16	¼	45	2	5/32	24¼	2	5/32	W	SJRN 4	6	100	9	21	6	S	..	..	...	4	6	D	2	6	S
Liberty Six 10-D	3	3/16	⅞	⅞	1	V	2	6	2¼	13½	2¼	40½	1¼	5/16	3/16	20 3/16	2	3/16	23 13/16	2½	3/16	P	613SHC	6	120	9	21	7	S	4	7	S	2	6	S	2	6	S
Lincoln	3	⅛	⅞	⅞	1½	V	2½	16¼	1¾	11¼	1¾	....	1	5/16	5/16	49¾	3	¼	46 9/16	2½	3/16	E	3LXPV-15	6	135	9¼	21	6	S	4	6	S	2	3	S	2	3	S
Locomobile 48, Ser. 8	3	¼	1⅛	⅞	1 11/16	V	2¾	2¾	1⅜	5	1⅜	54⅛	¾	⅛	½	97¼	3	3/16	58	2½	3/16	W	12-C-11	12	85	9¾	21	12	S	2	12	S	2	12	S	2	12	S
McFarlan Six	3	3/16	1¼	⅞	1¾	V	3	3½	2	9¾	1¼	41	¾	5/16	⅜	50⅞	2½	7/32	46⅜	2½	3/16	W	SJR 5	6	135	9	21	6	S	6	6	S	2	6	D	2	6	S
Marmon 34	3	3/16	1 3/16	⅞	1½	V	2½	3⅞	1¼	3⅞	1¼	42	9/16	⅜	⅜	54	2	3/16	47⅛	1½	3/16	P	617SHC	6	162	9½	21	8	S	4	8	S	2	8	S	2	8	S
Maxwell	3	⅛	¾	⅞	1	V	...	7¾	3½	7¾	2⅛	36½	⅝	¼	5/16	31	1½	5/32	19¾	1¾	3/16	U	CDX313X	6	106	8⅞	21	6	S	5	7	S	2	7	S	2	7	S

Mercer, Series 5	3	3/16	1	⅞	1½	V	3	6	1⅞	15	1⅛	32½	1	5/16	5/16	24	2½	3/16	17⅜	2½	3/16	P	617SHC	6	149	9¼	20	6	S	5	6	S	2	6	S	5	6	S
Metropolitan	3	3/16	¾	½	1	H	1½	....	...	....	...	36	1	5/16	¼	37	2	3/16	40	2	3/16	E	3XC-11-1	6	80	9	15	6	S	4	6	S	4	6	S	4	6	S
Mitchell F-50	4	3/16	43/64	⅞	1¼	V	2⅝	5⅜	1½	7¾	1⅛	33½	1¼	¼	5/16	40¾	2	3/16	40	1½	3/16	W	SJRN 4	6	117½	Opt	21	6	S	4	6	S	2	6	D	2	6	S
Monroe	3	3/16	1	⅞	1¼	H	1¾	5	2	15	1¾	44¼	1¾	5/16	3/16	34 7/16	2	5/32	31 3/16	1¾	5/32	USL	CDX313X	6	84	8¾	16	8	S	4	8	S	2	8	D	2	8	S
Moon 6-40	3	3/16	⅞	⅞	1	V	2	14	1½	4	1¼	39	1	5/16	¼	41	1¾	3/16	24	1½	3/16	E	3XC-13-1	6	85	8½	21	6	S	4	6	S	4	6	S	4	6	S
Moon 6-58	3	3/16	⅞	⅞	1¼	V	2¼	10	1¼	12	1¼	31	1¼	5/16	¼	41	1¾	3/16	41	1½	3/16	E	3XC-15-1	6	110	9	21	6	S	4	6	S	4	6	S	4	6	S
Nash 691	6	3/16	11/16	⅞	1¼	V	2	4½	1½	4	1¼	42¾	¾	5/16	5/16	48¾	2½	5/32	18 11/16	2½	3/16	W	SJRN 4	6	111	8¾	21	7	S	4	7	S	2	7	S	2	7	S
National 4	3	3/16	⅞	⅞	1	H	2⅜	14	2	17	2	33	⅞	5/16	5/16	38	2	3/16	42	2	3/16	W	SJR 3	6	90	8⅝	21	7	D	..	..	...	2	3½	D	2	3½	D
National 6-71	3	3/16	1 5/32	⅞	1½	V	2½	....	1½	13	1½	38	1¼	5/16	¼	48	2½	5/32	46⅜	2¼	5/32	P	615RHN	6	125	9¼	21	6	S	4	6	S	2	3	D	2	3	S
Noma A-B-C	3	3/16	1	⅞	......	...	...	10½	1⅜	10	1⅜	35	¾	⅜	⅝	45	2¼	3/16	43	2¼	3/16	W	....	6	120	.....	15	6	S	4	6	S	4	6	S	4	6	S
Oakland 6-44	3	3/16	41/64	⅞	1¼	V	2¼	16¼	1¼	3⅞	1	30 15/16	41/64	¼	5/16	38¼	1⅞	5/32	35½	1⅝	5/32	P	RH 613	6	100	8⅝	21	7	S	..	..	...	2	7	S	2	7	S
Oldsmobile 43-A	3	3/16	.85	⅞	1 3/16	V	2	6¼	1¼	10½	1¼	40½	¾	⅜	⅜	34¾	1⅞	5/32	35⅛	1⅝	5/32	W	SR 4	6	80	8½	15	6	S	4	6	S	2	6	S	2	6	S
Oldsmobile 46	3	3/16	⅔	⅞	1¼	V	1¾	....	...	....	...	.....	...	⅜	⅜	43 1/16	1⅞	..	40 15/16	1⅝	5/32	W	SR 4	6	80	7	15	6	S	4	6	S	2	6	D	2	6	S
Oldsmobile 47	3	3/16	⅔	⅞	1¼	V	1¾	12½	1¼	3½	1 1/16	44½	¾	⅜	⅜	34¾	1⅞	..	35⅛	1⅝	5/32	W	SR 4	6	80	8½	15	6	S	4	6	S	2	6	S	2	6	S
Overland 91	3	3/16	....	½	.....	H	2	....	...	....	...	.....	...	.....	.....	.....	...	..	.....	...	..	USL	CDN311X	6	80	8⅛	21	6	S	..	..	...	2	3	S	2	3	S
Packard Single Six	4	⅛	¾	⅞	1 3/16	V	2¼	4¾	1½	6¼	1½	33¾	⅝	5/16	¼	41¼	2	¼	39 9/32	1¾	3/16	P	613-SHC	6	100	8½	21	6	S	4	6	S	2	6	S	2	6	S
Packard Single Eight	3	⅛	⅞	⅞	1⅞	V	2¼	4¾	1½	6¼	1½	34 15/16	⅝	5/16	¼	16 9/32	2	¼	16 9/32	2	¼	P	613SHC	6	100	.....	32	6	S	2	6	S	2	6	S	2	6	S
Packard Twin Six	3	3/16	¾	⅞	1¾	V	2¼	8 1/16	1½	8	1⅝	45	¾	⅜	¼	53 1/16	2½	¼	42 5/16	2	3/16	W	SMR 7	6	120	8½	21	6	S	6	6	S	2	6	S	2	6	S
Paterson 23-6-52	3	3/16	⅞	⅞	1¼	V	2¼	12	1¼	14	1¼	32	1⅛	¼	⅜	42	2	3/16	17	2	3/16	W	SJRN 3	6	80	8½	32	6	S	3	6	...	4	3	D	4	3	D
Peerless 66-Type 23	3	3/16	⅞	⅞	1⅛	V	1⅞	7	1½	10	1¾	.....	...	⅜	5/16	42¾	2½	3/16	44	2½	3/16	E	3XXV	6	120	8	21	6	S	4	6	S	2	3	S	2	6	S
Pierce Arrow 33	3	3/16	1 1/16	⅞	2	V	2⅞	3	2	14¼	1½	42⅛	⅝	⅜	....	51⅛	3¼	3/16	33⅝	2¾	3/16	W	SJRN 6	6	162	.....	21	6	S	4	6	S	4	6	S	4	6	S
Pilot 6-45	4	3/16	1	⅞	1	H	2¼	10	1½	6½	1	32	¾	5/16	3/16	44½	2	5/32	41½	1¾	5/32	P	RHN611	6	86	8¾	21	6	S	..	..	...	2	6	D	2	6	S
Pilot 6-50	3	3/16	⅞	⅞	1¼	H	2¼	9¼	1½	6¼	1¼	33	1¼	5/16	3/16	44½	2	5/32	41½	1¾	5/32	P	RHN613	6	110	9	21	6	S	4	6	S	2	6	D	2	6	S
Pilot 6-56	3	3/16	⅞	⅞	1¼	H	2¼	4	1½	....	1¼	33	1¼	5/16	3/16	55	2	5/32	49	1¾	5/32	P	RHN613	6	110	9	21	6	S	4	6	S	2	6	D	4	6	S
Premier 6-D	3	3/16	55/64	⅞	1½	V	2	5¾	1¼	8¾	1¼	40½	¾	5/16	⅜	50½	2½	3/16	46¼	2½	3/16	P	613SHC	6	123½	9¾	21	6	S	4	6	S	2	6	D	4	6	S
Reo T-6	3	187	.984	½	.....	V	2½	12	1½	8¾	1¼	.....	...	¼	¼	43	2½	3/16	40 7/16	2½	3/16	W	SJRN 4	6	111	9	21	8	S	..	..	...	2	8	S	2	8	S
Re Vere Series C. D.	3	¼	1¼	⅞	.....	V	3	8	1¼	7	1¼	31	1¼	5/16	5/32	48	2¼	¼	52	2¼	¼	P	SHG 2	6	36½	8	16	6	D	8	6	D	3	6	D	3	6	S
Rickenbacker	3	3/16	¾	⅞	1 3/16	V	2¼	9¾	1	14¾	1	31 1/32	9/16	5/16	¼	42 11/16	2	5/32	22½	2	5/32	P	613RHN	6	108	9	21	6	S	5	6	S	2	6	S	2	6	S
Roamer 4-75-E	3	3/16	....	⅞	2	V	2½	8	1½	16	1½	32	1¼	5/16	⅜	49½	2¼	3/16	41	2¼	3/16	P	613SHC	6	117	8⅞	21	6	S	4	6	S	2	6	D	2	6	S
Roamer 6-54-E	3	3/16	1 5/32	⅞	1¼	H	2¼	10	1½	13	1¼	37½	⅜	5/16	5/32	49½	2¼	3/16	41	2¼	3/16	P	613SHC	6	117	8⅞	21	6	S	4	6	S	4	6	D	4	6	S
R & V Knight H	2	5/16	1	⅞	1¼	H	2½	10 5/16	2½	19	2¼	34¾	⅝	5/16	⅜	43¼	2½	3/16	41¾	2½	3/16	W	SJR 6	6	153	9	21	6	S	4	6	S	2	6	D	2	6	S
Rubay	3	⅛	25/32	⅞	1 25/32	V	1¾	3	1	3	1	36	⅝	5/16	5/16	12	1¾	3/16	12	1¾	3/16	E	....	6	100	8	21	6	S	4	6	S	2	6	S	2	6	S
Sayers	3	3/16	⅞	⅞	1¼	V	2¼	12	1¼	12	1¼	34½	1¼	¼	¼	42 9/16	2	3/16	34½	2	3/16	W	SJR 3	6	80	8¾	21	6	S	..	..	...	2	6	D	2	6	S
Seneca L-2	3	3/16	⅞	⅞	1	V	2¼	17	2¼	11	2¼	30¼	1	¼	5/16	36½	1¾	¼	34½	1¾	¼	P	RHN611	6	95	8⅝	15	6	S	2	6	S	2	6	D	2	6	S
Seneca 50 C.	3	3/16	1⅛	⅞	1	V	2¼	17	2¼	11	2¼	36¼	1¼	5/16	....	36½	1¾	¼	34½	1¾	¼	P	611RHN	6	95	8⅝	..	6	S	2	6	S	2	6-8	D	2	6-8	S
Standard 8, Model 98	3	⅛	⅞	⅞	1¼	V	1⅝	6½	1¼	6¼	1¾	.....	...	¼	....	21 11/16	2½	3/16	20	2½	3/16	W	SJR 6	6	160	8⅞	24	6	S	7	6	S	2	6	S	2	6	S
Star	3	⅛	.749	⅞	1	V	1¾	4⅝	1¼	3¾	1¼	37	1	¼	¼	31 5/16	1½	5/32	28 9/16	1½	5/32	USL	CDX311	6	80	8½	21	6	S	..	..	...	2	6	S	2	6	S
Stearns SKL-4	4	3/16	21/32	⅞	1¼	V	2¼	6⅝	1⅜	9	1⅜	36¾	1	5/16	¼	46¾	2½	3/16	18½	1½	7/32	E	6XC13-1	12	90	9¼	21	12	S	2	2	S	2	2	S	2	12	S
Stearns 6	4	3/16	43/64	⅞	1¼	V	2½	6½	1⅜	9	1⅜	36¾	5/16	¼	¼	46	2½	3/16	18¼	1½	7/32	E	6XC13-1	12	90	9¼	21	12	S	4	12	S	2	12	S	2	12	S
Stephens 6, Model 10.	3	3/16	1	⅞	1¼	H	2¼	11¾	2¼	11¾	2¼	34½	⅝	5/16	3/16	43¼	2	3/16	23¾	2½	5/32	U	HDX313X	6	116	9	21	6	S	4	6	S	2	6	S	2	6	S
Stephens 6, Model 20.	3	3/16	1	⅞	1¼	H	2¼	11¾	2¼	11¾	2¼	34½	⅝	5/16	3/16	43¼	2	5/16	23¾	2½	5/32	U	HDX313X	6	116	8½	21	6	S	4	6	S	2	6	S	2	6	S
Sterling	4	....	¾	⅞	1	V	1½	11	2¼	9	2¼	32	⅞	¾	5/16	54	2	¼	54	2	¼	W	....	6	90	9	21	16	S	..	8	D	12	8	S	12	8	S
Sterling 6	3	....	¾	⅞	1	V	1¾	14	2½	9	2¼	32	⅞	¼	5/16	54	2	¼	54	2	¼	W	....	6	110	9	21	6	S	..	8	D	12	8	S	12	8	S
Studebaker EL-6	4	3/16	1	½	1¼	V	2	10½	1½	8¾	1½	33¼	1⅛	¼	3/16	46¾	2	3/16	43¼	1¾	3/16	W	SJR 4	6	112	9½	21	6	S	..	..	S	2	6	S	2	6	S
Studebaker EK-6	4	3/16	1	½	1½	V	2	9½	1½	8¾	1½	33¼	1⅛	¼	3/16	46¾	2	3/16	43¼	1¾	3/16	W	SJR 4	6	112	9½	21	6	S	..	..	...	2	6	S	2	6	S
Studebaker EM-6	4	3/16	11/16	½	1	V	1¾	9½	1½	4	1½	25¾	¾	¼	3/16	43⅝	2	3/16	39⅞	1¾	3/16	W	SJRN 3	6	112	8½	21	6	S	..	..	...	2	6	S	2	6	S
Stutz KLDH	3	¼	1⅛	⅞	1½	V	3	8	2	2	1¼	36	⅞	⅜	¼	20⅜	2¼	5/32	16½	1¼	5/32	W	SJRN 5	6	125	9½	21	6	S	4	6	S	2	6	S	2	6	S
Velie 58	3	3/16	⅞	⅞	1	H	2	7	2¼	12¾	2¼	30½	1	5/16	¼	43⅞	2	5/32	39	1¾	5/32	W	SJR 3	6	100	9	21	6	S	4	6	S	2	6	S	2	6	S
Washington C.	3	3/16	⅞	⅞	1¼	V	2¼	7	1¼	10¾	1¼	32¾	1	5/16	¼	43⅞	2	5/32	39	1¾	5/32	E	3XC15-1	6	100	8¾	21	6	S	4	6	S	2	6	S	2	6	S
Westcott-44	3	3/16	55/64	⅞	1¼	V	2¼	7⅛	1¼	12	1¼	36	1¼	¼	¼	48	2½	3/16	22½	2	5/32	W	SJRN 4	7	117	8¾	21	6	S	4	6	S	2	3	D	2	3	S
Westcott-48	3	⅛	1 5/32	⅞	1¼	H	2¼	13	1½	2⅞	1¼	45	⅝	5/16	¼	44½	2½	3/16	40	2½	3/16	W	SJRN 4	7	117	8¾	21	6	S	4	6	S	2	3	D	2	3	S
Wills Sainte Claire	3	5/32	¾	⅞	1 5/32	V	1⅞	5¾	2¼	5½	2	.....	...	5/16	¼	41	2	3/16	38¾	1¾	5/32	W	SJRG 5	6	145	6	21	6	S	2	6	S	2	6	S	2	6	S
Willys-Knight 64	4	3/16	....	⅞	1¼	H	...	....	...	....	...	.....	...	.....	.....	.....	...	..	.....	...	..	USL	HDN317X	6	170	8½	21	6	S	2	6	S	2	3	S	2	3	S
Willys-Knight 67	4	3/16	....	⅞	1¼	H	...	....	...	....	...	.....	...	.....	.....	.....	...	..	.....	...	..	USL	HDN317X	6	170	8½	21	6	S	2	6	S	2	3	S	2	3	S
Winton	3	3/16	1	⅞	1½	V	2½	5¼	1½	22¼	1½	36 11/16	⅝	5/16	¼	50⅛	2½	3/16	46½	2½	3/16	W	SJRN	6	139	.....	21	6	S	6	6	S	2	6	S	2	6	S

* For piston diameters see Bore and Stroke Listings in Passenger Car Specification Table.

Q—Optional P—Prest-O-Lite A—Auto-Lite C—Columbia W—Willard U—Universal USL—USL E—Exide L—Cole Spark Plugs: M—Metric Ve—Vesta V—Varied

SPECIFICATIONS OF 1923 PASSENGER CARS

(From Automobile Trade Journal)

Line Number	Model Number and Trade Name	ENGINE											
		Engine Make and Model	Bore and Stroke	Piston Displacement	N.A.C.C. Rated Horsepower	Cylinder Cast, 2, 3, 4 or 6, Head Int. or Det.	Valve Arrangement	Camshaft Drive	How Cooled	Radiator	Lubrication	Fuel Feed and Capacity	Carburetor
Column Numbers, Key of Abbreviations		1					2	3	4	5	6	7	8
4 Cylinder Gasoline Passenger Cars													
1	Ace F.	Gra	3½x5	192.42	19.6	4 D	I	H	T	Own	F	V-18	Sco
2	Biddle B-1	Bud	3¾x5⅛	225.9	22.5	4 I	L	H	T	....	S	V-20	Zen
3	Biddle B-5	Bud	3¾x5⅛	225.9	22.5	4 I	L	H	T	....	S	V-20	Zen
4	Brewster 91	Own 41-91-02	4 x5½	276.46	25.6	4 I	S	C	P	E&M	F	V	Str
5	Buick 4	Own	3⅜x4¾	169.96	18.2	4 D	I	H	P	Own	B	V-10	Mar
6	Chevrolet Copper-Cooled	Own	3½x3½	134.69	19.6	1 I	I	H	A	....	F	V-10	Car
7	Chevrolet "Superior"	Own	3 11/16x4	170.14	21.7	4 D	I	H	P	Har	F	V-10	Opt
8	Climber 4	H-Sp 700	3½x5	192.42	19.6	4 D	L	H	T	Liv	S	V-18	Str
9	Dodge Brothers	Own	3⅞x4½	212.27	24.1	4 D	L	H	P	McC	B	V-15	Stw
10	Dort 18-23	Lyc K	3½x5	192.92	19.6	4 D	L	H	T	Fed	S	V-12	Car
11	Durant A-22	Own	3⅞x4¼	255.26	24.1	4 I	I	H	P	Fed	F	V-13	Till
12	Earl 40	Own 40	3 1/16x5¼	239.84	18.9	4 D	L	H	T	Spa	F	V-18	Sco
13	Elcar 4-40	Lyc 5A	3⅝x5	206.4	21	4 D	L	C	T	Jms	F	V-17	Car
14	Essex	Own	3⅜x5	178.9	18.2	4 D	D	C	T	Har	S	V-12	Own
15	Ford T	Own	3¾x4	176.70	22.5	4 D	L	H	T	Own	S	G-10	Own
16	Gardner, Series 5	Own C. E.	3 11/16x5	213.64	21.7	4 D	L	H	T	Fed	F	V-13	Zen
17	Gray	Own	3⅝x4	165.12	21	4 D	L	H	T	Cor	S	G-8	Scoe
18	HCS 4	Wei	3¾x5½	242.96	22.5	4 D	I	H	P	Fed	F	P-15	Str
19	Hupmobile R	Own	3¼x5½	182.49	16.9	4 D	L	C	T	McC	F	V-15	Str
20	Kelsey Gear 1922	Gra	3½x5	192.4	19.6	4 D	I	S	T	Lon	F	V-16	Sco
21	Kelsey 1922 Friction	Gra	3½x5	192.4	19.6	4 D	I	S	T	Lon	F	V-16	Sco
22	Kelsey (Gear Car)	Lyc	3⅝x5	206.4	21.02	4 D	L	S	T	Liv	F	V-16	Zen
23	Maxwell 1922	Own	3⅝x4½	185.76	21	4 D	L	H	T	Own	F	V-11	Stw
24	Mercer Series 5	Own	3¾x6¾	298.19	22.5	4 I	L	C	P	McC	F	V	B&B
25	Metropolitan	Own	2⅝x4	86.58	11	4 D	I	C	A	....	F	G-10	Own
26	Monroe	Own	3¼x4½	149.31	16.9	4 I	I	H	T	Fed	F	V-14	Zen
27	Nash 4	Own	3⅜x5	178.9	18.2	4 I	I	H	P	Lng	F	V-15	Mar
28	National 4	H-Sp	3½x5	192.42	19.6	4 D	L	H	T	Can	F	V-15	Str
29	Oldsmobile 43-A	Own	3 11/16x5¼	224.19	21.7	4 D	I	H	P	Har	F	V-14	Zen
30	Overland 91	Own	3⅜x4	143.12	18.2	4 D	L	H	T	Own	S	G-10	Til
31	Overland 92 Red Bird	Own	3½x4	153.94	19.6	4 D	L	H	T	Own	S	G-10	Til
32	Revere M	Dus G-1	4¼x6	364.44	28.9	4 I	H	C	P	Fed	F	V	Str
33	Revere M	Dus G-1	4¼x6	364.44	28.9	4 I	H	C	P	Fed	F	V-25	Str
34	Roamer 4-75-E	Roc	4¼x6	364.44	28.9	4 I	H	C	P	....	F	V-20	Str
35	Rubay	Own A	2¾x5¼	124.73	12.1	4 D	I	V	P	G&O	F	V-14	Str
36	Seneca L2	Lyc	3½x5	192.42	19.6	4 D	L	H	T	Whi	F	V-11	Zen
37	Seneca 50-C	Lyc	3⅝x5	206.4	21	4 D	L	H	T	Whi	F	V-13	Zen
38	Star	Cont	3⅛x4¼	130.37	15.6	4 D	L	C	P	Fed	F	V-11½	Till
39	Stearns SKL 4	Own	3¾x5⅜	237.45	22.5	4 D	S	C	P	Fed	F	V-24	Ray
40	Sterling M	Own	4 x4½	226.19	25.6	4 D	L	H	T	G&O	F	V-12	Zen
41	Sterling A	LeR	3⅛x4½	138.04	15.6	4 D	L	H	T	G&O	F	V-11	Zen
42	Stutz Series KLDH	Own	4⅜x6	360.77	30.6	4 D	T	H	P	Har	F	P-18	Str
43	Willys-Knight 64	Own	3⅝x4½	185.76	21	4 D	S	C	T	Own	F	V-16	Til
44	Willys-Knight 67 Touring	Own	3⅝x4½	185.76	21	4 D	S	C	T	Own	F	V-16	Til

KEY TO TABLE OF PASSENGER CAR SPECIFICATIONS—*Continued on next page*

1. Engine (Make)

Ansted	Ans
Beaver	Bev
Bud	Bud
Continental	Con
Curtiss	Cur
Duesenberg	Dus
Falls	Fal
Gray	Gra
Herschell-Spillman	HSp
Le Roi	LeR
Lycoming	Lyc
Northway	Nor
Rochester	Roc
Root & Vandervoort	R & V
Rutenber	Rut
Supreme	Sup
Teetor-Hartley	T-H
Weidely	Wei
Wisconsin	Wis

2. Valve Arrangement

Head & Side	D
Horizontal	H
L-Head	L
Over-head	I
Sleeve-Valve	S
T-head	T

3. Camshaft Drive

Chain	C
Helical Gear	H
Spur Gear	S
Vertical Shaft	V

4. How Cooled

Air	A
Pump	P
Thermo-Syphon	T

5. Radiator

Ansted	Ans
Bush	Bus
Candler	Can
C. A. S. Products	CAS
Corcoran	Cor
Drake-Myo	DrM
Eagle	Eag
English & Mersick	E&M
Eureka	Eur
Fedders	Fed
G. & O.	G&O
Harrison	Har
Hooven	Hoo
Jamestown	Jms
Kuenz	Kun
Livingston	Liv
Long	Lon
McCord	McC
Mayo	Myo
Moline	Mod
National	Nat
Peerless	Pee
Perfex	Per
Rome-Turney	R-T
Spartan	Spa
Standard	Stn
United States Cartridge	U. S.
Youngstown	Yng
White Cross	Whi

6. Lubrication

Force Feed & Splash	B
Splash	S
Force Feed	F

7. Fuel Feed

Gravity	G
Pressure	P
Vacuum	V

8. Carburetor

Automatic	Aut
Ball & Ball	B&B
Carter	Car
Eagle	Eag
Holley	Hol
Johnson	Jon
K. & D.	K-D
Kingston	Kng
Marvel	Mar
Miller	Mil
Newcomb	Nec
Rayfield	Ray
Schebler	Shb
Scoe	Sco
Stewart	Stw
Stromberg	Str
Sunderman	Sun
Swan	Swa
Tillotson	Til
Yale & Towne	Yale
Zenith	Zen

9. Ignition

Atwater Kent	A-K
Auto-Lite	AuL
Berling	Ber
Bosch	Bos
Connecticut	Con
Delco	Del
Eisemann	Eis
Gray & Davis	G&D
Kingston	Kng
Kokomo	Kok
K & W	K-W
Mayer	Myr
National	Nat
Northeast	NoE
Philbrin	Phb
Remy	Rmy
Scintilla	Sci
Simms-Magneto	Sim
Splitdorf	Spl
Wagner	Wag
Westinghouse	Wst

10. Lighting (Make)

Allis-Chalmers	AlC
Auto-Lite	AuL
Bijur	Bij
Bosch	Bos
Continental	Con
Delco	Del
Dyneto	Dyn
Exide	Exi
Gray & Davis	GD
Leece-Neville	LN
Northeast	NoE
Remy	Rmy
Splitdorf	Spl
United States Light	USL
Wagner	Wag
Westinghouse	W

	ELECTRICAL EQUIPMENT			TRANSMISSION OF POWER											MISCELLANEOUS					
Line Number	Ignition	Lighting	Engine Starter	Clutch—Make	Clutch—Type	Gearset—Make	Gearset—Loca'n	Speeds Forward	Universal Joints	Final Drive	Gear Ratio	Drive and Torque	Rear Axle—Make	Rear Axle—Type	Springs	Wheelbase	Wheels	Tires	Steering Gear	Speedometer
	9	10	11	12	13	14	15		16	17		18	19	20	21		22		23	24
4 Cylinder Gasoline Passenger Cars																				
1	A-K	AuL	AuL	B&B	P	Ful	U	3	UP	S	4.5	T	Sal	¾	L	114	Wd	32x4	Lav	Stw
2	Sim	G&D	G&D	War	D	War	U	4	Spic	S	4.5	S	StP	Flo	S	121	Op	32x4	Gem	Stw
3	Sim	G&D	G&D	War	D	War	U	4	Spic	S	4.5	S	StP	Flo	S	125	Op	32x4	Gem	Stw
4	Ber	USL	USL	Own	C	Own	U	3	K-B	S	4.25	T	Own	Flo	L	125	Wd	34x4½	Own	Stew
5	Del	Del	Del	Own	D	Own	U	3	Own	S	4.67	T	Own	¾	S	109	Wd	31x4	.....	.....
6	Rmy	Rmy	Rmy	Own	D	Own	U	3	MM	S	4.55	B	Own	½	Q	103	Wd	330x3½	Jac	AC
7	Rmy	Opt	Opt	Own	C	Own	U	3	Own	S	3.77	S	Own	½	Q	103	Wd	0x3½	M-P	Stw
8	A-K	Wst	Wst	B&B	D	B-Li	U	3	Hrt	S	4.9	S	Adm	½	S	117	Wd	33x4	CAS	VS
9	NoE	NoE	NoE	Own	D	Own	U	3	Own	S	4.16	B	Own	½	¾	114	Wd	32x4	Own	NoE
10	Con	Bos	Bos	Dtl	D	Own	U	3	MM	S	4.66	S	Fli	¾	L	108	Op	31x4	Gem	Stw
11	AuL	AuL	AuL	Own	D	War	A	3	Spi	S	4.33	S	Own	½	S	109	Wd	31x4	War	Stw
12	Con	AuL	AuL	B&B	D	Own	U	3	Own	S	4.18	S	Own	½	S	112	Wd	32x4	CAS	Stw
13	Del	Del	Del	B&B	P	War	U	3	MM	S	4.7	S	Sal	½	S	112	Wd	31x4	CAS	Stw
14	Bos	Bos	Bos	Own	D	Own	U	3	Spi	S	4.66	S	Own	¾	S	108½	Wd	32x4	Gem	Stw
15	Own	Own	Own	Own	D	Own	U	2	Own	B	3.64	T	Own	½	S	100	Wd	30x3½	Own	....
16	Wst	Wst	Wst	B&B	D	MM	U	3	Pet	S	4.8	S	Fli	¾	S	112	Wd	32x4	Dit	Stw
17	Wst	Wst	Wst	Own	D	Det	U	3	MM	S	3.9	S	Tim	½	C	100	Wd	30x3½	Own	Stw
18	Del	Del	Del	B-Li	D	B-Li	U	3	Spi	S	4.64	T	Own	¾	S	120	Wr	32x4½	Gem	Stw
19	A-K	Wst	Wst	Own	D	Own	U	3	UP	S	4.87	S	Own	¾	S	112	Wd	32x4	Jac	Stw
20	Bos	Bos	Bos	B&B	P	Det	U	3	Spi	S	4.75	S	StP	½	S	111	Wd	32x3½	Lav	J-M
21	Bos	Bos	Bos	Own	F	Own	R	...	T-H	S	4.5	T	Own	Ded	S	111	Wd	32x3½	Lav	J-M
22	Bos	Bos	Bos	B&B	P	W.M.	U	3	Spi	S	4.7	S	Sal	½	S	112	Wd	32x4	Lav	J-M
23	Rmy	Rmy	Rmy	Own	C	Own	U	3	T-H	S	4.56	S	Own	½	S	109	D	31x4	Own	A.C.
24	Eis	Wst	Wst	Own	D	Own	A	4	Spi	S	3.87	S	Own	Flo	S	132	Op	33x5	Gem	Stw
25	Bos	Bos	Bos	B&B	P	Own	A	3	MM	B	5	S	Own	½	S	100	D	30x3½	Own	Stw
26	Con	AuL	AuL	Own	D	MM	U	3	MM	S	5.3	T	Own	¾	P	115	Wd	32x3½	CAS	Stw
27	Del	Del	Del	B&B	P	Own	U	3	Own	S	4.99	S	Own	½	S	112	Wd	33x4	Gem	Stw
28	Eis	Dyn	Dyn	B&B	P	G-L	U	3	T-H	S	4.8	T	Per	½	¾	112	Wd	32x4	CAS	VS
29	Del	Del	Del	B&B	D	M-P	U	3	Own	S	4.7	S	Own	¾	S	115	Wd	32x4	Jac	Stw
30	AuL	AuL	AuL	B&B	P	Own	U	3	Own	S	4.5	S	Own	½	O	100	Wd	30x3½	Own	Stw
31	AuL	AuL	AuL	B&B	P	Own	U	3	Own	S	4.5	S	Own	½	O	106	Wd	30x3½	Own	Stw
32	Bos	Bij	Wst	B-Li	D	B-Li	U	4	Spi	S	3.6	T	Eat	Flo	S	131	Wr	32x4½	Gem	Stw
33	Bos	Bij	Wst	B-Li	D	B-Li	U	4	Spi	S	3.6	T	StP	¾	S	131	Wr	32x4½	Gem	Stw
34	Spl	Wst	Wst	B-Li	D	B-Li	U	4	T-H	S	3.77	S	Tim	½	L	128	Wr	32x4½	Jac	Stw
35	Bos	Bos	Bos	Own	P	Own	U	3	UM	S	5.7	T	Own	Flo	S	118	Wd	32x4	Own	Stw
36	AuL	AuL	AuL	B&B	D	G-L	U	3	UM	S	4.75	S	Per	Flo	L	108	Wd	30x3½	Dit	Stw
37	AuL	AuL	AuL	B&B	D	G-L	U	3	UP	S	4.5	S	Per	Flo	S	112	Wd	31x4	Dit	Stw
38	AuL	AuL	AuL	Own	P	War	A	3	Spi	S	4.88	S	Tim	½	S	102	Wd	30x3½	War	Stw
39	A-K	Wst	Wst	Own	D	Own	U	3	Cli	S	4.5	S	Own	½	C	125	Op	34x4½	Own	VS
40	Con	AlC	AlC	B&B	P	Cvt	U	3	Hrt	...	4	S	Wis	Flo	S	114	Op	33x4	Jac	Stw
41	Wst	Wst	Wst	B&B	P	W-Gr	U	3	Hrt	...	4.75	S	Per	Flo	S	110	....	30x3½	.....	....
42	Del	Rmy	Rmy	W-Gr	D	Own	R	3	Hrt	S	Opt	T	Own	½	S	130	Wr	32x4½	Gem	Stw
43	AuL	AuL	AuL	Own	D	Own	U	3	Own	S	4.44	S	Own	¾	S	118	Wd	32x4	Own	Stw
44	AuL	AuL	AuL	Own	D	Own	U	3	Own	S	5.12	S	Own	¾	S	124	Wd	32x4½	Own	Stw

11. Engine Starter

Allis-Chalmers	AlC
Apelco	Apl
Auto-Lite	AuL
Bijur	Bij
Bosch	Bos
Delco	Del
Disco	Dis
Dyneto	Dyn
Gray & Davis	G&D
Leece-Neville	L-N
Liberty	Lib
Northeast	NoE
Remy	Rmy
Simms-Huffs	S-H
Splitdorf	Spl
USL	USL
Wagner	Wag
Ward Leonard	W-L
Westinghouse	Wst

12. Clutch (Make)

Ansted	Ans
Borg & Beck	B&B
Brown-Lipe	BLi
Covert	Cvt
Detlaff	Dtl
Detroit	Det
Dooley	Doo
Durston	Dur
Fuller	Ful
Hartford	Hrt
Hoosier	Hoo
Long	Lng
Muncie	Mun
Muncie Products	M-P
Neilson	Nei
Northway	Nor
Rockford	Rfd
USL	USL
Warner Corp	War
Warner Gear	W-Gr

13. Clutch (Type)

Cone	C
Disc	D
Friction	F
Plate	P

14. Gearset

Brown-Lipe	BLi
Cotta	Cot
Covert	Cvt
Detroit	Det
Dundore	Dun
Durston	Dur
Fuller	Ful
Grant-Lees	G-L
Mechanics' Machine Co	MM
Muncie	Mun
Muncie Products	M-P
Northway	Nor
Warner Corp	War
Warner Gear	W-Gr
Warren	Wrn
Willis Morrow	W-M

15. Gearset Location

Amidships	A
Rear Axle	R
Unit with Engine	U

16. Universal Joints

Acme	Acm
Arvac	Arv
Climax	Cli
Flexite	Flx
Hartford	Hrt
Blood-Brothers	Bld
Kinsler-Bennett	K-B
Merchant & Evans	M&E
Mechanics' Machine Co	MM
Norwalk	Nor
Peters	Pet
Snead	Sne
Spicer	Spi
Sterling	Str
Thermoid-Hardy	T-H
Universal Drive Shaft	UD
Universal Machine	UM
Universal Products	UP

17. Final Drive

Bevel Gear	B
Chain	C
Spiral Bevel	S

18. Drive and Torque

Springs and torque tube	B
Springs	S
Torque	T

19. Rear Axle (Make)

Adams	Adm
American Gear & Mfg. Co	AmG
Clark	Cla
Columbia	Col
Eaton	Eat
Flint	Fli
General Motors Corp	GMC
Peru	Per
Salisbury	Sal
Spacke Machine & Tool Co	Spk
Standard Parts Co	StP
Timken	Tim
Walker Weiss	WW
Weston Mott	Mot
Wisconsin	Wis

20. Rear Axle (Type)

Dead	Ded
Floating	Flo
Semi-Floating	½
¾ Floating	¾

21. Springs (Front and Rear)

Cantilever (front and rear)	C
Full Elliptic (front and rear)	F
Own Construction	O
Quarter Elliptic (front and rear)	Q
Semi-Elliptic front. Cantilever rear	L
Semi-Elliptic front. Platform rear	P
Semi-Elliptic (front and rear)	S
Semi-Elliptic front. ¾ Elliptic rear	¾

22. Wheels

Disc	D
Wire	Wi
Wood	Wd

23. Steering Gear

CAS Products	CAS
Ditwiler	Dit
Gemmer	Gem
Jacox	Jac
Lavine	Lav
Muncie Products	M-P
Ross	Ros
Warner Corp	War
Wohlrab	Wol

24. Speedometer

A. C. Spark Plug	A.C.
Johns-Manville	J-M
Standard	Std
Stewart-Warner	Stw
Van Sicklen	VS
Waltham	Wtm

Line Number	Model Number and Trade Name	ENGINE											
		Engine Make and Model	Bore and Stroke	Piston Displacement	N.A.C.C. Rated Horsepower	Cylinder Cast, 2, 3, 4 or 6, Head Int. or Det.	Valve Arrangement	Camshaft Drive	How Cooled	Radiator	Lubrication	Fuel Feed and Capacity	Carburetor
	Column Numbers, Key of Abbreviations	1					2	3	4	5	6	7	8

6 Cylinder Gasoline Passenger Cars

1	Ace L	H-Sp	3¼x5	248.79	25.4	6 D	L	H	P	Own	F	V-18	Str
2	Ace C	Con	3⅝x5¼	325.08	31.5	6 D	L	C	P	Own	F	V-30	Opt
3	Ambassador	Con 6T	3⅝x5¼	325.08	31.5	6 D	L	C	P	Myo	F	V-25	Str
4	American D-66	H-Sp	3½x5	288.63	29.4	6 D	L	H	P	Liv	F	V-20	Str
5	Anderson 50	Con	3⅜x4½	241.52	27.3	6 D	L	H	P	Fed	F	V-17	Ray
6	Anderson 41	Con	3⅛x4¼	195.6	23.4	6 D	L	C	P	Fed	F	V-17	Zen
7	Apperson 6	Own	3⅛x4¼	195.6	23.4	6 D	I	...	T	Own	F	V-17	Str
8	Auburn 6-63	Own	3¼x5	248.79	25.4	6 D	H	C	P	Jms	F	V-19	Str
9	Auburn 6-43	Con	3⅛x4¼	195.6	23.4	6 D	L	C	P	Jms	F	V-15	Str
10	Barley 6	Con	3⅛x4¼	195.6	23.4	6 D	L	C	P	Mod	F	V-15	Str
11	Bay State	Con 8R	3⅜x4½	241.52	27.3	6 D	L	H	P	G&O	F	V-23	Str
12	Bour-Davis 21-S	Con	3½x5¼	303.06	29.4	6 I	L	H	P	Eur	F	V	Zen
13	Buick 44-45-46	Own	3⅜x4½	241.52	27.3	6 I	I	H	P	Own	B	V-16	Mar
14	Buick 48-49-50	Own	3⅜x4½	241.52	27.3	6 I	I	H	P	Own	B	V-16	Mar
15	Case X	Con 8R	3⅜x4½	241.52	27.3	6 D	L	H	P	Own	F	V-15	Ray
16	Case W	Con 6T	3⅝x5¼	325.08	31.5	6 D	L	C	P	Own	F	V-18	Ray
17	Chalmers	Own	3¼x4½	123.91	25.4	6 D	L	C	P	Own	B	V-16½	Str
18	Chalmers	Own	3¼x4½	123.91	25.4	6 D	L	C	P	Own	B	V-16½	Str
19	Chandler 6	Own	3½x5	288.63	29.4	6 D	L	C	P	....	F	V-20	Str
20	Cleveland Six 42	Own 42	3 1/16x4½	198.81	22.5	6 D	I	C	P	Har	F	V-16	Str
21	Climber 6	H-Sp 1100	3½x5	288.63	29.4	6 D	L	H	P	Liv	S	V-20	Str
22	Columbia Elite	Con	3⅜x4½	241.52	27.3	6 D	L	H	P	Har	F	V-17	Str
23	Columbia Six	Con	3⅛x4¼	195.6	23.4	6 D	L	C	P	Jms	F	V-12½	Str
24	Comet C-53-2	Con	3½x5¼	303.06	29.4	6 D	L	H	P	Can	F	V-20	Str
25	Courier	Fal	3⅛x4¼	195.6	23.4	.....	I	H	T	Stn	F	V	Strm
26	Crawford 23-6-70	Con	3⅝x5¼	325.08	31.5	6 D	L	H	P	Bus	F	V	Zen
27	Dagmar 23-6-70	Con	3⅝x5¼	325.08	31.5	6 D	L	H	P	Bus	F	V	Zen
28	Davis 63	Con	3⅜x4½	241.52	27.3	6 D	L	H	P	Jms	F	V-17	Str
29	Davis 70-1-2-3-4-5-6	Con 6Y	3⅛x4¼	195.6	23.4	6 D	L	C	P	Jms	F	V-17	Str
30	Dorris 6-80	Own	4 x5	377	38.4	3 D	I	H	P	Mod	F	V-20	Str
31	Dort 20-25	Fal TD8000	3⅛x4¼	195.6	23.4	6 D	I	H	T	Fed	F	V-12	Car
32	DuPont C	H-Sp	3½x5	288.63	29.4	6 D	L	H	P	Har	F	V-20	Strm
33	Durant	Ans	3¼x4½	123.91	25.4	6 D	I	H	P	Fed	F	V-20	Ray
34	Elcar 6-60	Con 8R.	3⅜x4½	241.52	27.3	6 D	L	H	P	Jms	F	V-16	Str
35	Elgin K-1 Tour Coupe	Fal	3⅛x4¼	195.6	23.4	6 D	I	H	T	Stn	F	V-16	Str
36	Elgin K-1 Scout	Fal	3⅛x4¼	195.6	23.4	6 D	I	H	T	Stn	F	V-16	Str
37	Elgin K-1 Sedan	Fal	3⅛x4¼	195.6	23.4	6 D	I	H	T	Stn	F	V-16	Str
38	Flint	Own	3⅜x5	268.38	27.3	6 D	L	C	P	Fed	F	V-20	Str
39	Fox	Own	3⅜x5	268.38	27.3	6 D	I	H	A	....	F	V-18	Zen
40	Franklin Series 10	Own	3¼x4	199.03	25.4	1 I	I	C	A	....	F	V-13.5	Own
41	Grant Six HX	Own	3⅛x4½	209.17	23.4	6 D	I	H	T	Lon	F	V-17	Str
42	Hanson Six 66	Con	3⅜x4½	241.52	27.3	6 D	L	H	P	Lon	F	V-17	Mar
43	Hatfield 6-55	H-Sp	3¼x5	248.79	25.4	6 D	L	H	P	Lon	F	V-15	Str
44	Haynes 57	Own	3½x5	288.63	29.4	6 I	L	H	P	Har	S	V-17½	Ray
45	Haynes 77	Own	3⅝x5 3/16	321.52	31.5	6 D	L	C	P	Har	F	V-17½	Str
46	HCS 6	Mid. Spec.	3½x5	288.63	29.4	6 D	I	C	P	Fed	F	P-18	Str
47	Holmes	Own	3½x4¼	245.34	29.4	6 D	I	H	A	....	F	V-16	Str
48	Hudson	Own	3½x5	288.63	29.4	6 D	L	C	P	Har	S	V-19	Own
49	Huffman (Six) R	Con 8R	3⅜x4½	241.52	27.3	6 D	L	H	P	Liv	F	V	Str
50	Jewett 6	Own	3¼x5	248.79	25.4	6 D	L	H	P	Nat	F	V-17	Str
51	Jordan MX	Own	3 5/16x4¾	244.70	26.3	6 D	L	C	P	Spa	F	V-16	Str
52	Jordan H	Own	3 5/16x4¾	244.70	26.3	6 D	L	C	P	Spa	F	V-16	Str
53	Kissel Cust. Built Tour	Own	3 5/16x5½	283.34	26.3	6 I	L	H	P	Spa	F	V-18	Str
54	Kissell 55	Own	3 5/16x5⅛	265.25	26.3	6 D	L	H	P	Spa	F	V	Str
55	Kline Kar 6-60L	Con	3⅜x4½	242.52	27.3	6 I	L	H	P	Fed	F	V-15	Ray
56	Kurtz Automatic	H-Sp	3½x5	288.63	29.4	6 D	L	H	P	Spa	F	V-18	Till
57	Leach 9-99	Own	3¾x5¼	347.89	33.8	6 I	I	S	P	Eag	F	V-22	Ray
58	Lexington 23	Ans D	3¼x4½	223.9	25.4	6 D	I	H	P	Har	F	V-17	Ray
59	Liberty 10D	Own	3⅛x5	232.41	23.4	6 D	L	H	T	Nat	F	V-14	Str
60	Locomobile 48, Series 8	Own	4½x5½	524.83	48.6	2 I	T	H	P	G&O	F	P	B&B
61	McFarlan Six	Own TV	4½x6	572.54	48.6	3 D	T	H	P	G&O	F	V-28	Ray
62	Marmon 34	Own	3¾x5⅛	339.6	33.8	3 D	I	H	P	McC	F	G-18	Str
63	Martin Wasp 231	Con 6T	3⅝x5¼	325.08	31.5	6 D	L	C	P	R-T	F	V-30	Str
64	Mercer Series 6	Own	3¾x5	331.32	33.8	6 D	I	H	P	McC	F	V	Strm
65	Mitchell F 5-50	Own	3½x5	288.63	29.4	6 D	L	H	P	Har	F	V-18	Str
66	Mitchell F-7-50	Own	3½x5	288.63	29.4	6 D	L	H	P	Mod	F	V-18	Str
67	Moon 6-40	Con 6Y	3⅛x4¼	195.6	23.4	6 D	L	C	P	Fed	F	V-15	Str
68	Moon 6-58	Con 8R	3⅜x4½	241.52	27.3	6 D	L	H	P	Fed	F	V-22	Str
69	Nash 691	Own	3¼x5	248.79	25.4	6 I	I	H	P	Lng	F	V-16	Mar

	ELECTRICAL EQUIPMENT			TRANSMISSION OF POWER											MISCELLANEOUS					
Line Number	Ignition	Lighting	Engine Starter	Clutch—Make	Clutch—Type	Gearset—Make	Gearset—Loca'n	Speeds Forward	Universal Joints	Final Drive	Gear Ratio	Drive and Torque	Rear Axle—Make	Rear Axle—Type	Springs	Wheelbase	Wheels	Tires	Steering Gear	Speedometer
	9	10	11	12	13	14	15		16	17		18	19	20	21		22		23	24

6 Cylinder Gasoline Passenger Cars

1	A-K	AuL	AuL	W-Gr	P	W-Gr	U	3	Hrt	S	4.5	T	Sal	¾	L	116	Wd	32x4	Lav	Stw
2	A-K	AuL	AuL	W-Gr	P	Ful	U	3	Hrt	S	3	T	Sal	Flo	S	120	Wd	33x4½	Lav	Stw
3	Bos	Wst	Wst	B-Li	D	B-Li	U	3	T-H	S	4.55	B	Tim	Flo	S	136	Wd	32x4½	Gem	Stw
4	A-K	G&D	G&D	B&B	P	B-Li	U	3	Hrt	S	4.5	S	Sal	Flo	S	127	Wd	33x4½	Lav	VS
5	Rmy	Rmy	Rmy	B&B	P	Dur	U	3	T-H	S	4.5	S	Sal	¾	S	120	Op	33x4	Gem	Stw
6	Wst	Wst	Wst	B&B	P	Dur	U	3	UM	S	4.75	S	Sal	½	S	115	Wd	32x4	Gem	Stw
7	Rmy	Rmy	Rmy	Rfd	P	MM	U	3	UD	S	5.1	S	Col	¾	¾	120	Wd	32x4	Lav	VS
8	Rmy	Rmy	Rmy	B&B	P	W-Gr	U	3	UD	S	4.6	S	Col	½	S	122	Wd	32x4½	Ros	Stw
9	Rmy	Rmy	Rmy	B&B	P	W-Gr	U	3	UP	S	4.6	S	Col	½	S	114	Wd	31x4	Jac	Stw
10	Del	Del	......	B&B	D	G-L	U	...	M&E	S	....	S	Col	½	S	118	Wd	32x4	Jac	Stw
11	Del	Del	Del	B&B	D	Det	U	3	Spi	S	4.67	S	Col	¾	S	121	Wd	32x4	Gem	Stw
12	Wst	Wst	Wst	Mun	D	Mun	U	3	Spi	S	4.5	S	Sal	¾	S	126	Wd	33x4½	Lav	Stw
13	Del	Del	Del	Own	D	Own	U	3	Own	S	4.4	T	Own	Flo	L	118	Wd	32x4	Own	Stw
14	Del	Del	Del	Own	D	Own	U	3	Own	S	4.7	T	Own	Flo	L	124	Wd	33x4	Own	Stw
15	Del	Del	Del	Own	D	Own	U	3	Sne	S	5	S	Col	½	S	122	Wd	32x4½	Jac	Stw
16	Del	Del	Del	Own	D	Own	U	3	Arv	S	4.45	T	Col	¾	S	129	Wd	34x4½	Jac	Stw
17	AuL	AuL	AuL	Ful	D	Ful	U	3	MM	S	5.1	S	Own	½	S	117	D	32x4	Gem	Stw
18	AuL	AuL	AuL	Ful	D	Ful	U	3	MM	S	5.1	S	Own	½	S	122	D	32x4	Gem	Stw
19	Bos	Bos	Bos	.....	P	Own	U	3	Own	S	4.4	S	Own	¾	S	123	....	32x4	.....	Stw
20	Bos	Bos	Bos	B&B	D	Own	U	3	MM	S	4.9	S	Own	½	S	112½	Wd	31x4	CAS	Stw
21	Bos	Wst	Wst	B&B	D	B-Li	U	3	Hrt	R	4.75	S	Adm	½	S	125	Wd	32x4½	CAS	VS
22	A-K	AuL	AuL	B&B	P	Dur	U	3	Spi	S	4.66	S	Tim	½	L	115	Wd	32x4	Gem	Stw
23	AuL	AuL	AuL	B&B	P	Dur	U	3	Spi	S	5.1	S	Tim	½	S	115	Wd	31x4	Gem	Stw
24	Wag	Wag	Wag	B&B	P	Mun	U	3	Acm	S	....	S	Tim	.....	S	125	Op	33x4½	Gem	Stw
25	A-K	Wst	Wst	B&B	P	Mun	U	3	Nor	S	5.1	S	Col	¾	S	116	Wd	32x4	Lav	Stw
26	Bos	Wst	Wst	B-Li	D	B-Li	U	4	Spi	S	5	S	Tim	Flo	S	138	D	33x5	Lav	Stw
27	Bos	Wst	Wst	B-Li	D	B-Li	U	4	Spi	S	4.8	S	Tim	Flo	S	138	D	33x5	Lav	Stw
28	Del	Del	Del	B&B	D	War	U	3	M&E	S	5.1	S	Tim	½	S	120	Op	32x4½	War	Stw
29	Del	Del	Del	B&B	D	War	U	3	M&E	S	5.1	S	Tim	½	S	115	D	31x4	CAS	Stw
30	Bos	Wst	Wst	Own	D	W-Gr	U	3	Spi	S	4.23	S	Tim	½	S	132	Wd	33x5	Ros	VS
31	Bos	Bos	Bos	Dtl	D	Own	U	3	MM	S	4.66	S	Fli	¾	L	115	Opt	31x4	Gem	Stw
32	Wst	Wst	Wst	B-Li	D	B-Li	U	3	Spi	S	4.45	S	Col	Flo	S	124	Wd	32x4½	Jac	Stw
33	AuL	AuL	AuL	Own	D	War	A	3	Spi	S	5.11	T	Tim	½	S	123½	Wd	32x4½	War	Stw
34	Del	Del	Del	B&B	P	War	U	3	Spi	S	4.75	S	Sal	¾	S	118	Wd	32x4	Gem	Stw
35	Wag	Wst	Wst	B&B	P	MM	U	3	MM	S	5.09	S	Col	¾	L	118	Wd	33x4	CAS	VS
36	Wag	Wst	Wst	B&B	P	Mun	U	3	UP	S	4.66	S	Col	¾	L	118	D	32x4	CAS	VS
37	Wag	Wst	Wst	B&B	P	Mun	U	3	UP	S	5.09	S	Col	¾	L	118	Wd	33x4	CAS	VS
38	......	......	......	Own	P	War	A	3	Spi	S	4.77	S	Adm	½	S	120	Wd	32x4½	War	Stw
39	Sci	Wst	Wst	B-Li	D	B-Li	U	3	Spi	S	4.9	S	Tim	¾	S	132	Opt	32x4½	Ros	Wtm
40	A-K	NoE	NoE	B&B	P	Own	U	3	Spi	S	4.73	S	Own	½	F	115	Wd	32x4	Own	Wtm
41	A-K	Bij	Bij	B&B	D	Dur	U	3	Spi	S	4.6	S	Col	¾	S	116	Op	32x4	Jac	Stw
42	Del	Del	Del	B&B	D	Det	U	3	UP	S	4.66	S	Tim	Flo	S	121	Op	32x4	Gem	Stw
43	Bos	Bos	Bos	B&B	D	Dur	U	3	Spi	S	4.63	S	Col	Flo	S	121	Opt	32x4	Gem	Stw
44	Kng	L-N	L-N	Own	D	Own	U	3	UD	S	4.11	S	Own	½	S	121	Opt	32x4½	Jac	A.C.
45	Kng	L-N	L-N	Own	D	Own	U	3	UD	S	4.6	S	Own	¾	S	132	Opt	33x5	Jac	A.C.
46	Del	Del	Del	B-Li	D	B-Li	U	3	Spi	S	4.64	T	Own	¾	S	126	Wr	32x4½	Gem	Stw
47	Eis	Dyn	Dyn	B-Li	D	B-Li	U	3	Pet	S	4.9	S	Tim	½	F	126	Wd	34x4½	Gem	VS
48	Bos	Bos	Bos	Own	D	Own	U	3	Spi	S	4.45	S	Own	¾	S	126	Wd	34x4½	Gem	Stw
49	Con	Dyn	Dyn	B&B	P	Cvt	U	3	Flx	S	4.5	S	Sal	Flo	S	120	Wd	32x4	Dit	Stw
50	A-K	Rmy	Rmy	Lng	P	War	U	3	MM	S	4.45	S	Tim	½	S	112	Wd	31x4	Gem	Stw
51	Del	Del	Del	Det	D	Det	U	3	UD	S	4.42	S	Tim	½	S	120	Wd	32x4	Gem	Stw
52	Del	Del	Del	Det	D	Det	U	3	UD	S	4.42	S	Tim	½	S	124½	Wd	32x4½	Gem	Stw
53	Rmy	Rmy	Rmy	War	D	War	U	3	UD	B	Opt	S	Own	Flo	S	124	Wr	32x4½	Jac	Stw
54	Rmy	Rmy	Rmy	B&B	...	W-Gr	U	3	Spi	B	4.66	S	Tim	¾	S	121	Wd	32x4	Jac	Stw
55	Con	Wag	Wag	B&B	P	G-L	U	3	T-H	S	4.75	S	StP	½	¾	121	Wd	33x4	Wol	Stw
56	Wst	Wst	Wst	B&B	D	G-L	U	3	T-H	S	4.5	S	Sal	¾	S	122	Wd	33x4½	Gem	Stw
57	Del	Del	Del	B-Li	D	Own	U	3	Own	S	4.23	S	Tim	Flo	S	134	D	32x4½	Gem	Wtm
58	Con	G&D	G&D	Ans	D	W-Gr	U	3	Sne	S	5.10	S	Sal	¾	S	123	Wd	32x4½	CAS	Stw
59	Wag	Wag	Wag	B&B	P	Det	U	3	Spi	S	4.8	S	Tim	½	S	117	Opt	32x4	Gem	Stw
60	Del	Wst	Wst	Own	D	Own	A	4	Own	S	3.8	T	Own	Flo	¾	142	Wd	35x5	Own	Stw
61	Wst	Wst	Wst	M&E	P	B-Li	A	3	Pet	S	3.65	S	Tim	Flo	S	140	Op	33x5	Gem	Stw
62	Del	Del	Del	Own	D	Own	A	3	Spi	S	4.1	T	Own	¾	O	136	Wd	32x4½	Own	VS
63	Bos	Bos	Bos	B-Li	P	B-Li	A	4	Sne	S	4.25	T	Eat	½	S	144	Wr	33x5	Gem	Stw
64	Eis	Wst	Wst	Own	D	Own	U	4	Spi	S	3.77	S	Own	¾	S	132	Opt	32x4½	Gem	Wtm
65	Rmy	Rmy	Rmy	B&B	D	Own	A	3	Own	S	4.41	S	Own	Flo	C	120	Wd	32x4	Own	Stw
66	Rmy	Rmy	Rmy	B&B	D	Own	A	3	Own	S	4.41	S	Own	Flo	C	127	D	32x4½	Own	Stw
67	Del	Del	Del	B&B	P	W-Gr	U	3	Spi	S	5.1	S	Tim	½	S	115	Wd	31x4	Gem	Stw
68	Del	Del	Del	B&B	P	B-Li	U	3	Spi	S	5.1	S	Tim	½	S	128	Wd	32x4½	Gem	Stw
69	Del	Del	Del	B&B	P	Own	U	3	Own	S	4.5	S	Own	½	S	121	Wd	33x4	Gem	Stw

Line Number	Model Number and Trade Name	ENGINE											
		Engine Make and Model	Bore and Stroke	Piston Displacement	N.A.C.C. Rated Horsepower	Cylinder Cast, 2, 3, 4 or 6, Head Int. or Det.	Valve Arrangement	Camshaft Drive	How Cooled	Radiator	Lubrication	Fuel Feed and Capacity	Carburetor
Column Numbers, Key of Abbreviations		1					2	3	4	5	6	7	8

6 Cylinder Gasoline Passenger Cars—Continued

70	National 6-31	Own	2⅞x4½	175.25	19.8	6 D	L	G	T	....	F	V-12	Own
71	National 6-51	Con	3½x4½	259.76	29.4	6 D	L	...	P	....	F	V	Str
72	National 6-71	Own	3½x5¼	303.06	29.4	6 D	I	C	P	Fed	F	V-20	Ray
73	Noma A, B, C	Con	3¼x4½	123.91	25.4	6 D	L	H	P	Liv	F	V-20	Cla
74	Oakland 6-44	Own	2 13/16x4¾	177.04	18.9	6 D	I	C	P	Har	F	V-12½	Mar
75	Packard Single Six	Own	3⅜x5	268.35	27.3	6 D	L	C	P	Fed	F	V-20	Own
76	Paige 6-70	Con 9 A	3¾x5	331.29	33.8	6 D	L	H	P	Nat	F	V-21.6	Ray
77	Paterson 23-6-52	Con	3⅜x4½	241.6	27.3	6 D	L	H	P	Lon	F	V-18	Str
78	Pierce Arrow 33	Own	4 x5½	414.68	38.4	6 D	T	H	P	Fed	F	P-26	Own
79	Pilot 6-45	T-H	3⅛x5	232.41	23.4	6 D	L	H	P	Jms	F	V-15	Til
80	Pilot 6-50	H-Sp	3¼x5½	248.87	25.35	6 D	L	H	P	Jms	B	V-20	Til
81	Pilot 6-56	H-Sp	3½x5	288.63	29.39	6 D	L	H	P	Jms	B	V-20	Til
82	Premier 6D	Own 6D	3½x5	295.19	27.3	6 D	I	H	P	McC	F	V-22	Str
83	Premocar 6-40A	Fal-S	3⅛x4¼	195.6	23.4	6 D	I	H	T	Own	F	V	Str
84	Reo T 6, 7 p	Own	3 3/16x5	239.39	24.3	6 D	D	H	P	Own	F	V-17½	Ray
85	Rickenbacker	Own	3⅛x4¾	220.79	23.4	6 D	L	C	P	Fed	F	V-21	Str
86	Roamer 6-54-E	Con	3½x5¼	293.06	29.4	6 I	L	H	P	....	F	V-20	Str
87	Rolls-Royce	Own	4½x4¾	453.26	48.6	3 I	L	H	P	Own	F	P-21	Own
88	R & V Knight H	Own	3½x4½	259.76	29.4	6 D	S	C	T	Fed	F	V-18	Str
89	Sayers Six D. P.	Con R	3⅜x4½	241.6	27.3	6 D	L	H	P	Fed	F	V-14	Str
90	Stephens Six Model 20	Own	3¼x4½	123.91	25.4	6 D	I	H	T	Fed	F	V-19	Str
91	Stearns-Knight	Own	3⅜x5	268.35	27.3	6 D	S	C	P	Fed	B	V-24	Ray
92	Stephens Six Model 10	Own	3¼x4½	303.06	25.4	6 D	I	H	T	Fed	F	V-19	Str
93	Sterling B	H-Sp	3¼x5	248.79	25.4	6 D	L	H	T	G&O	S	V-12	Zen
94	Stevens Duryea E	Own	4 7/16x5½	510.02	47.3	2 I	L	H	P	G&O	F	V-25	Str
95	Studebaker EL	Own	3½x5	288.63	29.4	6 D	L	H	P	McC	F	V-17	Str
96	Studebaker EK	Own	3⅞x5	353.40	36.2	6 D	L	H	P	McC	F	V-17	B&B
97	Studebaker EM	Own	3⅛x4½	209.17	23.4	6 D	L	C	P	McC	F	V-15	Str
98	Stutz 6	Own 690	3⅜x5	268.35	27.3	6 D	I	C	P	Fed	F	V-18	Str
99	Velie 58	Own V. S.	3 3/16x4¼	203.49	24.3	6 D	I	H	T	Jms	F	V-17	Str
100	Washington, C	Con 8R	3⅜x4½	241.6	27.3	6 D	L	H	P	Fed	F	V-18	Zen
101	Westcott 44	Con 8R	3⅜x4½	241.6	27.3	6 D	L	H	P	Jms	F	V-15	Ray
102	Westcott 48	Con 12X	3½x5¼	303.06	29.4	6 I	L	H	P	Fed	F	V-18	Ray
103	Winton 40	Own 40	3¾x5¼	347.85	33.8	2 D	L	C	P	G&O	F	V-24	Ray

8 Cylinder Gasoline Passenger Cars

1	Apperson 8	Own	3¼x5	331.8	33.8	4 D	L	H	T	Own	F	V-20	Jon
2	Cadillac 61	Own	3⅛x5⅛	314.43	31.2	4 D	L	C	P	Own	F	P-20	Own
3	Cole 890	Nor 311	3½x4½	346.36	39.2	4 D	L	S	P	Fed	F	V-20	Jon
4	Cunningham	Own	3¾x5	441.76	45	4 D	L	H	P	G&O	F	V	Str
5	Daniels 8D	Own D 19A	3½x5¼	404.08	39.2	4 D	L	H	P	G&O	F	P-21	Zen
6	Daniels 8D	Own D 19A	3½x5¼	404.08	39.2	4 D	L	H	P	G&O	F	P	Zen
7	Duesenberg S	Own	2⅞x5	259.64	26.4	8 D	I	V	P	Nat	F	V-22	Str
8	King 8K	Own	3 x5	282.72	28.8	4 I	L	C	T	Fed	F	V-18	B&B
9	King 8K	Own	3 x5	....	28.8	4 I	L	C	T	Fed	F		B&B
10	La Fayette	Own 134	3¼x5¼	348.39	33.8	4 D	L	C	P	Har	F	....	Jon
11	Lincoln	Own	3⅜x5	357.8	36.5	4 D	L	C	P	McC	F	P-20	Str
12	Oldsmobile 46	Own	2⅞x4¾	246.66	26.4	4 D	L	H	P	Own	F	V-20	B&B
13	Oldsmobile 47	Own	2⅞x4½	233.68	26.4	4 D	L	H	P	Har	F	V-20	B&B
14	Packard Single Eight	Own	3⅜x5	357.84	36.46	8 D	L	C	P	Fed	F	V-14	Jon
15	Peerless Type 23	Own 66	3¼x5	331.8	33.8	4 I	L	H	P	Fed	F	V-21	Own
16	Standard 8 Model 98	Own	3¼x5	331.8	33.8	4 I	L	H	P	Fed	F	V-20	B&B
17	Wills Sainte Claire A-68	Own	3¼x4	265.44	33.8	4 I	I	V	T	Myo	F	V-22	Zen

12 Cylinder Gasoline Passenger Cars

1	Packard Twin Six	Own	3 x5	424.39	43.2	6 D	L	C	P	Fed	F	P-20	Own

Line Number	ELECTRICAL EQUIPMENT			TRANSMISSION OF POWER											MISCELLANEOUS					
	Ignition	Lighting	Engine Starter	Clutch—Make	Clutch—Type	Gearset—Make	Gearset—Loca'n	Speeds Forward	Universal Joints	Final Drive	Gear Ratio	Drive and Torque	Rear Axle—Make	Rear Axle—Type	Springs	Wheelbase	Wheels	Tires	Steering Gear	Speedometer
	9	10	11	12	13	14	15		16	17		18	19	20	21		22		23	24

6 Cylinder Gasoline Passenger Cars—Continued

70	AuL	AuL	AuL	B&B	D	Own	U	3	UP	S	....	S	Own	¾	S	112	Wd	31x4	.. .	...
71	AuL	AuL	AuL	B&B	D	Cvt	U	3	....	...	....	S	Tim	¾	S	121	Wd	32x4	......	.....
72	Del	Wst	Wst	B&B	D	B-Li	U	3	UP	S	4.08	T	Col	Flo	S	130	Wd	32x4½	War	Stw
73	Del	Del	Del	B&B	P	Det	U	3	Spi	S	4.45	S	Tim	½	S	128	Wr	33x5	Lav	Stw
74	Rmy	Rmy	Rmy	Own	C	Mun	U	3	MM	S	4.7	S	GMC	¾	S	115	Wd	31x4	Jac	Stw
75	Del	A-K	A-K	Own	D	Own	U	3	Spi	S	4.6	B	Own	½	S	Opt	Wd	33x4½	Own	Wtm
76	A-K	Rmy	Rmy	Lng	P	W-Gr	U	3	MM	S	4.6	S	Tim	¾	S	131	Wd	33x4½	Gem	Stw
77	Del	Del	Del	B&B	D	Dur	U	3	Hrt	B	4.5	...	StP	Flo	S	120	Wd	32x4½	Jac	Stw
78	Del	Del	Del	Own	D	Own	A	3	Spi	S	4.28	B	Own	½	S	138	Wd	33x5	Own	Wtm
79	Del	Del	Del	B&B	D	Mun	U	3	Hrt	S	4.45	S	Spk	Flo	L	120	Wd	32x4	Dit	Stw
80	Con	Bij	Bij	B&B	D	Mun	U	3	Hrt	S	4.67	S	Col	¾	S	126	Wd	32x4½	Dit	Stw
81	Wag	Wag	Wag	Hoo	D	Mun	U	3	Bld	S	4.67	S	Col	¾	S	126	Wd	32x4½	Ros	Stw
82	Del	Del	Del	B&B	P	Own	U	3	Spi	S	4.58	S	Tim	½	S	126¾	Wd	Opt	Own	War
83	Bos	Bos	Bos	B&B	D	MM	U	3	Spi	S	4.66	S	Tim	½	S	117	Wd	32x4	Dit	Stw
34	NoE	NoE	NoE	Own	D	Own	A	3	Own	S	4.7	S	Own	½	S	120	D	33x4½	Own	NoE
85	Bos	Bos	Bos	Own	D	Own	U	3	MM	S	4.6	S	Own	Flo	S	117	Opt	32x4	Gem	Stw
86	Spl	Wst	Wst	B&B	D	G-L	U	3	T-H	S	4.45	S	Tim	½	L	128	Wr	32x4½	Jac	Stw
87	Own	Own	Own	Own	C	Own	A	4	Own	S	3.25	T	Own	Flo	L	143½	Wr	33x5	Own	Wtm
88	AuL	AuL	AuL	B-Li	P	B-Li	U	3	Spi	S	5.4	S	Tim	½	S	124	Wd	32x4½	Jac	Stw
89	Del	Del	Del	B&B	D	G-L	U	3	Arv	S	4.75	S	StP	½	S	118	Wd	33x4	Lav	Stw
90	Del	Del	Del	B&B	D	MM	U	3	MM	S	5.3	S	Tim	½	S	124	Wd	33x4½	Gem	Stw
91	A-K	Wst	Wst	Own	D	Cwn	U	3	....	S	4.9	S	Own	½	C	130	....	34x4½	...	....
92	Del	Del	Del	B&B	D	MM	U	3	MM	S	4.91	S	Tim	½	S	117	Wd	32x4	Gem	Stw
93	Wst	Wst	Wst	......	...	......	U	3	......	...	4.	...	Per	Flo	S	116	....	33x4½	......	......
94	Ber	Wst	Wst	Own	D	Own	U	3	Own	S	3.9	S	Own	Flo	¾	138	Wd	35x5	Own	Wtm
95	Rmy	and	Wag	Own	P	Own	A	3	Spi	S	4.33	S	Own	½	S	119	Wd	32x4	Own	VS
96	Rmy	and	Wag	Own	P	Own	A	3	Spi	S	3.7	S	Own	½	S	126	Wd	33x4½	Own	VS
97	Rmy	and	Wag	Own	P	Own	A	3	T-H	S	4.55	S	Own	½	S	112	Wd	31x4	Own	Stw
98	Rmy	Rmy	Rmy	B&B	P	W-Gr	U	3	MM	S	4.66	S	Tim	½	...	120	....	32x4	Gem	Stw
99	A-K	Wst	Wst	Doo	P	Dur	U	3	UD	S	5.1	S	Own	¾	S	118	Wd	32x4	Gem	Stw
100	Del	Del	Del	B&B	P	War	U	3	Bld	S	4.67	S	Col	¾	L	119	Wd	32x4	Ros	Stw
101	Del	Del	Del	B&B	P	W-Gr	U	3	Pet	S	5.09	S	Col	½	S	120	Wd	32x4½	Gem	Stw
102	Del	Del	Del	B&B	P	B-Li	U	3	Pet	S	4.45	S	Tim	½	S	125	Wd	32x4½	Gem	VS
103	Del	Del	Del	War	D	War	U	3	Cli	S	4.6	S	Tim	½	S	132	Wd	33x5	Own	Stw

8 Cylinder Gasoline Passenger Cars

1	Rmy	Bij	Bij	Own	P	Own	A	3	UD	S	4.25	S	Own	¾	¾	130	Wd	34x4½	Own	VS
2	Del	Del	Del	Own	D	Own	U	3	Spi	S	Opt	S	Own	Flo	P	132	Wd	33x5	Own	VS
3	Del	Del	Del	Nor	D	Nor	U	3	Spi	S	4.7	S	Col	Flo	S	127¼	Wd	33x5	Gem	Stw
4	Del	Del	Del	Own	D	Own	U	4	Sne	S	4.23	S	Tim	Flo	¾	142	Opt	33x5	Gem	Wtm
5	Del	Del	Del	Own	D	Own	U	3	Spi	S	4.08	S	Tim	Flo	S	132	Wd	33x5	Gem	Wtm
6	Del	Del	Del	Own	D	Own	U	3	Spi	S	4.08	S	Tim	Flo	S	138	Wd	33x5	Gem	Wtm
7	Del	Del	Del	Own	D	Own	U	3	Cli	S	4.45	T	Own	½	S	134	Wr	33x5	Lav	Stw
8	A-K	Wst	Wst	Det	P	Own	U	3	T-H	S	4.88	T	Col	Flo	L	120	Opt	32x4½	Jac	VS
9	Del	Del	Del	Own	D	Own	U	3	Own	S	Opt	T	Own	Flo	S	132	Wd	33x5	Own	Wtm
10	Del	Del	Del	Own	P	Own	U	3	Own	S	4.58	T	Own	Flo	S	132	Wd	....	Own	Wtm
11	Del	Del	Del	Own	D	Own	U	3	Spi	S	4.58	T	Tim	Flo	S	136	Wd	33x5	Own	Wtm
12	Del	Del	Del	Own	C	M-P	U	3	Spi	S	4.92	S	Mot	Flo	S	122	Wd	33x4½	Jac	Stw
13	Del	Del	Del	B&B	D	M-P	U	3	Own	S	5.1	B	Own	¾	S	115	Wd	32x4	Jac	Stw
14	Del	Dyn	Dyn	Own	D	Own	U	3	Spi	S	4.7	B	Own	½	S	136	D	33x5	Own	Wtm
15	Del	Del	Del	Own	D	Own	U	3	Spi	S	4.90	T	Tim	½	S	128	Wd	33x5	Gem	Wtm
16	Spl	Wst	Wst	B&B	D	G-L	U	3	Arv	S	4.46	S	Own	Flo	S	127	Wd	34x4½	Own	Stw
17	Del	Del	Del	Own	D	Own	U	3	Own	S	4.9	S	Own	½	S	121	D	32x4½	Own	Wtm

12 Cylinder Gasoline Passenger Cars

1	Del	Bij	Bij	Own	D	Own	U	3	Spi	S	4.36	B	Own	½	S	136	Wd	35x5	Own	Wtm

SPECIFICATIONS OF ELECTRICAL EQUIPMENT OF 1922 PASSENGER CARS

Pages 1064 and 1065 give the make of ignition system; gap to set contact-breaker points; position to set spark lever when timing ignition; spark-plug thread; make of generator; charging rate; make of starting motor; make of battery, and ampere-hour capacity.

Pages 1066 and 1067 give the voltage of the electric system; wiring; fuse capacity; lamp bulb candle power; diameter of headlight lens. (From *Motor Age.*)

MAKE AND MODEL	IGNITION						GENERATOR		Motor Make	Battery Make	Amp. Hr.
	System	Make	Control	Breaker point opening	Spark lever retarded	Spark plug thread length	Make	Charging rate at m. p. h.			
Ambassador R	Closed	Bosch	Hand				West	12–7	West	Exide	120
American C		At-Kent	Hand	.006			G&D		G&D	Willard	96
Anderson Ser. 40	Single*	Remy	Hand	.120	5°	½	Remy	10–20	Remy	Willard	111
Apperson Eight	Single**	Remy	Hand	.020			Bijur	15–20	Bijur	Exide	101
Auburn Beauty Six, 6-51	Open	Remy	Hand	.020	12°		Remy		Remy	Exide	90
Beggs 20T		Conn	Hand						A-L	Exide	
Biddle B-1, B-5	Single	Simms	Hand				G&D	10–	G&D	Willard	
Brewster 02		Bosch	Hand	.020	0°		USL	12–	USL	USL	80
Buick, Four 22-34-37	Single	Delco	H&A	.020	7°	⅝	Delco	15–25	Delco	Exide	
Buick, Six 22-44-47	Single	Delco	H&A	.020	7°	⅝	Delco	15–25	Delco	Exide	
Buick, Six 22-48-50	Single	Delco	H&A	.020	7°	⅝	Delco	15–25	Delco	Exide	
Cadillac 61	Double	Delco	Auto				Delco		Delco	Exide	130
Case X	Single**	Delco	Hand	.021	0°	¾	Bijur	15–20	Bijur	Willard	135
Chalmers 35-C	Closed	Remy	Hand				A-L	12–20	A-L	Presto-O-L	106
Chalmers 35-C											
Champion, Tourist		Dyneto	Hand				Dyneto				
Champion, Special		Dyneto	Hand				Dyneto				
Chandler, Six		Bosch	Hand				Bosch				
Chevrolet 490	Closed	Remy	Hand				A-L	7–15	A-L	Willard	91
Chevrolet FB		Remy					A-L				
Cleveland 40	Single*	Bosch	Hand	.018	0°	13/16	Bosch	14–25	Bosch	Prest-O-L	94
Climber, Six S	Double	Bosch	Hand		0°	¾	West		West	Willard	100
Climber, Four K	Double	At-K	Hand		2°	¾	West			Willard	100
Cole 870	Double	Delco	Hand				Delco		Delco	Willard	125
Columbia CC	Single**	At-K	Hand				A-L		A-L	Prest-O-L	80
Comet 6-C53-2	Open	Wagner	Hand						Wagner	Willard	
Crawford 22-6-49		At-K	Hand				West				
Crow-Elkhart L		Conn	Hand				Dyneto		Dyneto	Prest-O-L	
Crow-Elkhart S		Conn					Dyneto		Dyneto	Prest-O-L	
Cunningham V-4	Double	Delco	H&A	.020	5°		Delco	8–20	Delco	Willard	110
Daniels D-19	Double		H&A	.018		⅝	Delco	14–20	Delco	Willard	145
Davis 61-67		Delco	Hand				Delco		Delco	Willard	96
Dixie Flyer H	Single	Eisemann	Hand	.015	10°	½	Dyneto	15–25	Dyneto	Willard	80
Dodge Brothers	Single**	N.E.	Auto	.020			N. E.		N. E.	Willard	50
Dorris 6-80	Single	Bosch	Hand				West		West	Willard	138
Dort 19	Closed	Conn	Hand	.20	0°	½	Bosch	12–15	Bosch	USL	90
Driggs 1922	Closed	Bosch	Hand				Bosch	10–20	Bosch	Prest-O-L	84
Duesenberg, Straight 8	Double**	Delco	Hand				Delco	15–20	Delco	Exide	135
Du Pont A	Single	Eisemann	Hand				West				
Durant A-22	Closed	A-L	Hand				A-L		A-L	USL	
Durant B-22		A-L									
Earl 40	Single	Conn	Hand				A-L	13–	A-L	USL	95
Elcar K-4	Open	Delco	Hand	.020		½	Delco	12–12	Delco	Willard	
Elcar 7-R	Open	Delco	Hand	.020		½	Delco	12–12	Delco	Willard	
Elgin K-1	Closed	Wagner	Hand	.021	5°	½	West	11½–25	West	Willard	90
Essex	Single**	Bosch	H&A	.018		5/16	Bosch		Bosch	Exide	80
Falcon Light Four	Open	At-K	Hand				West	8–15	West	USL	84
Falcon Six	Open	At-K	Hand				West	8–15	West	USL	84
Falcon 12-D-22			Hand				Bosch		Bosch	Exide	100
Ferris 60		Split	Hand				Leece-N	15–20	Leece-N	Willard	120
Ferris 70	Closed		H&A				Leece-N	15–20	Leece-N	Willard	120
Ford T	Open	Own	Hand				Own	10–15	Own	Own	80
Fox		Bosch					West				
Franklin 9-B	Single**	At-K	Auto	.007		½	N. E.	12–18	N. E.	Willard	63
Frontenac		Delco									
Gardner R.T.S.	Double**	West	Hand	.012	0°	½	West	12–10	West	Willard	94
Grant	Closed	At-K	Hand	.015			Bijur	13–25	Bijur	Prest-O-L	100
Goodspeed	Open	Split	Auto				West		West	Prest-O-L	105
H.C.S. Ser. 3		Delco	Hand				Delco		Delco	Willard	
Handley-Knight B	Closed	A-L	S. A.	.020	½°		A-L		A-L	USL	
Hanson 60		Delco	Hand				Delco	10–20	Delco	Prest-O-L	80
Hatfield A-42	Single*	Conn	Hand	.016	2°	¾	Dyneto	10–15	Dyneto	Willard	100
Haynes 75	Single**	Kingston	Hand	.018	5°		Leece-N	15–18	Leece-N	Willard	132
Haynes 55	Single**	Kingston	Hand	.018	5°		Leece-N	15–18	Leece-N	Willard	132
Holmes Ser. 4		Eisemann	Auto	.012	9½°	⅞	Dyneto	12½–17	Dyneto	Willard	70
Hudson, Super-Six	Single**	Bosch	H&A	.018		21/32	Bosch		Bosch	Exide	105
Hupmobile R	Closed	At-K	Hand	.006	5°	½	West	16–19	West	Willard	117½
Jackson 6-38	Single	Remy	Hand				A-L				
Jordan M.X.	Open	Delco	Hand	.022		13/32	Delco	16–8	Delco	Willard	108
Jordan F	Open	Delco	Hand	.022	10°	15/32	Delco	14–10	Delco	Willard	108
King K	Closed	At-K	Auto	.018	5°	11/16	West	12–25	West	Prest-O-L	120
Kissel 45	Single*	Remy	H&A	.020	6°	⅝	Remy	15–20	Remy	Willard	117
Kline Kar 6-55-K	Double**	Conn	Hand	.020		⅜	Wagner	14–15	Wagner	Prest-O-L	100
Kurtz, Automatic A	Double**	West	Hand			⅞	West	12–25	West	Prest-O-L	
Lafayette 134	Double	Delco	H&A	.015		¾	Delco	18–35	Delco	Exide	150
Leach 999	Single*	Delco	Hand				Delco		Delco	Prest-O-L	
Lexington T-22	Open	Conn	Hand	.012			G&D	14–25	G&D	Willard	100
Lexington ST-22	Open	Conn	Hand	.012			G&D	14–25	G&D	Willard	100
Liberty 10-D	Open	Wagner	Hand				Wagner	15–18	Wagner		105
Lincoln	Closed	Delco	H&A				Delco	20–15	Delco	Exide	135

ABBREVIATIONS: Ignition: *Open **Closed *At-K*, Atwater-Kent; *Conn.*, Connecticut; *West*, Westinghouse; *N. E.*, North East; *Auto*, Automatic; *H. & A.*, Hand & Automatic; *S. A.*, Semi-Automatic; Generator: *A-L.*, Auto-Lite; *G. & D.*, Gray & Davis; *Leece-N.*, Leece-Neville; *N. E.*, North East; *Split*, Splitdorf; Motor: *A.-L.*,

[continued on next page

concluded from page 1064]

MAKE AND MODEL	IGNITION						GENERATOR		Motor	Battery	Amp. Hr.
	System	Make	Control	Breaker point opening	Spark lever retarded	Spark plug thread length	Make	Charging rate at m. p. h.	Make	Make	
Locomobile 48	Double	Berling	Hand	.018		13/16	West	7–25	West	Exide	120
Maibohm B	Single*	At-K	Hand	.005	10°	7/8	Bijur	14–25	Bijur	Willard	94
Marmon 34		Delco	H&A	.018		9/16	Delco	12–25	Delco	Willard	162
Maxwell									Sim-A-L	Prest-O-L	
McFarlan T.V.		West	Hand	.012	5°	3/4	West	15–20	West	Willard	135
Mercer Ser. 5	Single	Eisemann	Hand				West		West	Prest-O-L	149
Merit BC	Closed	Delco	Hand	.023		1/2	Delco	10–25	Delco	Willard	
Meteor 22-80	Single		Hand			7/8	West	15–20	West	Exide	
Mitchell F-50	Single	Remy	Hand	.022		15/32	Remy		Remy	Willard	113
Mitchell F-50	Single	Remy	Hand	.022		15/32	Remy		Remy	Willard	113
Monroe 8-9-10-11-12	Single	Conn	Hand	.015	0°	1	A-L	2½–15	A-L	USL	84
Moon 6-48	Single*	Delco	Auto	.025		7/8	Delco	12–25	Delco	Exide	110
Moon 6-75	Single*	Delco	Auto				Delco	12–25	Delco	Exide	130
Murray-Mac 70-T		Dixie	Hand				Bijur	10–15	Bijur	Willard	150
Nash 681-7		Wagner	H&A				Wagner				
Nash 682		Wagner	H&A				Wagner				
Nash 41-4		Delco	Hand				Delco				
National Ser. BB	Closed	Delco	Auto	.015	¾°	9/16	West	10–20	West	Prest-O-L	125
Noma 3C	Single*	Delco	Hand				Delco		Delco	Willard	90
Noma 1D	Open		Hand					10–15		Willard	90
Norwalk 4-30 KS	Open	Delco	Hand	.020		7/8	Dyneto	20–25	Dyneto	Willard	80
Oakland 6-44	Open	Remy	H&A	.020	0°		Remy	10–20	Remy	Prest-O-L	80
Ogren Six	Open	Bosch	Hand	.020		5/8	Bosch	10–20	Bosch	Willard	90
Oldsmobile 43A	Single	Remy	Hand	.016	0°	7/8	A-L	8–15	A-L	Willard	80
Oldsmobile 46	Double	Delco	Auto	.018	3°	7/8	Delco	8–15	Delco	Willard	80
Oldsmobile 47	Double	Delco	Auto	.018	0°	7/8	Delco	8–15	Delco	Willard	80
Overland 4	Single	Hand	Conn				A-L				
Packard Single Six	Single	Delco	H&A	.015		1/2	At-K	9–10	At-K	Willard	100
Packard Twin Six	Single	Delco	H&A	015		1/2	Bijur	16–12	Bijur	Willard	120
Paige 6-44	Single**	At-K	Hand	.006	12°	1/2	Remy	12–15	Remy	Willard	118
Paige 6-66	Single**	At-K	Hand	.006	12°	1/2	Remy	12–13	Remy	Willard	118
Pan American 6-55	Open	West	Hand	.004		11/16	West	8–10	West	Willard	
Parenti 1922	Single	Remy	Hand				Bijur	15–20	Bijur	USL	80
Paterson 22-6-52	Closed	Delco	Hand	.018		5/8	Delco	10–15	Delco	Willard	80
Peerless, 56 Ser. 7	Closed	At-K	Auto	.015		1/2	A-L	15–20	A-L	Willard	125
Piedmont 4-30	Single*	Delco	Hand				Dyneto	10–20	Dyneto	Willard	90
Piedmont 6-40	Single*	Remy	Hand				Remy	10–20	Remy	Willard	90
Pierce Arrow 33		Delco	H&A			9/16	Delco		Delco	Willard	
Pilot 6-50	Closed	Conn	Hand				Bijur	12–18	Bijur		120
Porter 46		Berling	Hand				West				
Premier 6-D		Delco	Hand	.010	12°	5/8	Delco	16–17	Delco	Willard	123
Premocar 6-40	Open	Wagner	Hand				Wagner		Wagner	Exide	
Raleigh A6-60		Bosch	Hand				Bosch	12–15	Bosch	Willard	120
Ranger A-22-4		West					Bijur		Bijur		
Ranger A-22-6		Philburn					Bijur		Bijur		
R&V, Knight R	Single	Wagner	Hand	.031	15°	9/16	Wagner	9–20	Wagner	Willard	117½
R&V, Knight J	Single	Wagner	Hand	.031	23°	9/16	Wagner	9–20	Wagner	Willard	117½
Reo T-6-B	Single*		Hand	.020			N. E		N. E	Willard	111
ReVere		Bosch	Hand	.031		1/2	West	18–18	West	Willard	120
Rickenbacker A	Closed	A-L	Auto				Simms	10–	Simms	Prest-O-L	106
Roamer 4-75-E		Bosch	Hand				West	12–25	West	Prest-O-L	80
Roamer 6-54-E		Bosch	Hand				Bijur	12–25	Bijur	Prest-O-L	80
Rock Falls 14		Bosch	Hand				West	11–30	West	Exide	167
Rolls-Royce	Double**	Own	Hand	.020	10°		Bijur		Bijur	Exide	90
Romer A-22		Conn	Hand				West	12–15	West	Willard	120
Saxon 125-G	Single**	Wagner	Hand	.025		9/16	Wagner	18–21	Wagner	Prest-O-L	100
Sayres Six	Open	Delco	Hand	.027	10°	7/8	Delco	16–20	Delco	Willard	93
Seneca 50	Single*	A-L	Hand				A-L	10–15	A-L	Prest-O-L	94
Standard Eight 11	Single	Split	Hand		0°	1/2	West	12–15	West	Willard	160
Stanwood A-22	Closed	At-K	Hand	.006		3/4	West	10–20	West	Willard	
Stearns-Knight SKL 4	Closed	At-K	Hand	.025	5°		West	10–25	West	Exide	90
Stephens 90	Open	Conn	Hand	.015	2°	1	A-L	12–20	A-L	USL	112
Stevens-Duryea E	Closed	Berling	Hand				West		West	Vesta	120
Studebaker Light Six			Auto								
Studebaker Special Six			Hand								
Studebaker Big Six			Hand								
Stutz K	Single		Hand			5/8	Remy		Remy	Willard	125
Templar 445		Simms	Hand		0°	1/2	Bijur	12–30	Bijur	Prest-O-L	100
Tulsa E-1-2-3	Double	Conn	Hand				Dyneto	12–25	Dyneto	Exide	90
Velie 58	Closed	At-K	Hand	.006			Bijur	12–15	Bijur	Willard	
Velie 48		At-K	H&A				Bijur				
Velie 34		At-K	H&A				West				
Vogue 6-55	Double**	Conn	Hand				A-L		A-L	Prest-O-L	
Vogue 6-66	Double**	Conn	Hand				A-L		A-L	Prest-O-L	
Westcott A-44	Single*	Delco	H&A	.018	2°		Delco	14–18	Delco	Willard	117
Westcott C-48	Single	Delco	H&A				Delco				
Wills Sainte Claire A-68	Double*	Delco	H&A				Delco	18–25	Delco	Willard	140
Willys-Knight 20	Single	Conn	Hand				A-L				
Winther Six 61	Open	West	Hand	.010	0°	3/4	West	14–20	West	Willard	115
Winton Six 25		Bosch	Hand				Bijur		Bijur		

Abbreviations: Ignition: *Open **Closed *At-K*, Atwater-Kent; *Conn.*, Connecticut; *West*, Westinghouse; *N. E.*, North East; *Auto*, Automatic; *H. & A.*, Hand & Automatic; *S. A.*, Semi-Automatic; Generator: *A-L.*, Auto-Lite; *G. & D.*, Gray & Davis; *Leece-N.*, Leece-Neville; *N. E.*, North East; *Split*, Splitdorf; Motor: *A.-L.*, See page 1064 for explanation of this and next page]

System Voltage	Wiring System	Units Combined	Fuses	Base Contact	Head-lights	Side-lights	Tail-lights	Dash-lights	Are Dash & Tail Lights in Series	Diameter of Head Light Lens	MAKE AND MODEL
			Amp.		CP.	CP.	CP.	CP.			
6	1	S	15, 30	Single	50		2		No	12	Ambassador R
6	1	GM	20	Sgl.&Dbl.	15	4	2	2	No	9	American C
6	1	S		Sgl.&Dbl.	21	2	2	2	No	8¾	Anderson Ser. 40
6	1	S	10	Sgl.&Dbl.	18		2	2	No		Apperson Eight
6	1	S		Sgl.&Dbl.	20	4	2	2		9 7/16	Auburn Beauty Six, 6-51
	2	S									Beggs 20T
		S	10	Double	17	2	2	2	No	9⅜	Biddle B-1, B-5
12	1	GM	10, 30	Sgl.&Dbl.	21	4	2	2	Yes	9¼	Brewster 02
6	1	GIM		Single	21		2	2	No	8 5/32	Buick, Four 22-34-37
6	1	GIM		Single	21		2	2	No	8½	Buick, Six 22-44-47
6	1	GIM		Single	21		2	2	No	8½	Buick, Six 22-48-50
6	1	GM									Cadillac 61
6	1	S	5	Single	21	4	2	2	No	8½	Case X
6	1	GI									Chalmers 35-C
											Chalmers 35-C
											Champion, Tourist
											Champion, Special
6											Chandler, Six
6	1	GI	20	Single	17		2			8⅛	Chevrolet 490
											Chevrolet FB
6	1	S	5, 20	Sgl.&Dbl.	17		2	2	No	8⅝	Cleveland 40
6	1	S	15, 30	Sgl.&Dbl.	28				No	10	Climber, Six S
6	2	S	15	Sgl.&Dbl.	28				No	10	Climber, Four K
6	1	S		Sgl.&Dbl.	21	5	4	5	No	9½	Cole 870
6	1	S									Columbia CC
	2	GIM			21		2	2	Yes	9	Comet 6-C53-2
6											Crawford 22-6-49
	1	S									Crow-Elkhart L
	1	S									Crow-Elkhart 8
6	1	S		Sgl.&Dbl.	21	4	2	2	No	11	Cunningham V-4
6	1	S		Sgl.&Dbl.	21	4	2	2	No	9⅜	Daniels D-19
6	1	S									Davis 61-67
6	2	S	10	Double	32	4	2	2	Yes	7⅝	Dixie Flyer H
12	1	GM		Single	15		2	2	Yes	8¾	Dodge Brothers
6	1	S	15	Single	21	2	2	2	No	9½	Dorris 6-80
6	1	S	10	Single	16		4	2	Yes	9	Dort 19
6	1	GI									Driggs 1922
6	1	GI		Single	21	4	4	4	No	9	Duesenberg, Straight 8
6											Du Pont A
	1	GI									Durant A-22
	2										Durant B-22
6	1	GI	20	Sgl.&Dbl.	21	2	2	2	No	8¾	Earl 40
6	1	S		Single	21	4	2	2	No	9½	Elcar K-4
6	1	S		Single	21	4	2	2	No	9½	Elcar 7-R
6	1	S	5, 20	Sgl.&Dbl.	21	2	2	2	No		Elgin K-1
6	1	S	5, 10	Single	15	2	2	2	No	8⅝	Essex
6	1	S									Falcon Light Four
6	1	S							Yes		Falcon Six
6		S									Falcon 12-D-22
6	1	S									Ferris 60
6	1	S									Ferris 70
6	1	S		Sgl.&Dbl.	18–21		2			8⅛	Ford T
											Fox
12	2	GM	10	Double	21	4	2	2	Yes	9	Franklin 9-B
											Frontenac
6	1	S	5, 20	Single	21		2	2	No	8⅝	Gardner R.T.S.
6	1	S	10, 15	Sgl.&Dbl.	21	2	2	2	No	8⅝	Grant
6	1										Goodspeed
	1	S									H.C.S. Ser. 3
	2	GI	20	Single	23	2	2	2	No	8¼	Handley-Knight B
6	1	S									Hanson 60
6	1	S		Single	17	4	2	4	No	8½	Hatfield A-42
6	1	GI	5	Single	21	2	2	2	No	8⅞	Haynes 75
6	1	GI	5	Single	21	2	2	2	No	8⅞	Haynes 55
12	1	GM	10	Single	21		2	2	No	9¼	Holmes Ser. 4
6	1	S	5, 10	Single	21	2	2	2	No	9 1/16	Hudson, Super-Six
6	1	S	5, 10	Single	15		2	2	No	8⅛	Hupmobile R
6											Jackson 6-38
6	1	S		Single	21		2	2	No	8¾	Jordan M.X.
6	1	S		Single	21		2	2	Yes	8¾	Jordan F
6	1	S	5, 10, 25	Single	18	2	2	2	No	8½	King K
6	1	S	20	Sgl.&Dbl.	21	4	2		Yes	8	Kissel 45
6	1	S	5, 10, 15	Sgl.&Dbl.	18		2	2	No	8¾	Kline Kar 6-55-K
	1	S	5, 20	Single			2	2	Yes	9¾	Kurtz, Automatic A
6	1	GM		Single	21	4	2	2	Yes	9⅛	Lafayette 134
	1										Leach 999
6	1	S	5, 15	Sgl.&Dbl.	21	4	2	2	No	8⅛	Lexington T-22
6	1	S	5, 15	Sgl.&Dbl.	21	4	2		No	8⅛	Lexington ST-22
6	2	S	5	Sgl.&Dbl.	15	2	2	2	No	9	Liberty 10-D
6	1	GM									Lincoln

Auto- Lite; *G. & D.*, Gray & Davis; *Leece-N.*, Leece-Neville; *West*, Westinghouse; *Sim-A.-L.*, Simms & Auto-Lite; Battery: *Prest-O-L.*, Prest-O-Lite; Wiring system: *G. I.* Generator & Ignition combined; *G. I. M.*, Generator, Ignition & Motor combined; *S.*, Generator-Motor Ignition Separate; *G. M.*, Generator & Motor combined; Base Contact: *Sgl. & Dbl.* ,Single & Double.

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System Voltage	Wiring System	Units Combined	Fuses	Base Contact	Head-lights	Side-lights	Tail-lights	Dash-lights	Are Dash & Tail Lights in Series	Diameter of Head Light Lens	MAKE AND MODEL
			Amp.		CP.	CP.	CP.	CP.			
6	2	S	10	Double	21	4	2	2	No	8¾	Locomobile 48
6	1	S	6	Single	17	4	2	2	Yes		Maibohm B
6	1			Single	27		2	2	No	9⅞	Marmon 34
6											Maxwell
6	1	GI	10, 30	Sgl.&Dbl.	32	2	2	2		9	McFarlan T.V.
6	1	S	5, 30	Sgl.&Dbl.	20		4	2		9¼	Mercer Ser. 5
	1	S		Sgl.&Dbl.	21		2	2	Yes	9	Merit BC
	1	S	5	Single	16	2	2	2	Yes		Meteor 22-80
6	1	S	10	Sgl.&Dbl.	21	2	2	2		8	Mitchell F-50
6	1	S	10	Sgl.&Dbl.	21	2	2	2		8	Mitchell F-50
6	1	S	20	Sgl.&Dbl.	16	4	2	2	No	8¾	Monroe S-9-10-11-12
6	1	S		Single	21	4	4	4	No	8⅝	Moon 6-48
6	1	S									Moon 6-75
6	1	S									Murray-Mac 70-T
6											Nash 681-7
6											Nash 682
6											Nash 41-4
6	1	S	5	Sgl.&Dbl.	21	4	2	2	No	9¼	National Ser. BB
6	1	S									Noma 3C
6	1	S									Noma 1D
6	1	S		Single	21		2	2	Yes	8⅝	Norwalk 4-30 KS
6	1	S		Sgl.&Dbl.	15		2	2	No		Oakland 6-44
6	1	S	15	Sgl.&Dbl.	21		2	2	No	10¼	Ogren Six
6	1	GI		Sgl.&Dbl.	21		2	2	No	8⅝	Oldsmobile 43A
6	1	GI		Sgl.&Dbl.	21	2	2	2	No	8⅝	Oldsmobile 46
6	1	S		Sgl.&Dbl.	21	2	2	2	No	7¹⁵⁄₁₆	Oldsmobile 47
											Overland 4
6	1	S		Single	15		2	2		8½	Packard Single Six
6	1	S	10	Single	24		4	4	No	8½	Packard Twin Six
6	1	S	5, 20	Sgl.&Dbl.	15	2	2	2	Yes	9⅜	Paige 6-44
6	1	S	5, 20	Sgl.&Dbl.	15	2	2	2	Yes	8⅞	Paige 6-66
	1	S	15	Single	21		2	2	Yes	9½	Pan American 6-55
6	2	S	10	Sgl.&Dbl.	15		2	2	No	8	Parenti 1922
6	1	S		Sgl.&Dbl.	12	4	2	2	Yes	8½	Paterson 22-6-52
6	1	S	10	Single	21	4	2	2	No	9⅜	Peerless, 56 Ser. 7
6		S									Piedmont 4-30
6	1										Piedmont 6-40
6	1	S		Single	21		4	4			Pierce Arrow 33
6	1	S									Pilot 6-50
12											Porter 46
6	1	GI		Sgl.&Dbl.	21	2	4	4	No	1½	Premier 6-D
	1	S									Premocar 6-40
6	1	GM									Raleigh A6-60
											Ranger A-22-4
											Ranger A-22-6
6	1	S	20	Sgl.&Dbl.	21		2	4	No	9⅝	R&V, Knight R
6	1	S	20	Sgl.&Dbl.	21		2	4	No	9⅝	R&V, Knight J
6	1	S	5	Single	21	2	2	2	No	9¾	Reo T-6-B
6	1	S	6, 8	Sgl.&Dbl.	16	8	3	3	No		ReVere
6	1	S									Rickenbacker A
6	1	S									Roamer 4-75-E
6	1	S									Roamer 6-54-E
6	1	S	15, 30	Single	15	6	2	2		9⅝	Rock Falls 14
12	2	S	5, 10	Double					No	11	Rolls-Royce
6	1	S									Romer A-22
6	1	S	15	Single	17	2	2	2	No	8¾	Saxon 125-G
6	1	S		Sgl.&Dbl.	21	6	2	2	Yes	8¾	Sayres Six
6	1	S		Sgl.&Dbl.	16		2	2			Seneca 50
6	1	S		Single	20	7	7	4	No	8⅞	Standard Eight 11
6	1	S	10	Sgl.&Dbl.	21	4	2	2	No	9¼	Stanwood A-22
12	1	S	20	Single	21		2	2	No	9¼	Stearns-Knight SKL 4
6	1	GI	20	Sgl.&Dbl.	15	2	2	2		9¾	Stephens 90
6	1	S									Stevens-Duryea E
	1	GM									Studebaker Light Six
	1	GM									Studebaker Special Six
	1	GM									Studebaker Big Six
6	1	S		Sgl.&Dbl.	21		2	2	No	9½	Stutz K
6	1	S	20	Sgl.&Dbl.	21	2	2	2	No	9⅝	Templar 445
6	1	GI									Tulsa E-1-2-3
	1	S	10	Single	21	2	2	4			Velie 58
6											Velie 48
6											Velie 34
	1	S									Vogue 6-55
	1	S									Vogue 6-66
6	1	S		Single	21	4	2	2	No	8¾	Westcott A-44
6											Westcott C-48
6	1	GM									Wills Sainte Claire A-68
6											Willys-Knight 20
6	1	S	5, 20	Single	24		2	2	No	8¼	Winther Six 61
6											Winton Six 25

Auto- Lite; *G. & D.*, Gray & Davis; *Leece-N.*, Leece-Neville; *West*, Westinghouse; *Sim-A.-L.*, Simms & Auto-Lite; Battery: *Prest-O-L.*, Prest-O-Lite; Wiring system: *G. I.* Generator & Ignition combined; *G. I. M.*, Generator, Ignition & Motor combined; *S.*, Generator, Motor Ignition Separate; *G. M.*, Generator & Motor combined; Base Contact: *Sgl. & Dbl.* ,Single & Double.

SPECIFICATIONS OF 1922 MOTORCYCLES (From *Motor Age*)

	POWER PLANT								TRANSMISSION						FRAME AND WHEELS						MISCELLANEOUS								
	CYLINDERS								GEAR RATIO																				
NAME AND MODEL	Number Bore and Stroke	Arrangement	Piston Displacement	Cycle Type	Lubrication Type	Carbureter Make and Size	Ignition Make	Max. H. P.	1st	2nd	3rd	Change Speed Gear Type	Clutch Type	Final Drive	Wheelbase	Frame Type	Front Forks Type	Tires—Size (in.)	Road Clearance Exclusive of Pedals	Height of Saddle Above Ground	Starting System	Lighting System	Brakes—Number and Type	Gas Tank Capacity (gals.)	Oil Tank Capacity (qts.)	Weight Empty (lbs.)	Speed—Normal Nig. M. P. H.	Price	Price—Electrically Equipped
Cleveland 1922	1-2¾x2¾	Vert.	16.3	2	O&G	Scheb-	Bosch	5	6.2	10.3	......	Pos.	O-D.	Chain	56¼	Dia.	Hel.	26x3	6	29½	K	Split	1-Ext.	2¼	......	180	35	$185	$220
Excelsior	2-3²¹⁄₆₄x3½	Vee	61.0	4	Spl	Scheb-1	Brlng.	17	9.9	6.7	4.1	Prog.	D-D.	Chain	59	Dia.	Hel.	27x3½	5½	30	K	Split	1-Ext. 1-Int	3	3	385	70	......	365
Evans G	1-2 x1¾	Vert.	90.0	2	O&G	Own	Brlng.	......	10.0	......	......	......	......	Belt	49	Loop	......	......	7	......	P	Brlng.	Coast. Hub	1¼	......	70	28	......	140
Harley-Davidson	2-2¾x3	Opp.	35.6	4	Spl.	Scheb-¾	Own	6	12.9	8.3	5.0	Prog.	O-D.	Chain	53½	Dia.	Hel.	26x3	......	28	K	OwnGen Exi Bat	1-Est. 1-Int†	2½	2	260 280	....	310	340
Harley-Davidson	2-3⁵⁄₁₆x3½	Vee	60.3	4	Spl.	Scheb-1	Own	16	9.7	6.5	4.3	Prog.	D-D.	Chain	60	Loop	Hel.	28x3	......	30½	K	Own Gen Exi Bat	1-Int. 1-Ext†	3⅛	4¾	345 365	65	335	365
Harley-Davidson	2-3⁷⁄₁₆x4	Vee	74.0	4	Spl.	Scheb-1¼	Own	18	9.7	6.5	4.3	Prog.	D-D.	Chain	60	Loop	Hel.	28x3	......	30½	K	Own Gen Exi Bat	1-Int. 1-Ext†	3⅛	4¾	350 370	70	360	390
Henderson	4-2¹¹⁄₁₆x3½	Vert.	80.4	4	Force	Zen-1	Simms	24	7.5*	5.6	3.4	Prog.	O-D.	Chain	60	Crad.	Hel.	27x3½	4¼	29	K	Split	1-Ext. 1-Int	3	3	410	72	......	475
Indian Scout	2-2¾x3¹⁄₁₆	Vee	36.3	4	SpF	Scheb-¾ or Carter	Split	11	12.0	7.6	4.8	Prog.	O-D.	Chain	54	Loop	Leaf	26x3	5	28	K	Split	1-Ext.	2¾	3	300 327	....	......	345
Indian Standard	2-3⅛x3³¹⁄₃₂	Vee	60.8	4	SpF	Scheb-1¼ or Carter	Split	18	10.5	6.6	4.2	Prog.	D-D.	Chain	59½	L&CS.	Leaf	28x3	5½	32	K	Split	1-Ext. 1-Int	3¼	3	378½	....	......	370
Indian Chief	2-3⅛x3³¹⁄₃₂	Vee	60.8	4	SpF	Scheb-1¼ or Carter	Split	18	11.9	7.5	4.8	Prog.	O-D.	Chain	60⅜	Loop	Leaf	28x3	5	30	K	Split	1-Ext. 1-Int	3⅜	3⅛	410	....	......	435
Iver-Johnson 16-7CTS	2-3¼x3¾	Vee	31.1	2	Force	Scheb-	Bosch	8	6.5	3.7	......	Hub.	D-D.	Chain	56	Dia.	Leaf	28x3	6	32	K	Prest.	1-Ext.	2	1½	260	....	250	......
Iver-Johnson 16-7	2-3¼x3¾	Vee	31.1	2	Force	Scheb-	Bosch	8	6.5	3.7	......	Hub.	D-D.	Chain	56	Dia.	Leaf	28x3	6	32	K	Prest.	1-Ext.	2	1½	260	....	225	......
Iver-Johnson 16-4CTS	1-3¼x3¾	Vert.	31.1	4	Force	Scheb-	Bosch	5	6.5	3.7	......	Hub.	......	Chain	56	Dia.	Leaf	28x3	6	32	K	Prest.	1-Ext.	2	1½	220	....	200	......
Iver-Johnson 16-4C	1-3¼x4¼	Vert.	35.2	4	Force	Scheb-	Bosch	5	4.2	......	......	......	D-D.	Chain	56	Dia.	Leaf	28x3	6	32	K	Prest.	1-Ext.	2	1½	220	....	175	......
Iver-Johnson 16-4B	1-3¼x3¾	Vert.	31.1	4	SpF	Scheb-	Bosch	4	......	......	......	......	D-D.	Belt	56	Dia.	Leaf	28x3	6	32	K	Prest.	1-Ext.	2	1½	215	....	150	......
Nera Car	1-2½x2¾	Vert.	13.5	2	O&G	B&B	Own	2½	......	......	......	......	......	Chain	55½	......	......	26x3	8½	......	K	Own	1-Int.	2	......	165	....	......	225
Reading Standard 22T 22TE	2-3⅜x4	Vee	71.5	4	Spl.	Scheb-1¼	Bosch	16	3.9	6.0	9.2	Prog.	D-D.	Chain	58	Dia.	Hel.	28x3	5	30	K	Split	1-Ext. 1-Int	3	3½	343 366	65	345	375
Schickel	1-3 x2½	Vert.	17.6	2	O&G	Own	Split Brlng.	3½	6.0	9.0	......	D-G.	O-D.	Chain	53	Keys.	Hel.	26x2¼	5½	29	K	Brlng.	1-Ext.	1½	......	160	30	185	195

*Reverse—5.87
†Optional.

ABBREVIATIONS

Lubrication Type
O&G—Mix Oil with Gasoline
Spl—Splash
SpF—Splash and Force
Ignition Make
Eisem—Eisemann

Carbureter
Zen—Zenith
Scheb—Schebler
B.V.B—
Change Speed Gear Type
D-G—Direct Gear

Fric—Friction
Hub—2-Speed Hub
Pos—Positive Clutch
Prog—Progressive Sliding
Plan—Planetary
Slid—Sliding

Frame Type
Crad—Cradle
Dia—Diamond
Keys—Keystone
L&CS—Loop and Cradle Springs

Front Forks Type
Hel—Helical Spring
Leaf—Leaf Spring
Clutch Type
O-D—Oil Disk
D-D—Dry Disk.

Starting System
K—Kick
P—Pedal
H—Hand Crank

Registration of Cars, Trucks, and Motorcycles in the U. S., up to February, 1922. (from Table compiled by Automotive Industries, New York.)

Passenger cars, 7,628,949; *Commercial cars*, 958,259; *Motorcycles*, 181,194; *Total Registrations*, 10,449,785; *Total Fees*, $98,499,925.66.

The state with the greatest number of registrations is New York, with 754,085; Ohio is next with 742,713; Pennsylvania is next, with 689,589; California is next, with 674,830; Illinois is next, with 670,452. The state with the least number is Nevada, 10,819. *Ohio has the greatest number of passenger cars*, 647,774; California next, 638,922. *New York has the greatest number of trucks*, 172,170; Illinois next, 79,906; Pennsylvania next, 57,048. *New York has the greatest number of motorcycles*, 25,024; Ohio next, 21,938; Pennsylvania next, 21,111.

SPECIFICATIONS OF THE ROLLS-ROYCE CAR[1]

Engine: 6-cylinder; cast in two blocks of 3 cylinders each.

Bore: 4½″.

Stroke: 4¾″.

Carburetor: Special Rolls-Royce design and make.

Engine H.P.: 48.6 (N.A.C.C. Rating); Max. 80.

Max. torque at 1,300 revs.

Engine r.p.m.: 200-2,750.

Total length of frame: 178¾″.

Total width of frame: 30″ front; 36″ rear.

Wheelbase: 143½″.

Wheel track: 56″.

Size of tires: 33″ x 5″.

Ground clearance: 12¼″.

Gear ratio—rear axle: 3.25 to 1.

Gear box: 4 speeds ahead and 1 reverse.

Gear-box ratio: 3.25-1; top, 1-3.25; third, 1-4.83; second, 1-7.23; first, 1-11.06.

Type of steering: Worm and nut.

Turning radius: 23.8′ left—25′ right.

Chassis speed: 4 to 80 miles per hour on direct gear.

Chassis weight: 3,200 pounds.

Lubricating system: Pressure.

Fuel feed: Pressure.

Gas consumption: 11 to 13 miles per gallon (U.S.)

Oil consumption: 1 gallon per 1,000 miles.

Capacity of gas tank: 21 gallons.

Capacity of crank case: 6 quarts.

12-volt starting and lighting system.

Ignition system: Two systems: magneto and battery; may be used separately or together.

Water system: Centrifugal pump; recording thermometer on dash board.

Rear axle: Full floating type; Gleason spiral bevel.

Clutch: Cone type, cotton fabric lined.

Brakes: Both internal expanding on rear wheels.

Ferodo lined foot brake: 17″ diameter.

Hand brake: 12″ diameter.

Springs: Front, semi-elliptic; solid eye top plate; rear, cantilever.

SPECIFICATIONS FOR DUESENBERG STRAIGHT EIGHT AUTOMOBILE[2]

Engine: Eight cylinders in a row; bore 2⅞″; stroke 5″; displacement 260 cu. in.; developing from 90 to 100 h.p.; speed 3 to 90 m.p.h.

Cylinder block: Gray iron; the upper half of the crank case and cylinder block are cast in block.

Cylinder head: Removable, with overhead cam shaft, rocker-arms, valves and springs enclosed by a detachable cover; the vertical drive shaft and gears are so arranged that the timing of the valves cannot be changed when the head is removed.

Cam shaft: One-piece hollow drilled for pressure oil feed to the five bearings; it is driven by a vertical drive shaft and spiral bevel gears.

Rocker-arms: Forged alloy steel; locked adjustment for the valve clearance at the end of the rocker-arm; bearings are oiled under pressure through a hollow drilled rocker-shaft.

Valves: Two per cylinder, each actuated by a rocker-arm and two springs, one inside the other; springs secured by taper keys.

Combustion chamber: Bored out in a spherical shape and polished to prevent collection of carbon.

Vertical drive shaft: In two pieces so arranged that the head can be removed and replaced without the possibility of changing the valve timing.

Oil pump: Driven direct from the crank shaft; a special Duesenberg feature consisting entirely of a system of gears capable of delivering a pressure of 250 lbs. per sq. in.

Water pump: An impeller of the centrifugal type.

Crank shaft: One piece having three main bearings; front 2⅜″ x 2¼″; center 2⅜″ x 2½″; rear 2⅜″ x 3″; the connecting rod bearings are 2″ x 1⅞″; the crank shaft is drilled, and oil is forced to all bearings under pressure.

Connecting rods: Length 9¾″; machined all over; hollow tubular type; piston pin held in place by a lock screw; lower end is arranged with fins which provide lightness, strength, and a large cooling area.

Pistons: Flat-top 3⅛″ rings are used; diameter 2⅞″; length 3⅛″.

Oil pan: Aluminum, removable while engine is in frame; lower half is used as a reservoir for oil; oil is drawn through a strainer from the sump in the bottom of the oil pan by the oil pump and forced to all bearings under pressure.

Breather: Covered by a hinged cap which also acts as a convenient oil-filler pipe and has the oil gauge mounted on the front of it.

Flywheel: Steel forging machined all over with gear teeth cut in periphery for the starting motor.

Carburetor: 1½″ mounted on right side of engine; gas passes from the intake manifold through the head of the motor to the left-hand side, where it is distributed to the cylinders through an aluminum ramshorn intake; a part of the exhaust manifold is cast integral with the intake manifold, and through this the exhaust passes, creating a hot spot.

Electrical equipment: Delco is used throughout; the distributor is mounted on the generator; this locates the distributor centrally making possible a very neat distribution of wires to the spark plugs.

Spark plugs: Metric threads, one per cylinder, set in the head at an angle to prevent fouling; amply cooled and very accessible.

Engine mounting: Three-point suspension; the rear of the engine is suspended by side arms on a bell housing bolted directly to the frame; the front is supported by a patented trunnion, which makes an extremely strong, light, and flexible mounting.

Accessibility: Adjustment on the engine, carburetor, electrical equipment, and spark plugs are extremely easy to make because of the simplicity of engine construction.

Clutch: Single dry plate of a special Duesenberg design with an adjustable pedal.

Transmission: Three speeds forward and one reverse, with ground gears of a special Duesenberg design; gear ratio reverse 4.016 to 1; first speed, 3.167 to 1; second speed, 1.654 to 1; high direct drive 1 to 1.

Universal joints: The drive to the real axle is through a double flexible joint and a tubular drive shaft, which is enclosed in a torque tube.

Drive gears: Spiral bevel; ratio of 4.6 to 1.

Rear axle: One-piece reinforced molybdenum steel of a new design extremely light and strong; ball bearings are used throughout.

Differential: Consists of a forged steel case enclosing a spider arm, four bevel gears and two side gears splined for the axle shaft.

Axle shaft: Molybdenum steel hollow; shaft and hub are one piece.

Rear axle mounting: The front end of the torque tube is hinged to the center cross-member by a yoke; both ends of the springs suspend the frame by shackles; two radius rods run from the axle to the front end of the torque tube to provide strength.

Front axle: Tubular; axle ends and steering knuckles are of molybdenum steel of a new design from 25 to 40 per cent lighter than the majority of axles now in use and from 25 to 40 per cent stronger.

Wheel base: 134″.

Springs: Semi-elliptic; front 2¼″ wide by 40″ long; rear 2½″ wide by 59″ long.

Frame: Chrome nickel steel 6 7/16″ in depth of section by 2⅛″ cross-section; it is strongly braced by five rigid cross-members.

Hydraulic brakes: 16″ forged drums are fitted to all four wheels, ground to give a perfect braking surface; circumferential fins are machined on the outer edge to provide strength, lightness, and radiating surface; the four brakes are operated by hydraulic pressure; a master-cylinder is attached to the foot brake and the liquid is forced through the lines running to the four wheels by a piston in the cylinder; a small cylinder in each one of the four brakes has a piston which is forced upward by the liquid entering the cylinder; the piston then operates a toggle arm which in turn expands the two brake shoes in each brake.

Hand brake: Operates manually a contracting brake on a drum at the forward end of the propeller shaft.

Wheels: Rudge Whitworth wire wheels are used.

Spare wheels: One spare wheel is carried on a 3-point mounting on the rear of the car and locked in place by a patented Duesenberg device.

Tires: 33″ x 5″ cord tires are used all around.

Weight: The weight of the car is 3,200 lbs.

Clearance: Clearance, lowest point 10″.

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[1] Manufactured by Rolls-Royce Co. of America, Springfield, Mass.

[2] Duesenberg Auto & Motor Co., Indianapolis, Ind.

Bumper: The bumpers are a part of the car and are of a special design.

Shock absorbers: Are standard equipment.

Chassis lubrication: Alemite.

Gas tank: Capacity 20 gallons; located at the rear.

Vacuum system: A special Stewart vacuum tank is located on the cast-aluminum dash.

Body: Aluminum; steel fenders; running boards.

Instrument board: Instruments are grouped and enclosed under plate glass, making them dust proof; they are illuminated by indirect lighting.

Dimming head lights: A specially designed dimming arrangement is located in a convenient position on the steering wheel.

Manufactured by Duesenberg Automobile & Motors Co., Inc. Indianapolis, Ind.

SPECIFICATIONS OF THE PIERCE ARROW "MODEL 32"

The Pierce-Arrow: model "32" car numbers run from 321,001 to 329,999. This model is manufactured in conjunction with the 38 and 48 h.p. right-hand drive models, the latter being produced in limited quantities.

Engine: 6 cylinders, T-head which is removable with cylinders in-block, instead of in three pairs, as in the 1918, 1919 and 1920 models. **There are two cam shafts,** one on each side of the engine. One cam shaft (right-hand side) operates the exhaust valves, and on the left side, the inlet valves. **There are two inlet and two exhaust valves to each cylinder,** called "dual valves." The outside diameter of the inlet and exhaust-valve head is 1⅝″. The diameter of the throat, where the bevel of the valve begins, is 1½″, and the lift of the valves is 11/32″. This dual-valve engine was first incorporated in "Series Five" in June, 1918. The **valve clearance** on the exhaust valve is .005″, and the inlet .003″, adjusted when the engine is hot.

Cylinder dimensions are 4″ bore by 5½″ stroke. The speed of the engine is 200 to 3,000 r.p.m., the latter speed corresponding to 75 miles per hour. See page 54 for illustration of Pierce-Arrow engine.

Ignition: Delco closed-circuit system, with automatic spark advance. There are two spark plugs to each cylinder, this being called "double ignition," comprising two complete systems, either of which can be used alone if desired. The two plugs in each cylinder insure positive ignition and complete combustion.

Spark plugs: ⅞″ A.L.A.M., with 1/32″ gap; timer contacts should open .030″; **firing order,** 1, 5, 3, 6, 2, 4.

Starting motor: A Delco starting motor in a separate unit, with a mechanically shifted pinion which meshes with the gear on the flywheel, is on the right side of the engine.

The generator is a third-brush regulated, shunt-wound Delco generator, mounted as a separate unit on the right side of the engine. **Storage battery:** Willard, 6-volt. See Index under "Wiring diagram Pierce-Arrow electric system."

The carburetor is the Pierce-Arrow, similar to that used in the 1919 model. A few of the first cars of this model were equipped with a special Stromberg carburetor.

Gasoline feed is by air pressure. One pipe from the fuel tank in the rear is connected to a power and hand air pump, and is called the air-pressure pipe; the other is the fuel pipe to the carburetor. The **air pressure** of the gasoline gauge varies from 3½ lbs. to 4 lbs. per square inch.

The oiling system is a full-force system. The oil is not only forced to the cam-shaft and crank-shaft bearings, but is also forced to the piston pin. **Oil pressure** varies from 0 to 75 lbs. per square inch. A pressure of from 2 lbs. to 3 lbs. should show when the engine is throttled down to its lowest speed, and from 14 lbs. to 20 lbs. when the engine is running at 40 m.p.h. on level roads. Readings are taken when the engine is warm.

Transmission: Three forward and one reverse speed. Some of the earlier models had four speeds. The **final drive** is by means of spiral bevel gears. **Rear axle,** semi-floating. **Tires,** straight side 33″ x 5″. **Gasoline capacity,** 26 gallons. **Wheel base,** 136″. **Tread,** 56″. **Clutch,** multiple disk, dry plate. **Gear shift** is the standard S A.E.

The rear-axle ratio of the six and seven-passenger car, model "32," is 4.29 to 1; on the four-passenger car, 4.00 to 1; on the model "RBT," 3.75 to 1.

Transmission ratio in first speed, 3.45 to 1.
Transmission ratio in second speed, 1.73 to 1.
Transmission ratio in third speed, direct.
Transmission ratio in reverse speed, 4.26 to 1.
Total gear reduction in third, 4.29 or 4.00 or 3.75.
Total gear reduction in reverse, 18.27 or 17.04 or 16.01.

Earlier models of the Pierce-Arrow: Three models were formerly made; the model using a **38** h.p., 6-cylinder engine with bore of 4″ and a stroke of 5½″, speed 200 to 2,200 r.p.m.; the model using a **48** h.p., 6-cylinder engine, bore 4½″, stroke 5½″, speed 250 to 2,000 r.p.m.; the model using a **66** h.p., 6-cylinder engine, bore 5″, stroke 7″, speed 150 to 1,800 r.p.m.

Ignition used was the Bosch type "ZR 6," model 4, high-tension magneto, and a second system consisting of a battery and coil which was a part of the Westinghouse **generator.**

The starting motor was a Westinghouse, with an automatic electromagnetic pinion shift.

The double-unit Delco ignition was used on the "48," model "511," in 1919. (Pierce Arrow Co., Buffalo, N.Y.)

SPECIFICATIONS OF THE "STAR" CAR[1]

This car is a Durant creation, manufactured by the Star Motors Inc., 511 Fifth Ave., New York, N.Y.

Engine: 4 cylinders; L-head; made by Continental Motors Corpn.; cylinders cast integral with upper crank case; detachable cylinder head; lower crank case detachable, made of sheet metal; **bore** 3⅛″; **stroke** 4¼″; develops maximum of 35 h.p. at 2,500 r.p.m.; 152.1 cu. in. piston displacement; cam shaft and generator shaft driven by chain at front end of engine; chain has triangular layout; **engine has 4-point suspension.**

Lubrication: Oil under pressure is forced through hollow cam shaft, and thence, still under pressure, to the main bearings; connecting-rod bearings and pistons are lubricated by splash system.

Manifolds: Inlet and exhaust manifolds are cast in one common wall, thus producing "hot spots" for incoming charge.

Fuel system: Fuel tank of cylindrical shape mounted on rear of frame; Stewart-Warner vacuum feed to carburetor; Tillotson carburetor.

Clutch: Single-plate disk (see Fig. 14).

Transmission: Selective type, 3 speeds.

Universal joints: Spicer.

Axles: Front axle I-beam; rear axle of Timken make, semi-floating, spiral bevel gear, 4⅞ to 1 ratio; differential can be removed through cover plate in rear-axle housing.

Cooling: Water-circulating pump driven by extension of generator shaft; belt-driven fan.

Steering: Cross type; steering gear of worm-and-wheel type; steering wheel of usual type, but carries horn button only.

Spark and throttle levers: Mounted on dash, of bell-crank type (see Fig. 14), foot accelerator inter-connected.

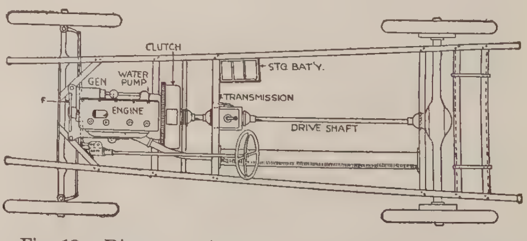

Fig. 13. Diagrammatic view of Star chassis, showing approximate layout of various units and general type of construction employed. Note that a device termed a "tubular backbone," extending from the transmission cross-member to the rear cross-member, is used which prevents racking or squeaking of the body. The muffler is enclosed therein.

Springs: Front springs semi-elliptic, 1¾″ wide by 34″ long; rear are semi-elliptic, 6-leaf, 1¾″ wide by 48″ long.

Brakes: Internal hand brake and external foot brake acting on rear wheel drums.

Bearings: Wheels and differential mounted on Timken bearings.

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[1] Illustrations from *Motor World.*

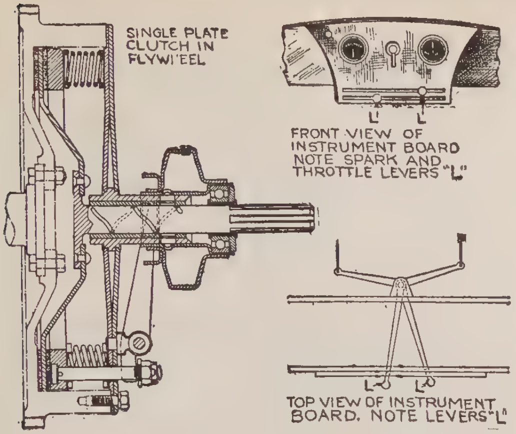

SINGLE PLATE CLUTCH IN FLYWHEEL
L L
FRONT VIEW OF INSTRUMENT BOARD NOTE SPARK AND THROTTLE LEVERS "L"
L L
TOP VIEW OF INSTRUMENT BOARD. NOTE LEVERS "L"

Fig. 14

Ignition: Auto-Lite make; high-tension coil mounted on top of generator; distributor mounted on vertical shaft behind generator.

Electrical system: Auto-Lite generator; cut-out mounted on side of generator ; U.S.L. battery; this equipment furnished on all cars.

Tires: 30″ x 3½″ all around; demountable rims furnished on chassis, runabout, or phaeton at extra cost.

Wheel base: 102 inches.

The prices of the Star car, f.o.b. Detroit, are as follows:

Chassis	$285.00
Phaeton	348.00
Phaeton with starter and demountable rims	443.00
Runabout	319.00
Runabout with starter and demountable rims	414.00
Coupé with starter and demountable rims	580.00
Sedan with starter and demountable rims	645.00

STANDARD ADJUSTMENTS OF THE PACKARD TWIN SIX "3-25" AND "3-35"

Ignition interrupter points should be set .015″ to .020″ when fully separated.

Ignition timing: The spark setting in the fully advanced position should be 2⅝″ (measured on the circumference of the flywheel) before upper dead center.

Should it become necessary **to check this,** proceed as follows: Remove the motor-starter switch cover over the flywheel. Set the spark lever on the steering wheel in the fully advanced position. Open all priming cups with the exception of the one in No. 1 cylinder in the right block. Crank the engine by hand until compression begins in this cylinder; then open this priming cup and continue to crank the engine slowly to the point where the right interrupter points just begin to separate. In this position, the letters "S.R." on the flywheel should be just opposite the center line of the engine, as indicated on the crank case.

In order to test the synchronism of the left hand block, proceed as above, excepting that the priming cup in No. 1 cylinder in the left block should be closed. Under these conditions, the letters "S.L." should be just opposite the center line of the engine as above.

Spark-plug points should be separated .032″.

The auxiliary air valve should have a 5/32″ drop when the control on the instrument board is set for the best idling position.

To check, proceed as follows: Set the auxiliary air-valve control for the best idling position. In this position groove No. 4 is flush with the end of the instrument board bracket.

Measure the height of the top of the air-valve stem from some fixed point on the engine. Depress the air valve until it strikes the inside spring. Measure the height of the top of the stem as before. The difference in these two measurements is the air-valve drop.

Make sure that the air-adjusting connecting rod clevis is so adjusted that the air shutter completely closes when the control on the instrument board is pulled out.

Clutch brake: Adjustments for wear can be made by loosening the nut on the stud which projects through the slot in the clutch cover, and by sliding the whole assembly toward the rear.

Before tightening the nut, be sure that the brake facing does not make contact with the clutch-brake disk when the clutch is engaged.

The amount of clearance should be governed by the speed of shift desired.

The standard setting allows ⅛″ to 3/32″ compression of spring with the clutch completely disengaged.

To adjust the foot (external) brakes properly make the clearance between the band and the drum 1/32″, and equal all around. In making this adjustment proceed as follows:

Adjust the nut on the rear support until the clearance between the drum and the brake band is 1/32″ at this point. Adjust the two nuts on the shank of the clevis just below the eye bolt at the front of the brake until the distance between the lower half of the brake band and the drum is 1/32″. Adjust the T-handle, which operates the adjusting screw, until there is a clearance of 1/32″ between the upper half of the brake band and drum.

The hand (internal) brakes should be evenly adjusted, so that when applied there is the same resistance on each rear wheel. The following adjustments are to be made:

Make all adjustments for wear on the side-pull rods connected to the cam-shaft levers.

By removing the rear wheel the hand-brake band can be set concentric with the brake drum by means of the adjusting set screw at the rear. The band should just clear the drum at this point.

The hand lever should be in the sixth notch from the front when brakes are applied.

Adjust the accelerator pedal to have a clearance of 3/16″ between the pedal and the top of the floor board when the throttle is wide open.

The oil pressure should be 20 lbs. to 25 lbs. at 1,000 r.p.m., corresponding to a speed of approximately twenty-five miles per hour; with the engine hot. A lower pressure when the supply is up to level indicates that the oil being used has low viscosity, or that the relief valve opens too far.

To adjust the relief-valve opening, change the tension of the relief-valve spring located in the pump housing.

Compression in the cylinders should show 75 lbs. plus or minus 3 lbs. pressure with the engine cold and at cranking speed, with all cylinder petcocks closed and the throttle wide open.

Gasoline pressure: The gauge on the instrument board should show 1½ lbs. to 2½ lbs. pressure.

The pressure may be increased by removing the plug at the top of the pressure-pump cylinder and unscrewing the smaller plug at its base. To decrease pressure, screw in the plug.

Valve clearance: Inlet and exhaust valves should have .004″ clearance between the valve stem and the roller-holder set screw when the engine is cold. Be sure that the valve is fully seated when measuring clearance.

The vibration damper on the front end of the crank shaft should be adjusted to slip under a pull of approximately 140 lbs.

Clutch pedal: When the clutch is in the fully engaged position, the pedal should depress 1¼″ under light spring pressure before resistance of the heavy clutch spring is encountered.

If the pedal is brought against the floor board before the clutch is entirely engaged, full action of the clutch spring is not obtained, and the clutch will slip.

The rod connecting the clutch pedal with the clutch release lever on the left of the clutch housing gives the necessary means for obtaining the correct adjustment for the clutch pedal. Lengthening the rod by means of the thumbscrew will increase the amount of travel under light pressure before disengaging the clutch.

No other change from the original adjustment will be required, as the clutch surfaces are automatic in their compensation for wear.

Front wheels should "toe-in" ⅜″.

Refer to the Index for the different parts of the Packard car.

INSURANCE

Fire insurance is very essential in the operation of an automobile, on account of the exposure it is subjected to, both on the street and in the garage, and most owners carry fire and theft policies.

Liability insurance is also a very important asset, and owners should be very careful about their selection of a company to carry their risk. The company should necessarily be one with large assets, and of sufficient financial strength to protect the policy holder through years of action in the courts, because in some cases, especially where serious injury is involved, regardless of the cause or blame for the accident, years have elapsed before settlement is agreed upon, or final judgment is rendered.

Kinds of Insurance

There are five classes of automobile insurance, as follows:

1. Fire and theft.
2. Liability.
3. Property damage.
4. Collision.
5. Loss of use.

Fire and theft can be combined in one policy, or fire insurance can be written separate, excluding theft; but the theft feature cannot be written unless accompanied by the fire insurance. Collision can also be included in the fire policy, or in the fire and theft policy, but it, like the theft insurance, cannot be written separately. Liability and property damage is usually written in a separate policy although several companies are writing a joint "all risks" policy covering fire, theft, liability, property damage, and collision. This can be done by re-insurance between the liability and the fire companies.

1. **The standard automobile fire and theft policy** covers the body, machinery, and equipment of the car. Extra bodies, robes, automobile coats, hats, caps, gloves, leggings, boots, goggles, and chauffeur's livery are not included unless provided for under a separate endorsement, for which additional premium is charged in accordance with the amount of coverage desired. Automobile fire insurance is written in two forms: one covers fire and theft, and is known as a "valued policy," on account of the company being liable for the amount stated in the policy at the time of a loss; the other provides that the company may deduct a reasonable amount from the loss for depreciation, however caused. A credit in the rate is given for the latter form of coverage, which is known as the "non-valued form." A credit of 15 per cent is granted from the fire rate where an approved chemical fire extinguisher is attached to the automobile.

Theft insurance, as stated above, can only be written in connection with a fire policy, and the same conditions regarding "valued" and "non-valued" clauses apply. On all cars listing under $2,000 the companies require the attachment of an approved locking device for which a credit of 15 per cent is granted from the theft rate. Where no lock is provided, an additional charge of $15 is made.

2. **Liability insurance** provides protection against accidents to the public resulting in injury or death. The usual limits of liability are $5,000 for an accident resulting in an injury to one person, and $10,000 for an accident resulting in injury to more than one person. The purpose of this insurance is to pay judgments, costs of court, attorney fees, witness fees, investigation and settlement costs, and other expense necessary to the protection of the automobilist, not exceeding, however, the limits above stated. These limits may be increased where necessary, by payment of an additional premium.

3. **Property damage insurance** covers damage to the property of others, not exceeding $1,000.

4. **Collision insurance** covers loss or damage to your car caused by a collision with another object. There are three classes of collision insurance: one, known as the $50 deductable form, provides that the company will deduct $50 from each claim; another known as the $100 deductable form, provides that the company will deduct $100 from each claim, and still another, known as the full-coverage form, which provides that the company will pay all claims in any amount. The insurable value on collision insurance is based upon the same principle as fire insurance, a fixed percentage of the list price of the car being granted in accordance with the age, use, physical condition, etc.

5. **Loss of use:** This form of coverage has just recently been included, and applies in connection with the property damage insurance, providing reimbursement to the owner on account of sums he may be called upon to pay to others through the loss of the vehicle which has been damaged, i.e., cost of rental of another vehicle pending repairs to the one damaged, not exceeding $1,000.

Rates

Insurance rates vary in different parts of the country. Therefore it is advisable to see your local insurance agent.

LAWS

The automobile laws of the different states are so varied that it would require far too much space to give them in detail in this book.

If those who are interested will write to the Touring Board of the American Automobile Association (A.A.A.), 1108 16th Street, N.W., Washington, D.C., and enclose twenty-five cents in stamps, mentioning *Dyke's Automobile Encyclopedia* in connection, a complete **Digest of the Motor Car Laws of the United States and Cars entering Canada** will be mailed. This will be found as comprehensive as its title indicates, and it will be extremely serviceable, as well.

It is well, also, to write to the Secretary of State of your own state, and he will inform you where to obtain the laws of that state on the subject.

Automobile Licenses of Different States: the Cost and How to Secure a License

There are, in most states, two kinds of licenses issued for automobiles: One is issued to the owner of the car, covering a tax or fee on a car, as well as entitling the owner to drive the car. The other kind is a license issued only to a **professional chauffeur.**

Some states do not require chauffeur's license. Other states require the chauffeur to obtain a license, which is usually done by writing to the Secretary of State at the capital city for a form to fill out. When this is filled in, and the amount of the license is remitted, he is then furnished with a badge and receipt. Other states require an examination.

The necessary information, even though you do not purchase a license, can be obtained by writing to the Secretary of State of your state. Inasmuch as the laws are sometimes amended or changed, it would be well for the reader to write for the information, which will be supplied to him gratis, or send for the complete Digest of the laws of all states mentioned on page 1072.

The age of driver of an automobile in most states must not be less than 18 years. This varies, however, in different states, and is to be ascertained definitely from the complete **Digest of Motor Car Laws** issued by the A. A. A. Touring Board.

Note. We advise all who are interested in automobiles to join the A.A.A. See page 655.

QUESTIONS AND ANSWERS AS TO SOME OF THE "FIRSTS"

First Auto Show

Q.: In what year was the first automobile show held in Chicago and also in New York?

Ans.: The first show held in New York was in November, 1900, at Madison Square Garden, under the auspices of the Automobile Club of America. A feature of the show was a board hill built on the roof of the garden, to prove that the new vehicle would not only propel itself, but would climb a grade. The novelty of the idea appealed to the public. The first automobile show in Chicago was at the Coliseum in March, 1901. Eighteen vehicles were displayed. The gate receipts were $3,200. Mr. Sam Miles was the manager.

First Four-Cycle Gasoline Engine

Q.: Who invented the first gasoline engine?

Ans.: Nicolaus August Otto, Deutz, Germany, on August 14, 1877, was granted patents covering the four-cycle engine and the principle of compressing the mixture before exploding it. This is the principle still used on automobile engines at present. The conception of compression and four-cycle operation was not, however, original with Otto. He combined these ideas into a practical engine. They were twelve years in the making, and three countries participated in their evolution. The conception started in 1862, when a Frenchman, Alphonse Beau de Rochas, obtained a patent and wrote a pamphlet on the four-cycle engine. Six years later Boulton, an Englishman, secured a patent covering the use of compression in an engine. However, Boulton failed to work out the necessary means for compression in a practical way.

First Power-Propelled Vehicle

Q.: When was the first power-propelled vehicle invented?

Ans.: Experiments date back to 1770, when Joseph Cugnot, a French engineer, built the first automobile. He constructed a steam automobile that hauled 2½ tons at 3 miles per hour, and this vehicle is still preserved in France. In 1802, the first practical steam automobile was built by Richard Trevitluck of England, using a crank shaft for the first time, and driving by gears from the engine to the road wheels. In 1821, Julius Griffiths of England built the first comfortable steam vehicle, the first vehicle to have a coach design of body, with seats carried on springs, as they are today. In 1831 Summers & Ogle of England built a three-wheel tubular boiler and two-cylinder engine which attained a speed of thirty-two miles per hour. The first motor vehicle to carry passengers regularly for hire was built by Walter Hancock of England in 1834. The motive power was steam.

First Pneumatic Tires

Q.: (1) Who invented the pneumatic tire? (2) In what year did American manufacturers of automobiles begin to use the double-tube tire? (3) What were the prices of tires from 1900 to 1915?

Ans.: (1) At present the honor of inventing pneumatic tires is disputed between two claimants: R. W. Thompson, a Scotchman, and John Dunlap, an Irishman. The former devised an automobile rubber tire in 1839, but it never came into use, as it was a very crude affair, and seemed of no practical service. Thompson's tire was a single-tube appliance, and was invented in 1845. The solid rubber-cushion tire and the single-tube air tire were used considerably in 1899 and 1900. The double-tube pneumatic tire did not come into general use on automobiles until 1902. (2) Single-tube pneumatic tires were generally used up to 1903. Double-tube tires were in use in 1902, and were extensively adopted in 1903. (3) For a 30″ x 3½″ single-tube tire the price in 1900 was $28; in 1901, $25; in 1903 the double-tube tire casing and tube cost $41; in 1913, $21.95; in 1915, $14.30.

First American Auto Road Race

Q.: Where and when was the first American Automobile Road Race run in America?

Ans.: *Motor Age*, April 19, 1900, says: "America's first auto road race was run over a fifty-mile course on the famous Merrick road on Long Island yesterday morning. A. L. Riker, with a five horse-power electric racing wagon, won by a quarter of an hour; time, 2:03:30. S. T. Davis, Jr., in a steam Locomobile, four and a half horsepower, was second; time, 2:18:27. Alexander Fisher, in a gasoline runabout built by the Automobile Company of America, was third; time, 2:30:01." The article further states that the racers wore auto caps, goggles, and mouth protectors. Riker wore no auto togs at all, but got there just the same. This speed is averaged now almost daily on the streets.

First Auto Race

Q.: Where was the first automobile race held in America? How many cars started? How many finished?

Ans.: Chicago made the earliest attempt at an automobile race, November 25, 1895. Six cars started over a course of fifty-four miles, from Jackson Park to Evanston and back again, for a prize of $500 offered by the Chicago *Times-Herald*. Four of the cars were propelled by gasoline and two by electricity. Two cars finished. Charles E. Duryea won in ten hours and twenty-three minutes. The course was covered under highly unfavorable conditions, the roads being heavy with mud and snowy slush.

First Rubber Tire

Q.: When was rubber first discovered, and who made the first rubber tires?

Ans.: The first mention of rubber was in 1525, when the Spaniards in Mexico saw the natives playing with balls of a remarkable elasticity. In 1770 it was suggested as an eraser for pencil marks. In 1823 Macintosh of Manchester, England, found that rubber would dissolve in benzine, and began making waterproof fabrics. In 1832 the Roxbury Rubber Company was formed in Massachusetts to engage in this work, and Charles Goodyear was one of its employees. Goodyear discovered vulcanization in 1835. In 1842 he began producing rubber shoes. The first use of rubber tires was when Dietz in 1835 patented a rubber cushion applied to an iron ring or tire. R. W. Thompson, an Englishman, on December 10, 1845, patented the first pneumatic tire.

Auto Club of America

Q.: In what year was the Automobile Club of America organized, and how many cars were produced that year?

Ans.: On Wednesday, January 7, 1899, a public meeting was held at the Waldorf-Astoria Hotel New York, and as a result the National Automobile Club of America was chartered on the following August 6. Six hundred machines were produced in 1899.

Jump-Spark Coil Invented

Q.: When was the jump-spark coil invented and first used?

Ans.: In February, 1852, Emperor Napoleon of France offered 50,000 francs to the man who could produce the most important electric invention during the next five years, which period was later extended five years. This award was finally given to H. D. Ruhmkorff, a Paris instrument maker, for inventing the jump-spark coil, often referred to as the Ruhmkorff coil or high-tension coil. This coil, however, was first actually developed by Prof. Charles G. Page of Washington, D.C., following the researches of Faraday, Joseph Henry, and W. Sturgeon, about 1831, and really should be more properly termed Page's coil.

Knight Engine: Its History

Q.: Has the Knight engine been tried out fully, or is it still an experiment? What foreign manufacturers use it?

Ans.: The Knight sleeve-valve type of engine was invented in Chicago in 1903. The engine was under experiment until 1905, at which time it was given severe tests in Elyria, Ohio. In 1906 Charles V. Knight submitted his engine to the largest motor car company of England, the Daimler Company. After tests, the Daimler Company adopted it. Other leading European automobile manufacturers who adopted this type of engine are the Panhard Company, France; Mercedes Company, Germany; and the Minerva Company, Belgium.

INSTRUCTION No. 84

DICTIONARY: Meaning of Motoring Terms

Note. If the Dictionary does not give the meaning, or if a description is desired, see Index for the subject.

See page 529 for "Storage Battery Words and Terms." See page 1079 for English-French Dictionary.

By referring to the Index, the definition of many other words can be found.

A

Abrasion: The act of wearing or rubbing away; a chafe.

Accumulators: A set of secondary cells—also called storage batteries containing positive and negative plates, and filled with electrolyte.

Advance Spark Lever: See Index.

Air: Composed of approximately one-fifth oxygen and four-fifths nitrogen, with some carbonic gas.

Air gap: A term having almost the same meaning as "clearance." Often applied to the space between the field poles of a generator, motor, or magneto and its armature.

A.L.A.M.: Means Associated Licensed Automobile Manufacturers. Now known as S.A.E. (Society of Automotive Engineers).

Alternating current: A current changing its direction of flow, or "alternating" backwards and forwards.

Aluminum: This metal, the chief characteristic of which is its lightness, is not generally used in its pure state, but is alloyed with a small proportion of zinc; sometimes, for special requirements, a small quantity of copper and manganese are added.

Ammeter: An instrument that indicates amperes or rate of current flow.

Ampere: See page 529.

Ampere-hour capacity of a battery: A term used to express the amount of current that can be gotten out of a battery of a given size. An actual 50 ampere-hour accumulator should be capable of giving 1 ampere for 50 hours, or 2 amperes for 25 hours; but the ratio becomes disproportionate as a higher rate of current is taken from the cell. See also page 560.

Annealing: Softening of metal. By placing it in a fire and getting it red hot, and then permitting it to cool without water, it softens.

Annular ball bearing: See page 19.

Anode: The positive (+) pole of a current; opposed to cathode.

Anti-clockwise rotation: Same as counter-clockwise.

Asbestos: This material is of mineral origin (large quantities come from Canada). In its natural state it is fibrous and somewhat brittle. As it resists great heat, it finds considerable application in motor work for engine jointing in the form of packing washers (of copper sheet and asbestos). Asbestos cord is used for covering exhaust pipes where these pass through woodwork, etc. Worked up into a fabric with brass wire, it is largely used for brake-band linings and clutch covering, as it cannot be burned out by excessive friction.

Atmospheric pressure: The earth is surrounded by a large, thick envelope of gases which is known as the atmosphere, and is commonly spoken of as the air. Contrary to general belief, the air does possess weight. In fact, if we went to the sea-shore and took a column of air one inch square and as high as the atmospheric envelope exists, this column would weigh about 14.7 lbs.; consequently the atmospheric pressure at sea-level is 14.7 lbs. per square inch. The higher the altitude above sea-level, the less will be the atmospheric pressure.

Atom: The smallest divisible part of a chemical element.

Aviatrix: Feminine for Aviator. A woman who operates a flying machine.

B

Backlash: The play between the teeth of two gears which are engaged (in mesh); see also Index under "Backlash."

Back-pressure: Term applied to restricted exhaust discharge. Unless the muffler is of sufficient size, there will be back pressure, and the exhaust will not be discharged as rapidly as it should.

Ballast resistor: See page 430.

Benzol: A promising motor fuel. It is a by-product of coke. It contains the same elements as gasoline, but the chemical formula is slightly different. In England it is used to great extent for fuel, also for explosives, dyes, and chemicals. All gas plants in England are being equipped to produce benzol. It is stated that experiments with the material are being made in the United States.

Bezel: The groove in which the glass cover of the speedometer or clock is fitted.

Bore and stroke: See Index.

B.H.P. (Brake horsepower): Measurement of horsepower of an engine of actual net work of the engine or horsepower delivered at the crank shaft. See page 1044.

British thermal unit (B.T.U.): The amount of heat required to raise the temperature of 1 lb. of water 1° F. (at its maximum density, which is at 39.1° F.). This expression is much referred to in the study of the value of various fuels for engines: thus gasoline ranges about 19,000 to 20,000 B.T.U. per lb. A pound of gasoline of 58 s.g. is approximately eight-tenths of a pint. 1 B.T.U. is equivalent to 778 foot lbs. of work. See also "Thermal efficiency."

B.T.U.: See "British Thermal Unit."

By-pass: A means by which a flowing substance can take a course other than its usual one; an extra passage.

C

Calorific value: This term is used with reference to various fuels, such as gasoline, benzol, paraffin, etc., and represents the effective heating power per pound in terms of British Thermal Units. 1 lb. of gasoline contains about 19,000 B.T.U.'s.

Calorimeter: An instrument to determine the heat content of a substance, that is, how much heat it will give off when burned. Used to determine the number of B.T.U.'s per pound of gasoline.

Calory: The unit of heat (metric system) to express the amount of heat required to raise 1 gram of water from 0° to 1° Centigrade.

Cam shaft: The shaft running through the engine which has the cams placed upon it at certain fixed positions.

Camber: To curve or bend. As applied to the automobile, it refers to the camber of the front wheels at the ground. See page 906.

Carbon: One of the well-known non-metallic elements. It is an excellent conductor of electricity. As applied to the automobile, it refers to the carbon deposit which accumulates in the combustion chamber of an engine. In a hard state it works well as a contact medium in conjunction with copper or brass; it is, therefore, largely used for the brushes of the magneto, and also for the brushes of car-lighting dynamos. Carbon, in its natural form of graphite, is used as a lubricant for gearing. It is generally mixed with grease, and is supplied ready prepared by lubricant manufacturers.

Carbonize: The deposit of carbon upon the points of the spark plugs and the various internal portions of the engine cylinder and exhaust passages.

Caster: As applied to the automobile the word refers to the "caster" or "cant" or inclination from the vertical, as given to the front axle. See page 907.

Cathode: The negative pole (−) of a current; opposed to anode.

Cell: An electrical cell is a vessel complete with its contents, and a number of these form a battery, or a set of storage batteries. Each cell must contain positive and negative plates, and some form of electrolyte.

Celluloid: A compound of camphor and gun-cotton. Its transparency and flexibility are its chief characteristics. Non-inflammable celluloid is now made for windshields.

Center of gravity: The point at which a body balances. For example if you lift an engine out of a car with a hoist, you always try to attach the chain so that the engine will stay level when hoisting. In other words, you try to place the chain at the center of gravity of the engine. If a car has a high center of gravity, it has a tendency to turn over when making a turn at high speed. Such a car would be called "top heavy." In order to prevent turning over, racing cars are built with a low center of gravity. For example, the center of gravity of a wheel is the center of the wheel hub, because that is where it balances. If a body is placed below that center it will have less tendency to be "top heavy" than if placed above the center of the wheel, because the center of gravity of the automobile would be nearer the ground.

Centigrade: A scale of temperatures usually used in foreign countries and in scientific work. See page 1048.

Chamfer: A small channel or groove cut in metal or wood; the corner beveled off.

Change gears: The transmission or system of changing the gears in the gear box.

Chassis: Pronounced "chas-sy." Derivation, French; a frame in wood or metal; the framework of a wagon; later the term was applied to the framework of a locomotive; then to the longitudinal and transverse frame members of a motor car. By extension it also designates the whole of the mechanical portion of a motor car. More correctly, however, the word chassis should only apply to the metal framework receiving the engine gearset and controlling mechanism.

Chauffeur: Pronounced "Sho-fur." Derivation, French, chauffeur, a person or a thing that heats. A chauffeur is a man in charge of a furnace or boiler fire. The first use of the word chauffeur was during the revolution of 1789, when bands of brigands heated (*chauffé*) the feet of their victims in order to make them reveal the place where their money was hidden. The "chauffeurs" were stamped out during the Consular period. The word chauffeur was first applied to motor-car drivers under the popular supposition that they had to tend a fire. On the French railroads the chauffeur is the fireman; the engine driver is the mechanician.

Chauffeuse: A woman chauffeur.

Check-valve: A valve which permits the passage of a fluid or gas in one direction only.

Chemical compound: When two or more chemical elements are united they form a chemical compound. This can be a solid, a liquid, or a gas.

Chemical element: Matter which cannot be divided into simpler chemical forms. It can be a solid, a liquid, or a gas.

Circuit: The path of the electrical current; the conducting material, or wires.

Circuit-breaker: See "Contact breaker"; "Interrupter."

Circulating pump: Pump used to circulate the cooling water. Operated by the engine.

Clearance: As applied to the automobile, this refers to the permissible space or air-gap between the valve stem and tappet; also to the air-gap space between ignition contact points when separated; also to the air-gap of spark-plug points and other parts. It also refers to the lowest point of an automobile which is above the ground. It also refers to the space or oil film allowed between a bearing surface and the shaft.

Clockwise rotation: Rotation to the right, or in the direction of the hands of a clock. See Index under "Magnetos, clockwise rotation from drive end."

Clutch: A device for connecting and disconnecting the engine from the transmission—usually placed in or on the inner face of the flywheel rim.

Clutch pedal: The foot pedal which connects and disconnects the clutch.

Coefficient: A known constant quantity. That which co-operates with a variable or unknown quantity.

Coil and battery system of ignition: In a battery the electricity is obtained by chemical means instead of mechanical means, as when a dynamo is used. The coil has nothing to do with the generation of the electric current, its function being "to gear up," intensify, or increase the pressure or transform the low-voltage primary current into a high-voltage secondary current, to enable a spark to be produced across the air gap of the plug points.

Combustion space: The space between the end of the piston (when on upper dead center) and the head of the cylinder. That portion over the valve is also included.

Compensating air valve: Also termed auxiliary air valve; a valve which counteracts the tendency of an over-rich mixture as the speed increases.

Compensating gear: See "Differential."

Compound: A mixture of several ingredients.

Compression: A term implying that the explosive charge of gas and air drawn into the cylinder on the suction stroke is subjected to a strong squeezing effect on the next stroke. The charge is pressed into a space about one-fifth the volume or space of that occupied by it on the suction stroke, equaling 55 lbs. to 90 lbs. pressure per square inch. See also page 116.

Compression tap or cock: A small tap placed at the upper end of the cylinder, which can be opened to relieve the compression, to make cranking easier.

Concentric: The opposite of eccentric. Applied to carburetor floats and piston rings.

Condensation: The process of turning a vapor into a liquid. As an example: The carburetor takes in raw gasoline and air, thus forming a gaseous "mixture" known as a vapor and thereby performing the process of vaporization. If this mixture (vapor) now comes into contact with a cold inlet manifold, it will be turned into small drops of raw gasoline; this latter process is called "condensation." Another example: Small drops of water often collect on the outside of a glass of ice water, due to the condensation of the moisture (vapor) in the air, or due to the warm air vapor striking the cold glass. If steam comes in contact with a cold surface, it will condense into water, just as the vapor in the air did in the example above: the reverse of evaporation.

Condenser: An important part in a spark-coil or high-tension magneto. See Index.

Conductor: A material along which electricity will readily flow, such as copper, platinum, steel, and, in fact, all metals. Silver is the best conductor, but copper is only very slightly inferior. Carbon is a non-metallic element, but an excellent conductor much used in magneto construction for the brushes. The wires or cables of the ignition circuit are sometimes referred to as conductors or "leads."

Connecting rod: That member which connects the piston to the crank shaft of an engine. It has an oscillating movement.

Constant: A value which remains the same under all conditions, that is, the value is constant. The word is often used in connection with another value which is variable. See also page 1044.

Contact-breaker: The interrupter on a magneto. Also applied to the interrupter arrangement on the "make-and-break" igniter. See "Interrupter."

Contact-screw: The small screw, having a platinum point, against which the trembler vibrates.

Contact sector: One of the sectors in a timer or distributor.

Continuous or direct current: This implies that the current flows in one direction. The direct opposite of alternating current.

Contraction: The opposite of expansion, usually the result of cooling.

Counter-clockwise rotation: A direction opposite to clockwise rotation.

Crank shaft: The main shaft in an engine which rotates as a result of the force exerted on its cranks which are connected to the pistons.

Current: The flow of electricity.

Cut-out (electric): See Index.

Cut-out (muffler): A valve opening into the exhaust pipe at a point between it and the muffler, which, when opened, permits the exhaust gases to escape through it directly into the atmosphere instead of being forced through the muffler.

Cylinder en-bloc: The cylinders cast together in one piece.

Cylinder priming cock: Same as the compression relief cock. Usually placed in the head of the cylinder for injecting gasoline.

D

Dead rear axle: A rear axle that does not turn. Type usually used on double chain-driven cars, and internal gear-drive trucks.

Demountable rim: A form of rim that can be taken off the wheel without deflating the tire.

Density: Compactness; mass of matter per unit of volume See also page 530.

Depolarize: To deprive of polarity.

Differential gear: See page 17.

Direct current: Electric current where the current flows continuously in one direction. Unlike "alternating" current.—the opposite.

Distributor or Distributer: A special form of rotary switch, which directs the high-tension current to the various spark plugs.

Dry battery: Called dry cells or primary cells. A series of primary cells which do not contain liquid electrolyte.

Dynamo: A generator of electricity. The dynamo is usually used on a motor car to light the electric lights and to recharge storage batteries and in some instances furnishes current for the ignition.

E

Earth connection, or "ground": An inaccurate term when applied to the electric circuits of a motor car. The car is insulated from the road by the tires, hence the "earth" is not used at all. What is meant is that the framework of the car is used as a return conductor, so as to dispense with some of the wires.

Eccentric: Two circles (one inside the other) are said to be eccentric when their centers are not at the same point.

E.H.P.: Electric horsepower (746 watts).

Electric ignition: Any form of ignition by which the mixture in the combustion chamber is ignited by means of an electric spark.

Electrode: The insulated part placed in the igniter of a low-tension system of "make-and-break" ignition. The center rod of a spark plug.

Electrolyte: A liquid that undergoes chemical decomposition when an electrical current is passed through it. The solution used in a storage battery. Is generally made by mixing sulphuric acd and distilled water in proportion of two parts of acid aid five parts of water. These parts are measured out by volume. An earthen vessel must be used and the solution stirred while mixing. Never pour the water into the acid. See "Specific gravity."

Electro-magnet: If an insulated wire is wound around an iron core and current is passed through the wire, this is an electro-magnet. Sometimes the wire is wound on a spool made of non-magnetic material, and is so arranged that the core can be inserted or withdrawn as desired. This form is known as a solenoid magnet.

Element: The simplest divisible conception; for example, a pencil may be considered as made up of several elements, namely, the wooden case, the lead or graphite core, the rubber eraser, etc.; as applied to the storage battery, see page 527, and Index.

E.M.F.: Electromotive force. The voltage. The pressure. Tension. See pages 175 and 180.

En-bloc: Cast in one piece, as four or six-engine cylinders. A French term. The English expression is "in-block."

Energy: The capacity for doing work. Passing a current of electricity through a storage battery causes energy to be stored up in a chemical form. Then this energy is taken off in an electric form. Winding a watch causes energy to be stored up in a mechanical form in the spring.

E.P.M.: Explosions per minute of a gasoline engine.

Exciter brush: Could refer to the third brush of a third-brush regulated generator, as the current for exciting the field windings passes through this brush.

Exhaust box: See "Muffler" and "Silencer."

Expansion: When anything becomes larger in size, it is said to expand. This term is usually used in connection with the effect of heat. For example, if a valve stem is heated up, it will become longer; if an engine cylinder is heated, the bore will become greater; if a piston is heated, it will become larger in diameter.

F

Fahrenheit: A scale of temperatures usually used in English-speaking countries. See page 1048.

Fiber: A slender, thread-like substance, or filament; raw material which can be separated into threads for making up textile fabrics, such as brake lining, clutch lining, etc. Also used for insulated bases for electrical purposes.

Field: The seat of magnetic flow, between the pole pieces of a generator or motor.

Field coil: The coil of insulated wire which surrounds the field poles.

Fierce clutch: See Index.

Flash point: See page 165.

Fliverboob: A reckless driver; the term is used in the same manner that the term "jaywalker" describes the careless pedestrian.

Flux, magnetic: Lines of magnetic force that pass or flow through a magnetic field.

Flywheel: A heavy wheel rotating without contact with anything save its axle, by the momentum of which an even running of the engine is obtained.

Foot pound: This is a unit of work or energy. The lifting of one pound one foot. The same unit is also applied to torque. See page 1043.

G

Galvanometer: An instrument for measuring the presence, extent, and direction of an electric current.

Garage; plural, garages: Derivation, French. The word has been taken bodily, pronunciation and spelling from the French language, in which it is a variation of the word *gare*, a station or terminal for either railway trains or boats. Garage, as a noun, means, in both French and English, a place in which motor cars are kept, and is sometimes applied to shops wherein motor cars are repaired. The verb, "to garage," means the act of putting a car in the garage building. Pronounced with the final *g* soft, the final *a* open and the accent upon the last syllable.

Gas: A substance which readily changes both shape and volume according to physical conditions imposed upon it, as, for instance, pressure and temperature which determine the volume. If the gas is a compound, it can be divided into molecules. If the gas is an element, it can be divided into atoms. A gas which is a compound may be divided into two or more gases, which are elements. Each one of these gases can then be divided into atoms.

Gasoline or gasolene: English, gas; Latin *oleum* (oil). A light grade of petroleum.

Gear box: See "Transmission."

Gear ratio: The number of revolutions of the engine made for one revolution of the road wheels—this depending on which "speed" or gear is in use. Thus the high-speed gear ratio may be 4 to 1, i.e., four revolutions of the engine to one of the road wheels. See Index.

Gear set: The transmission.

Governor: A device to regulate the speed.

Gram: A metric unit of weight. One pound equals 454 grams. A gram is, therefore, the 1/454th part of a pound.

Gravity: The attraction between the earth and various matter; the force which causes bodies to fall, water to run down hill, etc. The term is usually applied to the gasoline fuel-feed method, where the gasoline is fed to the carburetor by gravity or from a higher level to a lower level; also often applied to the specific gravity of a storage battery. See also page 529.

Ground: Connection of electric wiring to the frame of the car or metal part of the engine. The term was originally derived from the fact that with telegraph and telephone systems one wire was used, which was insulated from the ground. For the other, or return wire, to complete the circuit, the ground was used. A piece of wire was attached to an iron pipe and driven deep into the ground at each end of the circuit. This same principle is used in automobiles. One wire is insulated from the frame or metal part of the car. The frame is used as the return wire.

Gudgeon pin: The wrist pin, also referred to as the piston pin, the latter being the correct term.

H

Half-speed shaft: The small shaft, revolved at one-half the speed of the crank shaft by means of any suitable gearing—the cam shaft.

Heat units: The unit of heat. See "British Thermal Unit."

Helical: Shaped as a helix.

Helix: A line shaped like a screw thread or a coil of wire (page 181), or a coil tube.

High gear: Combination of gears ordinarily used in running. The highest ratio of gearing—on some cars 2½ to 1, others 3 to 4½ to 1.

High tension and low tension: See Index.

Hydraulic: Pertaining to fluids in motion. For example, hydraulic analogy is often mentioned in this book, and refers to water.

Hydraulic analogy: A method of explaining something by means of stating how water would act under like conditions. Often used in this book to show how a current of electricity acts in a manner similar to a current of water.

Hydro-carbon engine: A gasoline, kerosene, or gas engine.

I

Idling: Refers to the engine when running slow, and the car is standing still.

Igniter: Has various meanings. On "make-and-break" ignition, the part that makes the spark. On high tension it sometimes means the spark plug, and others call the "commutator" or "timer" the igniter. The correct meaning should be the part that ignites the gas.

Ignition cam: The small cam on the half-speed shaft which either causes a make-and-break of the current, or is notched to receive the nose of the trembler in timers of the mechanical vibrator type.

In-block: English form of the French expression "en-bloc."

"Indicated" horsepower or I.H.P.: The power delivered to the piston inside of the cylinder; it can be measured by taking an indicator diagram which shows the pressure of the explosion in pounds per square inch. From this the mean effective pressure during the stroke can be calculated.

Induced current: The momentary current set up in a circuit, by the proximity of wires conveying the primary current, but not connected with those wires.

Induction: An influence exerted by an electrically charged body, or by a magnetic field, or by neighboring bodies, without apparent communication or connection.

Induction coil: A step-up transformer. An apparatus through which the primary current is made to pass close to the secondary wires, thus setting up the induced, or high-tension current.

Inductor: See Index under "Magnetos, inductor types."

Inertia: A property which tends to keep still bodies at rest. The same property also tends to keep moving bodies in uniform motion. For example, an automobile is standing still on a level road. It will require considerable effort to move it, because the inertia tries to keep it at rest. Another example: an automobile is traveling at the rate of 60 m.p.h. It will require considerable effort to stop it, because the inertia tries to keep it in uniform motion.

Inlet-valve cage: A housing used over an inlet valve.

Inspiration: Means the same as "suction" or "intake," as, suction stroke, intake stroke, or inspiration stroke.

Insulated: When one conductor is separated from another conductor by an insulator they are insulated from each other. In the single-wire system, the conductors connected to the negative (−) terminal of the battery are insulated from the car frame when the positive (+) terminal of the battery is connected to the frame.

Insulation: The protection of wires, or leads by some suitable material which is a non-conductor of electricity.

Insulator: A material through which electricity cannot flow, for instance, porcelain, mica, india-rubber, fiber, vulcanite, glass, celluloid, paraffine-wax, silk, shellac, steatite, slate, etc.

"Int": When found stamped on a coil or terminal, means interrupter connection.

Integral: The whole made up of parts.

Intensify: To increase, to render more intense—to intensify the voltage (pressure) means to increase the voltage.

Intensity coil: See "Induction coil."

Intermediate gear: Combination of gears intermediate in power and speed, between the low gear and the high gear, usually "second gear."

Intermittent: Applied to a cam on the engine, meaning that the motion is not steady but at intervals.

Internal combustion engine: See Index.

Interrupter: A device used on ignition systems for interrupting the flow of current in the primary winding of a coil or magneto. Also termed "contact-breaker" and "circuit-breaker" (which see, under respective headings).

J

Jaywalker: A careless pedestrian. One who does not observe regulations.

Jump spark: A spark which jumps from one terminal of the secondary coil to the other. See "Induction coil."

Jump-spark coil: Another name for induction coil, spark coil, or high-tension coil.

Jump-spark plug: See Index.

K

Kilometer: 1,000 meters, or ⅝ of a mile.

Kilowatt: 1,000 watts, or 1 1/3 horsepower

L

Laminate: Built up of thin plates of metal, as shims or a "laminated core" in armatures.

Lapping: A term applied to the operation of grinding in or fitting rings, pistons, etc.

Limousine; plural limousines: Derivation, French. A motor car body with a permanent top projecting over the driver and having a protecting front. The name was originally applied to a cloak worn by the inhabitants of Limousine, an old province of central France. It was later extended to the covering of a carriage, and then to one type of enclosed motor-car body. At present, the term often is applied to a complete car having a limousine body. (See page 5.)

Liners: Metal plates, usually very thin, placed between two halves of a bearing so that by taking out a liner the bearings can be tightened.

Lines-of-force: Imaginary lines, in the direction of which it is assumed that the lines of magnetic attraction and repulsion pass or act. See also pages 179, 180, 250, 338.

Liquid: Any substance which remains constant in volume, but readily assumes the shape of the vessel in which it is contained.

Live: The parts connected to the negative (−) or insulated battery terminal are referred to as "live" when the (+) terminal is connected to the frame of the car.

Live axle: See page 6.

Lost motion: Suppose that, for the purpose of towing, we attached a tow rope between a disabled automobile and a trouble car. Owing to the slack in the rope, the trouble car when started would move a certain distance before it started to pull the disabled car. This distance would be "lost motion." In general, when one mechanical device is connected to a second mechanical device (as, for example, two gears where the teeth are meshed), and the first moves a certain distance before it imparts motion to the second, this distance is known as "lost motion." There is also lost motion between a shaft and a worn bearing, more often termed "clearance" (see Index.).

Low speed: The ratio of gearing in a transmission for running the rear axle at the lowest speed.

M

Magnetic circuit: The complete circuit, or course through which magnetic lines-of-force pass from N pole around the circuit returning to the same N pole. See page 179.

Magnetic field: The field surrounding a magnet through which the magnetism flows from N pole to S pole.

Magneto: A device operated mechanically and driven direct from the engine, and which generates electric current but "alternating" instead of "direct." There are two forms: the low tension and the high tension.

"Make-and-break" ignition: Low-tension system. No spark plug used.

Manganese bronze: Composed of copper, zinc, and manganese. It makes very strong and tough castings. Forged front axles of this alloy are used on some American cars.

Mechanical efficiency: The ratio between the indicated h.p. and the h.p. available for useful work at the engine shaft.

Mechanical equivalent of heat: This is represented by the number 778, which is the number of foot pounds of work equivalent to one British thermal unit of heat.

Mechanical valve: Applied to either the exhaust or inlet valves when operated by a cam or mechanical means. The exhaust valve is always mechanically operated, whereas the intake is sometimes opened automatically by the suction of the piston.

Mechanician: A racing driver's helper.

M.E.P.: See page 1044.

Mesh: Usually applied to the meshing of the teeth of two gears; for instance, the teeth of the large half-time gear, in Fig. 82, page 52, (G2), meshes with drive gear (G1) on the crank shaft.

Misfiring: Term applied to missing of one of the spark plugs.

Molecule: The smallest divisible part of a chemical compound. Iron or steel is said to be made up of molecules. They may be considered as little magnets. See Index.

Mono-block cylinders: Another name for in-block, or all in one casting.

Motor: The engine or motive power. Technically it refers to an electric motor, and should never be used when referring to the engine.

M.P.H.: Miles per hour.

Muffler: A device used to muffle or silence the noise of the exhaust gases passing from the exhaust valve of an engine. See page 48.

N

Negative pole—minus sign: The point to which the current returns after passing through the circuit. Designated thus: (−)

Nickel: Used in the form of an alloy with steel, viz., nickel-steel. For exhaust valves a high percentage (20 to 25 per cent) nickel steel is the most suitable material, as it effectively resists the intense heat and oxidizing action of the exhaust gases. Nickel is now the standard material for spark-plug electrodes.

North pole: The pole of a magnet from whence the lines-of-force start.

O

O: A small (°) placed alongside of a figure expresses degrees. See Index for meaning of degrees.

Ohm: A unit of electrical measurement of resistance. The resistance that an electric current meets in flowing through a conductor is measured in ohms.

Open circuit: If a conductor is broken, or if it becomes loose from its connection, the electrical circuit is open and no current can pass.

Oscillate: To swing back and forth like a pendulum. A connecting rod has an oscillating movement. The word also refers to the action of a condenser of an ignition system where the electric current oscillates when the condenser is in action. See page 191.

Oscillating discharge of condenser. See page 191.

Otto, or four-stroke "cycle." is an expression often used in connection with gasoline engines. It means that the power is developed during a complete cycle or four strokes, the principle first adopted in the Otto gas engine. The complete cycle comprises four distinct operations, one occurring at each half-revolution or every stroke of the piston: thus (1) suction stroke, (2) compression stroke, (3) impulse or firing stroke, and (4) exhaust stroke.

P

Parabolic: Pertaining to, or formed like a parabola. One of the conic sections. See also page 436.

Periphery: That part of a wheel or disk farthest from its center. The circumference.

Permanent magnet: A magnet made of hard steel that possesses magnetic power and tends to retain it.

Pet cock (also called relief cock and compression cock): A small valve usually placed in the head of a cylinder or on the carburetor.

Petrol: Gasoline.

Phosphor-bronze: An alloy mainly consisting of copper and small proportions of tin, lead, and phosphorus, the proportion of the latter being very small. It is a very tough hard-wearing alloy. Largely used for engine bearings.

Pinions: Gears that have the teeth cut right in the hub.

Platinum: This very expensive metal (price ranging from $30 to $40 per oz., according to the market) is used for the contacts of the magneto. It is practically infusible (it has a very high melting point) and non-corrodible, and thus effectively resists the burning and oxidizing action of the electric spark. It is also used for the "leading in" wires of the electric bulbs used for car lighting, as its ratio of expansion (due to heat) is the same as glass. Sparking-plug electrodes are, in a few instances, also made of it. Tungsten is now extensively used instead.

Polarity: Refers to the North or South pole of a magnet; the positive or negative terminal of an electric circuit.

Poppet valve: The word poppet probably is a corruption of the name puppet applied to this type in England, on account of its resemblance to the popping up and down of the puppets in the old-time Punch and Judy shows.

Porcelain: The insulating material of the spark plug.

Port: Openings in the cylinder for exhaust, inlet, water, or valves.

Positive pole: Usually indicated with a plus sign (+), means the positive terminal, or wire from which the current starts in an accumulator or dynamo. The carbon terminal of a primary or dry battery is positive.

Potential: Refers to ability to exert electrical energy. Usually expressed in terms of volts.

Potential difference: Difference of electrical pressure which causes an electric current to flow. See also page 175.

Potential drop: Loss of electrical pressure. See also page 175.

Precision: Accuracy.

Pre-ignition: Ignition occurring earlier than intended.

Primary battery: A series of either wet or dry cells depending upon chemicals for the generation of electricity, without charging from a dynamo or other battery.

Primary wires: The wires, or leads, conducting the primary or low-tension current to the place, or places, where it is required for use.

Propeller shaft: The drive shaft from the transmission to the rear axle.

Q

Quadrant: Usually applied to the quarter-circle on which the spark lever and throttle lever is attached on the steering wheel.

R

Reciprocating: A back-and-forth movement applied to the action of the pistons in the engine.

Rectifier: An electrical device for changing alternating into direct current.

Relay: An electrical device usually termed a "cut-out." See "Cut-out, electric" in Index.

Resistor. See pages 547, 554, 564.

Retard: A decrease in the speed. Usually applied to "retarding the spark," meaning to set the timer back so that the ignition will be later or slower.

Rotary: Revolving motion; opposite of reciprocating motion.

Rotary valve: See page 52.

R.P.M.: Revolutions per minute.

Rubber: For tire construction rubber supplies come from various parts of the world. Among the finest grades is the well-known "Para" or Brazil rubber. South America rubber generally is considered very good, but excellent supplies now come from Borneo, India, Ceylon, Federated Malay States, and, in fact, many other tropical lands. Pure rubber lacks certain important physical characteristics indispensable for tires, such as stability under change of temperature. Pure rubber becomes soft under the influence of heat, and hard and brittle when subjected to cold. The process of vulcanization renders the rubber proof against heat and cold, and also renders it tough and resilient, so as to possess "life" and vibration-absorbing properties.

S

Scored: Marred by ridges or grooves. Usually referred to in connection with cylinders.

Seats: That part of the chamber upon which the valve rests. Applied to the valve in the engine.

Secondary battery: A storage battery.

Secondary coil: The winding in which the high-tension current is generated, which is quite distinct from the primary current.

Seize: As applied to the automobile, this refers to the piston, as when it is said that the "piston seizes" or sticks to the wall of a cylinder when unduly heated as a result of expansion. It also applies to the bearings when they "seize." Generally caused by lack of lubrication or too tight a fit of the piston.

Shim: Thin sheets of paper or metal which are used as spacers to regulate the distance between two objects, such as two halves of a bearing. See pages 36, 783.

Short-circuiting: Providing a shorter path; placing a wire or other conductor from positive to negative side.

Shunt: To turn aside or branch off. See also Index.

Silencer: See "Muffler."

Sleeve valve: See page 88.

Solid: A substance which does not readily change either shape or volume.

Solenoid: An electromagnetic helix. See page 181.

South pole: The pole of a magnet where the lines-of-force flow into it.

Spark: The spark which passes between the points of the spark plug.

Spark coil: A coil through which electric current is passed and intensified.

Spark control lever: The lever on the steering column (usually the short one) attached to the timer.

Spark gap: A safety device on a magneto to prevent the armature windings being strained or short-circuited owing to a faulty spark plug or wiring circuit; also applies to the gap between the points of the spark plug.

Spark plug: A device consisting of two electrodes separated by an air-gap and used to obtain a spark from high-tension electricity, thus igniting a charge of gas. See pages 188, 233.

Specific gravity: The relative weight of a substance as compared to water at 4°C. Thus if a cubic foot of a substance weighs twice as much as a cubic foot of water, the specific gravity of that substance is 2. See page 530.

Spelter: Zinc; used for brazing, etc.

Starting crank: A crank for starting the engine.

Starting plug: A small brass plug which fits into an opening on the dashboard and closes the circuit. When removed, the circuit is broken.

Streamline body: See Index.

Stroke: Usually referred to as the stroke of an engine, meaning the length of the up-and-down motion of a piston.

Stroke of engine: See page 48.

Studs: Bolts, with threads cut on both ends, screwed into engine cylinders to fasten them to the base; also used to fasten down cylinder heads.

Substance: Refers to any type of matter, such as solids, liquids, or gases.

Suction: Assume two tanks A and B. In tank A, we have any kind of gas such as air, gasoline, vapor, etc., at a pressure of 20 lbs. per square inch, while in tank B, we have a gas at a pressure of 10 lbs. per square inch. If we now connect the two tanks with a pipe, it is obvious that gas will flow from A to B, that is, from the high pressure to the low pressure. In this case, since B has a lower pressure than A, we should consider that B exerts a suction on A. In ordinary usage, we consider that suction exists when the pressure is lower than atmospheric pressure. Thus if we had gas in tank B which was at a pressure less than 14.7 lbs. per square inch, and opened a valve in this tank, air would rush into the tank and we should consider the tank as exerting a suction on the air. (See "Vacuum.")

Symbols: See Index.

Synchronization: The act of synchronizing.

Synchronize: To cause to happen at the same time. To time two or more sparks to occur exactly at the same instant, or at a similar period in a given cycle of operation. To set the distributor brush on contact with a spark-plug terminal at the same time that the contact-breaker is made to open —timing the ignition, for example; termed "synchronization."

Synchronous: Happening at the same time. For example, on an ignition system, where a distributor and contact-breaker are used, the contact points of the timer are made to open or close at the same time that the distributor brush makes contact with a spark-plug terminal. See page 195.

T

Tappet: A push rod connected between the cam and valve; also termed a plunger.

Thermal efficiency: The ratio of work actually done, when expressed in heat units, to the total heat supplied in the fuel that enters the combustion chamber is always less than 100 per cent. For example: Suppose we introduce a pound of gasoline (approximately .8 pint) into a cylinder. This amount of gasoline contains about 19,000 B.T.U.'s (see "B.T.U."). Now suppose we received from the crank shaft, during the consumption of this pound of gasoline an amount of work equal to 4,424,600 foot pounds of work. One B.T.U. is a unit or quantity of heat, therefore energy, and by experiment has been found to be equal to 778 foot pounds. The 4,424,600 foot pounds of work we received from the crank shaft could be expressed as

$$\frac{4{,}424{,}600}{778} \text{ or } 5700 \text{ B.T.U.}$$

The thermal efficiency of the engine would then be 5,700 B.T.U. ÷ 19,000 B.T.U., or 30 per cent thermal efficiency.

Third brush: Refers to an auxiliary brush used for the purpose of exciting the field-windings. It is so placed on the commutator in relation to the main brushes that it serves to regulate or govern the current output of the generator.

Throw: Usually referred to as the crank, or the part where the big end of the connecting rod attaches to the crank shaft.

Timer: Refers to the ignition commutator. Also often referred to as the "ignition interrupter" or "contact-breaker."

Timing gears: The gears connected with the crank shaft of the engine and the cam shaft, which, when timed or meshed correctly, cause the valves to open and close at the correct time.

Toe-in: Refers to the "toe-in" of the front wheels, at the front, opposite the hubs. See page 906.

Tonneau (plural Tonneaux): Derivation, French word meaning a barrel; a wooden vessel formed of staves and hoops and made to contain a tonneau (1,000 kilogrammes) of oil. Later, a horse-drawn carriage, known in England as a governess car, having a rear entrance. A similar type of body was first applied to a motor car by M. Huillier, of Paris, and by reason of its resemblance to a barrel and to the horse-drawn tonneau already existing, was known as a tonneau.

Torque: The word torque is a definite one and means the same whether referring to automobiles or to any other piece of mechanism, and means the twisting or wrenching effect produced by the engine or motor. See also page 1043.

Touche: The small plug used in the switch to complete the electrical circuit when required. (French.)

Transformer: Another name for a high-tension coil. An electrical device for transforming the current from a low tension to a high tension. An induction or secondary or high-tension, double-wound, coil.

Transmission: A system of gearing for reducing the ratio of the driving member (engine crank shaft) to that of the driven member (rear axle) of an automobile.

Trembler: The small vibrating spring used for making and breaking the primary circuit of a coil.

Tube ignition: A small tube, usually of platinum —having its outer end closed—is screwed into the combustion chamber. This tube is so placed that the flame of a blow-lamp, generally supplied from a separate and small tank of gasoline acts upon it and causes it to become incandescent. An old method of ignition now out of date.

Tuning an engine: Extreme care and special adjustment—as tuning up a car for a race, etc.

Two-to-one gear: The gearing, usually consisting of two-gear wheels, one having exactly double as many teeth as the other; also called "timing gears" and "half-time gears."

V

Vacuum: Exists where there is absolutely no pressure. A perfect vacuum has never been made. In connection with the automobile, this word is used to define a pressure less than atmospheric pressure, that is, a suction. The vacuum in a cylinder means the suction; a vacuum tank is a suction tank. (See "Suction.") For example, when the piston of an engine starts down on suction stroke, a vacuum is created within the cylinder because the pressure in the cylinder becomes less than atmospheric pressure; therefore the atmospheric pressure behind the gas in the carburetor pushes it into the cylinder. Thus it will be noticed that the piston does not draw the gas into the cylinder, but serves to decrease the pressure in the cylinder so that the atmosphere can force the gas into the lower pressure of the cylinder.

Valve lifter: An additional lever by means of which the exhaust valve may be raised and kept out of action, thereby reducing the compression and preventing the creation of a vacuum within the cylinder, so causing the inlet valve to remain closed. Used extensively on aero and stationary gasoline engines. This term also applies to a "valve spring lifter."

Vaporizer: An early form of carburetor valve. The vaporizer is also a means of heating the fuel.

Venturi: Applies to the mixing chamber of a carburetor; Venturi shaped. See page 98.

Viscosity: The adhesive or glutinous characteristic of oils used for lubrication.

W

Water: Composed of two parts hydrogen and one part oxygen. Its greatest density and the point at which it occupies least space is at 39° F.

Watt: The unit of electrical power obtained by multiplying volts by amperes.

Wet-cell: A battery using a liquid solution.

White metal or anti-friction metal: An easily fusible alloy of lead, antimony, and tin used for "lining" re-metalling bearings.

Wind resistance: Increases in proportion to the "square" of the speed: thus at 20 miles per hour it is four times what it is at 10 miles, and at 30 miles per hour nine times, and so on.

Worm gear: A device for transmitting power, consisting of a screw as the driving member, which engages with a toothed wheel as the driven member. See pages 7, 17 "Worm gear"; see page 956, "Worm-gear ratio."

English-French Dictionary of Some of the Motoring Terms

Ammeter	Ampèremêtre	Hub	Moyeu	Rope	Corde
Armature	Induit	Ignition advance	L'allumage à avance	Screw	Vis
Automobile (small)	Voiturette	Insulation	Isolation	Shaft	Arbre
Axle	Essieu	Jack	Cric	Speed	Vitesse
Blacksmith	Forgeron	Jet (carburetor)	Gicleur	Speed (high)	Vitesse grande
Carburetor	Carburateur	Lamp	Lampe	Speed (low)	Vitesse petite
Clutch pedal	Pédale de dêbrayage	Lamp oil	Huile à bruler	Start, to	Partir, dêmarrer
Copper wire	Fil de cuivre	Lamp wick	Mêche	Steer, to	Diriger
Driver	Chauffeur	Link (chain)	Maillon	Steering gear	Direction
Electricity	Electricitê	Magneto	Magnêto	Switch	Interrupteur
Engine	Engin	Magneto ignition	Allumage par magnêto	Terminal	Borne
Explosion	Explosion	Map	Carte	Tire (rubber)	Caoutchouc bandage
French chalk	Talc	Misfire	Rate	Tools	Outils
Full speed	Toute vitesse	Nail	Clou	Universal joint	Cardan
Funnel	Entonnoir	Nut	Ecrou	Valve seat	Siêge de soupape
Gas	Gaz	Odometer	Odomêtre	Valve, single	Monosoupape
Gasoline	Essence de pêtrole	Oil	Huile	Vise	Etau
Generator	Gênérateur	Oil can	Burette	Voltmeter	Voltmêtre
Grease	Graisse	Overheating	Surchauffage	Vulcanized	Vulcanise
Hammer	Marteau	Pressure (high)	Haute pression	Water circulation	Circulation d'eau
Hood	Capote	Pressure (low)	Basse pression	Weight	Poids
Horn	Corte	Pump	Pompe	Wheel	Roue
Horn bulb	Poire	Radiator	Radiateur	Wire	Fil
Horn reed	Auche	Rim	Jante	Wrench	Clef

INSTRUCTION No. 85

THE MODEL "T" FORD: Principle of Construction; Operation; Care and Repair; Useful and Instructive Hints and Suggestions

FORD PRODUCTS

These consist of the following:

1. Touring car.
2. Runabout.
3. Coupé.
4. Sedan.
5. Chassis.
6. Truck (see page 912 "Ford truck").
7. Tractor (see page 990 "Fordson tractor").

Ford touring car: Five-passenger. May be purchased either with or without Ford electric starting and lighting system, and with or without demountable rims. Demountable rim equipment includes 30″ x 3½″ non-skid tires all around, extra rim and tire carrier. Price, without electric starting and lighting system, $348.00; extra for the same with demountable rims, $95.00.

Ford runabout: Two-passenger. May be purchased either with or without Ford electric starting and lighting system, and with or without demountable rims. Demountable rim equipment includes 30″ x 3½″ non-skid tires all around, extra rim and tire carrier. Price without electric starting and lighting system, $319.00; extra for the same with demountable rims, $95.00.

Ford coupé: Two-passenger. Standard equipment includes Ford electric starting and lighting system, demountable rims, non-skid tires all around, extra rim and tire carrier. Interior finished in grey whipcord. Permanent top with sliding plate-glass windows. Price $580.00.

Ford sedan: Five-passenger. Standard equipment includes Ford electric starting and lighting system, demountable rims, non-skid tires all around, extra rim and tire carrier. Interior finished in grey whipcord. Permanent top with sliding plate-glass windows. Price $645.00.

The Ford chassis: Chassis equipment includes hood for motor, front fenders, running boards with running-board shields, headlights, tail light, horn, and set of tools. Ford dealers are able to supply the type of light delivery body required for your business. Chassis may be purchased equipped with or without Ford electric starting and lighting system and with or without demountable rims. Price without electric starting and lighting system, $285.00; extra for the same with demountable rims, $95.00.

GENERAL DATA AND INFORMATION ON THE FORD

Engine Numbers

Cars are recorded by engine numbers, rather than by car numbers, and the numbers of the engine and of the car are not the same.

Year 1912	88,900 to 171,300
1913	171,300 to 370,400
1914	370,400 to 611,000
1915	611,000 to 1,029,200
1916	1,029,200 to 1,614,600
1917	1,614,600 to 2,449,100
1918	2,449,100 to 2,831,400
1919 (to Sept. 30)	3,429,400

These numbers are stamped on the left-hand side of the cylinder block, above the inlet hose connection.

Engine

Bore, 3¾″; **stroke,** 4″; **piston displacement,** 189 cu. in.; **piston rings** (3), 3¾″ x ¼″; **valves:** diameter, 1½″; **valve clearance** 1/32″; **firing order,** 1, 2, 4, 3; **timing gears:**

cam gear	42 teeth
cam gear, diameter	5 1/3 in.
crank-shaft gear	21 teeth
crank-shaft gear, diameter	2 2/3 in.

Ford Torque and H.P. Table

R. P M.	Speed in miles per hour		Pounds Torque	Horsepower
	Car	Truck		
300	7 5	4	35	2
400	10	5 25	57	4 5
500	12 5	6 55	69	6 5
600	15	7 9	73	8 5
700	17 5	9 2	78	10 40
800	20	10 50	81	12 33
900	22 5	11 85	83	14.20
1000	25	13 15	82	15 60
1100	27 5	14 50	81	16.66
1200	30	15 80	79	18 20
1300	32 5	17 10	77	19
1400	35	18 45	73	19.66
1500	37 5	19 75	70	20
1600	40	21 05	65	20
1700	42 5	22 40	60	19 40
1800	45	23 75	53	18 20
1900			47	17

The words "Pounds Torque" above should be "Foot Pounds Torque."

The **torque and horse-power figures given above were obtained with a wide-open throttle.** They represent only the maximum power that can be developed at the given speeds. As the throttle is seldom wide open when driving the car, the speed is rarely indicative of the horsepower the engine is developing. Notice that the torque (pounds pull) begins to drop off at 900 r.p.m. The engine exerts its greatest pull at this speed (900 **r.p.m.**). See also page 1043, "Torque, meaning of."

Cooling System

Thermo-syphon principle: Radiator capacity including jackets, 12 quarts, formerly 11 quarts; not including jackets, 8 quarts, formerly 7 quarts.

Radiator hose: Inlet, 1¾″, 3-ply, 2¼″ long; outlet 2″ internal diameter, 4-ply, 3¼″ long.

Hose bands are 2⅛″ and 2½″ inside diameter.

Gear Ratio

Rear axle ratio: The drive pinion gear has 11 teeth; the driven differential ring gear has 40 teeth; therefore 40÷11= 3 7/11 (or 3.63). Thus on **high gear or direct drive,** the engine crank shaft turns over 3 7/11 (or 3.63) times to 1 of the rear wheels.

On **low gear** the total gear reduction is 9.99 to 1.

On **reverse gear** the total gear reduction is 14.5.

See also pages 8 and 9; "Gear ratio, how to compute."

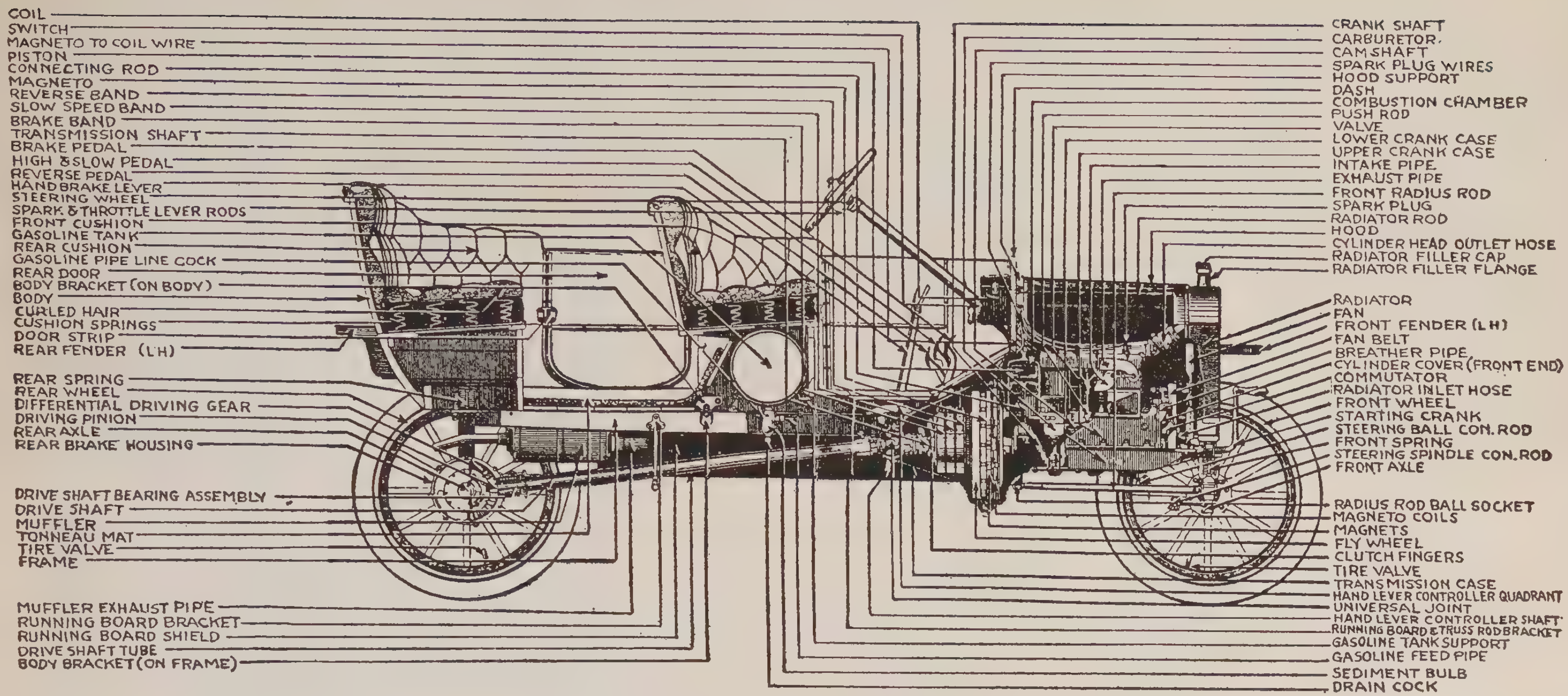
To find the speed in miles per hour:

Eng. Speed per min.	Mi. per Hr. Reverse	Mi. per Hr. 1st Speed	Mi. per Hr. High Speed
500	3.892+	5.589−	12.295+
600	4.761+	6.706−	14.754+
1,000	7.784+	11.178−	24.590+
1,500	11.676+	16.767−	36.885+

Engine speed per mile: The crank shaft of a Ford car makes 2,446 revolutions in one mile on high speed, and when running at a rate of 22 m.p.h. it turns over 897 times every minute.

Overall Dimensions

Model	Height	Width	Length
Touring	7′	5′ 7½″	11′ 2½″
Runabout	6′ 9″	5′ 7½″	11′ 2½″
Sedan	6′ 9″	5′ 7½″	11′ 2½″
Coupe	6′ 9″	5′ 7½″	11′ 2½″
Chassis	....	5′ 7½″	10′ 8″
Truck Chassis	....	5′ 7½″	12′ 9″



Parts of the Ford Car (Model "T")[1]

Engine: Four-cylinder. Cylinders cast en bloc. L-head, detachable type, with valves on the right side. Bore, 3¾″; stroke, 4″; horsepower, 20.

Transmission: Special Ford planetary type. Multiple steel disk clutch operating in oil.

Ignition: Magneto; special Ford design, built in and made a part of the engine. Magneto is built into the flywheel.

Starter: Ford starting and lighting system, optional on touring car, runabout, or chassis. Included as **standard** equipment on coupé and sedan.

Cooling: Thermo-syphon water system, with a fan behind the radiator.

Wheel base: 100 inches.

Wheel equipment: Demountable rims, including 30″ x 3½″ non-skid tires all around; extra rim and tire carrier are **standard** equipment on coupé and sedan, and optional equipment on touring car, runabout, or chassis.

Track or tread: 56 inches.

Road clearance: 9 inches.

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[1] By courtesy of *Fordowner and Dealer*.

Shipping Weights

Touring A	1,500 lbs.	Engine and trans	380 lbs.
Touring B	1,580 lbs.	Runabout body	300 lbs.
Runabout A	1,390 lbs.	Touring body	415 lbs.
Runabout B	1,480 lbs.	Coupe body	450 lbs.
Sedan B	1,875 lbs.	Sedan body	600 lbs.
Coupe B	1,685 lbs.		
Chassis A	1,060 lbs.		
Chassis B	1,080 lbs.		

A = without starter equipment; B = with starter equipment; add 18 lbs. if equipped with demountable rims; if equipped with 5 demountable rims, add 29 lbs.

Space for Housing a Ford

The smallest garage measurement for housing a Ford, and which will allow 2′ 2¼″ on the sides and 2′ 4¾″ play at each end, would be 10′ wide, 16′ long, and 8′ high.

Gasoline Tank Gauge and Measurements

A good idea for a simple gasoline gauge for Ford gasoline tanks is to get an 18″ flat rule, marked in inches and fractions thereof. Coat it with plumbago by applying the domestic stove-polish brush. If you insert this rule vertically into the tank, right down to the bottom—the car being level—the gasoline will leave a mark on it. The quantity can be gauged by marks on the rule.

Gallons	Square Tank	Round Tank	Oval Tank
1	3/4″	1 17/32″	1 7/16″
2	1 1/2″	2 9/16″	2 3/16″
3	2 1/4″	3 1/2 ″	2 15/16″
4	3″	4 11/32″	3 5/8 ″
5	3 3/4″	5 1/8 ″	4 5/16″
6	4 1/2″	5 29/32″	5″
7	5 1/4″	6 3/4″	5 11/16″
8	6″	7 11/16″	6 7/16″
9	6 3/4″	8 23/32″	7 3/16″

Note. While the **round tank** dimensions vary considerably for each gallon, it will be noted that in the **square tank** each three-quarters of an inch represents a gallon. The **oval tank** may be roughly estimated by one and one-half inches for the first gallon and three-quarters of an inch for each additional gallon up to nine.

Magneto Speed and Voltage

The Ford magneto varies in voltage, amperes, and cycles with the speed of the engine. The table below gives the variation compared to the speed in the engine and the speed of the car and truck:

R.P.M.	Miles Per Hr.		Volts	Amperes	Cycles
	Car	Truck			
200	5	2.63	5	6.1	26.4
400	10	5.26	9.8	7.9	52.8
600	15	7.89	14.4	8.5	80.0
800	20	10.52	18.8	8.8	106.4
1,000	25	13.15	22.8	8.9	146.4
1,200	30	15.8	26.2	9.	160.0

Brakes

Brakes on the hub of the rear wheels have cast-iron shoes, size 7⅞″ x 15/16″ x ⅛″. Brakes are controlled by a side-hand lever. **The brake on the transmission** is controlled by the foot.

The size of the brake, low speed and reverse drum lining on the transmission can be 5/32″ or 11/64″ thick, 1⅛″ or 1 3/16″ wide, and 23 5/16″ or 23⅜″ long.

Prices of Ford Cars from 1909 to 1922

Year	Touring	Run-about	Chassis	Sedan	Coupelet	Towncar	Truck
1909	$850	$825	$.	$ . .	$ 950	$1,000	$ . . .
1910	950	900	. . .	. .	1.050	1,200	. . .
1911	780	680	. . .	. . .	1.050	1,200	. . .
1912	690	590	. . .	. . .	. . . . .	900	. . .
1913	600	525	. . .	. . .	. . .	740	. . .
1914	490	440	. . .	975	750	690	. . .
1915	440	390	360	740	590	640	. . .
1916	360	345	325	640	505	595	. . .
1917	360	345	325	645	505	. . .	600
1918	525	500	475	775	650	. . .	550
1919	525	500	475	775	650	. . .	550
1920	575	550	525	975	850	. . .	600
1920	575	550	525	975	850	. . .	640
1920	440	395	360	795	745	. . .	545
1921 (Jan.)	415	370	345	660	595	. . .	445
1921 (Sept.)	355	325	295	660	595	. . .	445
1922	348	319	285	645	580	. . .	430

Note. The prices for 1921 and 1922 are without the electric starting and lighting system or demountable rims on the touring car, roadster, and chassis; extra for these, $95. Price of coupelet and sedan includes the electric starter and lighting system and demountable rims. The price of the truck is without electric starting and lighting system; extra for these, $70.00. The terms coupelet and coupé refer to the same style of car.

OPERATING AND LUBRICATING A FORD CAR

Before attempting to start the engine, see that the hand-brake lever is pulled back. This hand lever disengages the clutch and applies the brakes at the rear hubs, so that the car will not travel forward when the engine is being cranked.

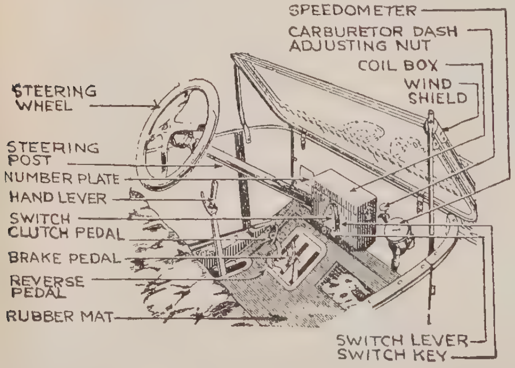


Fig. 1. Control members and parts as viewed from the seat.

Be sure to retard the spark lever, that is, move the lever on the left-hand side of the steering column **upward**, or toward the front of the car, as far as it will go. (When speaking of the right or left-hand side of the car, it is always considered that one is sitting in the driver's seat and facing forward.)

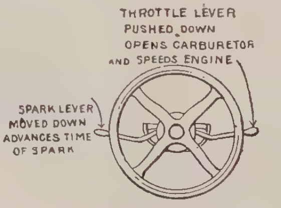

THROTTLE LEVER PUSHED DOWN OPENS CARBURETOR AND SPEEDS ENGINE
SPARK LEVER MOVED DOWN ADVANCES TIME OF SPARK

Fig 2

The throttle lever, on the other side of the steering column, should be pulled downward about five or six notches from the extreme forward, or closed position.

Now close the switch on the coil box, that is, move the switch key all the way over to the "mag." mark on the cover of the switch. If the switch key is moved over to the battery side, the engine cannot be started. The cars are not fitted with batteries, and this connection is left on the switch only in case (at some future time) you should wish to equip your car with batteries for starting.

Priming: With present-day grades of gasoline, it is usually necessary to prime the engine while it is being cranked. Priming shuts off some of the air, so a richer mixture of gasoline vapor is drawn into the carburetor.

This priming is done by pulling forward a small ring on the end of a wire that projects out through the radiator at the front. This priming ring must be held out, at the same time that the engine is cranked.

Cranking the engine: Grasp the starting handle firmly with the right hand, and push the starting crank in as far as it will go, feeling for the ratchets which the starting crank should engage. Hold the priming ring out with the left hand, and pull the starting crank up quickly.

The crank should be kept pushed in, while the handle is being pulled up. This requires a certain knack that is soon acquired by practice. If not pushed in, the crank will slip out of the notches, and the sudden release may throw the driver off his balance.

The crank should be pulled up sharply. Slow pulls are of no value, for, unless the engine is turned over quickly, the magneto will not give enough current to make a good spark.

Starting the Car

Speed up the engine a little by opening or moving the throttle lever toward you, a couple of notches. Also, advance the spark to a normal running position, about five to seven notches, from the front of the quadrant.

Place one foot on the foot brake, which is the pedal farthest to the right, so that you will always be prepared to stop; accidents may thus be prevented. Place the other foot on the clutch pedal, which is the farthest one to the left. Hold it in about mid-position, that is, do not push this pedal all the way down, or let it come back all the way.

Now grasp the hand-brake lever handle with the left hand, having the palm of the hand turned toward the outside of the car and the thumb turned downward, so that the thumb can be used for disengaging the latch. This may seem awkward at first, but it is the way this lever is intended to be operated. Now, pull back on the handle, then press the latch with the thumb. It is easy to release the latch, if one pulls back on the lever first. **Now hold the steering wheel with both hands,** and push the clutch pedal forward slowly, until the car begins to move. At the same time that the clutch pedal is pushed forward, push the side hand lever forward as far as it will go, so that the clutch pedal may return to "high" when the car is under way.

Gradually push the clutch pedal harder until you feel that there is no slipping in the low-speedgear and then speed up the engine so that the car is traveling at from 8 to 10 miles an hour.

Let the clutch pedal come all the way back quickly, and your car will be in high gear. Practice will teach you how to make the change from low to high gear smoothly and easily, without jerk to the passengers or strain on the mechanism.

Reversing the Car

Pull the hand-brake lever back just far enough to draw the clutch pedal forward and disengage the clutch, but do not pull the brake lever back far enough to engage the rear hub brakes.

Place one foot on the brake pedal, for use if necessary, and press gently on the middle, or reverse pedal. Do not attempt to drive backward rapidly at first, for the steering is very likely to be confusing, and it is not easy to drive backward in a straight line. After the driver has become more experienced, he can reverse by holding out the clutch with the clutch pedal, and using low speed forward as a brake.

Stopping the Car

Partially close the throttle; release the high speed by pressing the clutch pedal forward into neutral; apply the foot brake slowly but firmly until the car comes to a dead stop.

Do not remove the foot from the clutch pedal without first pulling the hand lever back to neutral position, or the engine will stall.

To stop the engine, open the throttle a trifle to speed up the engine and then throw off the switch. The engine will then stop with the cylinders full of explosive gas, which will naturally make the next start easier.

Spark Control

The left-hand lever under the steering wheel is the spark lever. Good operators drive with the spark lever advanced just as far as the engine will permit. But if the spark is advanced too far, a dull knock will be heard in the engine, owing to the fact that the explosion occurs before the piston has completed its compression stroke. The best results are obtained when the spark occurs just at the time that the piston reaches its highest point of travel—the gas being then at its highest point of compression. The spark should be retarded only when the engine slows down on a heavy road or a steep grade; but care should be exercised not to retard the spark too far, for when the spark is "late," instead of getting a powerful explosion, a slow burning of the gas, with excessive heat, will result. Learn to operate the spark as the occasion demands. The greatest economy in gasoline consumption is obtained by driving with the **spark advanced sufficiently to obtain the maximum speed.**

How Speed of Car is Controlled

The different speeds required to meet road conditions are obtained by opening or closing the throttle. Practically all the running speeds needed for ordinary travel are obtained on high gear, and it is seldom necessary to use the low gear except to give the car momentum in starting. The speed of the car may be temporarily slackened in driving through crowded traffic, turning corners, etc., by "slipping the clutch," i.e., pressing the clutch pedal forward into neutral.

Oiling Engine and Transmission

Oiling is most important, and is taken care of by pouring oil through the breather pipe on the front end of the engine base on the right side. This pipe is covered by a metal cap, which can be easily pulled off, when oil is to be poured into the crank case. The lubrication of the engine is explained on page 159. See page 1137 for one method of cleaning the oil pipe.

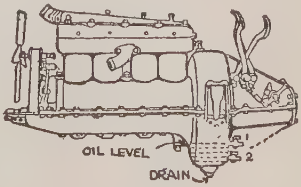


Fig. 3. Oil level.

When the engine is new: Pour in oil until it runs freely out of the upper petcock in the engine base (1) (Fig. 3). Be sure to close this petcock, for if it is left open, the action of the flywheel will splash all of the oil out through this petcock and the bearings will be ruined for lack of oil.

After the engine has been limbered up. The best results will be obtained by carrying the oil level about midway between the two petcocks—but under no circumstances should the oil level be allowed to get below the lower petcock.

Testing the oil level: Open the upper petcock. If oil does not drip out, open the lower petcock. If oil drips out, then there is enough oil for a short distance, but it is better to put more oil in if the car is to be driven a considerable distance. It is necessary at intervals to clean out these petcocks, as they become clogged with dirt or sediment.

Oiling Other Parts

This includes the filling of the different oil cups on the front axle system, the rear axle system, and the oiling of parts of the control system, which move but little. Oiling of these parts will tend to eliminate squeaks and prevent wear.

Oiling of the Commutator

Oil is injected through the small cup on the top of the commutator shell. Engine oil is rather heavy for the oiling of the commutator, and is likely to so insulate the roller from the contact points that starting may be difficult. This is especially true in winter, when the cold will so congeal a heavy oil that it will be almost impossible to obtain a good spark. "Three-in-one" oil is thin enough to be used in the commutator.

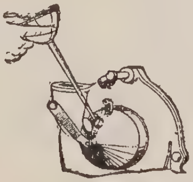


Fig. 4

Kind of Engine Oil to Use

A light, high grade of gas-engine cylinder oil is recommended. This light oil will reach into the closely fitted bearings of the engine more quickly, and so less heat and friction will be developed. The oil should have sufficient body to prevent the heat and pressure in the cylinders from squeezing out the oil from between the cylinder walls and the pistons. It is expensive to use a cheap oil. Good oils save repairs to the engine, increase the mileage per gallon of gasoline, and do not form carbon nearly as rapidly as do inferior oils. In cold weather an oil that does not congeal easily at low temperatures must be used. Otherwise the clutch will drag, owing to the oil acting as an adhesive.

Among the oils that are recommended for the Ford engine are Gargoyle Mobiloil "E," and White Star Extra Quality Oil, which is used at the Ford factory.

Graphite should never be used in either the engine or the transmission, as it is apt to short-circuit the magneto and thus cause expensive repairs.

Draining Oil out of Engine

The new car should have the oil drained out at the end of the first 500 miles. This also applies to an overhauled engine, when the bearings have been refitted. The oil is drained out by removing the plug at the bottom of the crank case, and by cranking the engine. The front wheels should be about six inches higher than the rear wheels, so that the oil will drain to the rear of the crank case. Use at least a gallon of fresh oil, when refilling the crank case, and be sure to replace the plug in the bottom of the crank case tightly. If this plug drops out, the engine bearings are almost sure to be ruined for lack of oil. After the first 500 miles the oil should be drained from the crank case every 1,000 miles.

Lubrication of Chassis

The plan view of the chassis (Fig. 5) should be studied carefully, so that one will know how often the parts should receive attention and lubrication.

The oil cups can be supplied with the same kind of oil used in the engine, although a slightly heavier oil will not run away so rapidly and is better adapted to this use.

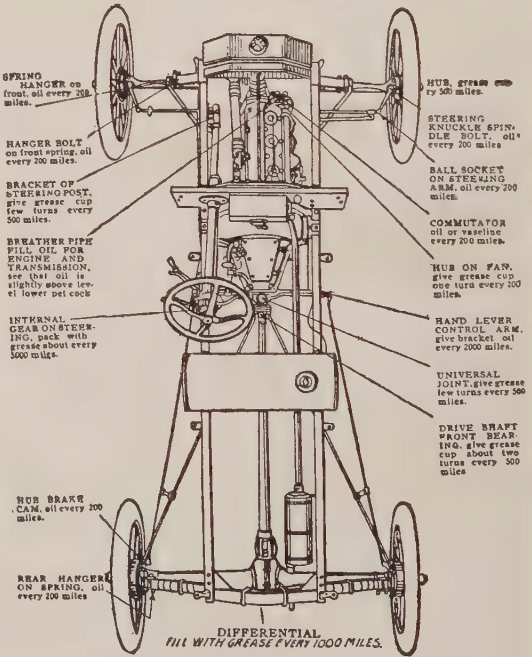

SPRING HANGER on front, oil every 200 miles.
HANGER BOLT on front spring, oil every 200 miles.
BRACKET OF STEERING POST, give grease cup few turns every 500 miles.
BREATHER PIPE FILL OIL FOR ENGINE AND TRANSMISSION, see that oil is slightly above level lower pet cock
INTERNAL GEAR ON STEERING, pack with grease about every 5000 miles.
HUB BRAKE CAM, oil every 200 miles.
REAR HANGER ON SPRING, oil every 200 miles
HUB, grease every 500 miles.
STEERING KNUCKLE SPINDLE BOLT, oil every 200 miles
BALL SOCKET ON STEERING ARM, oil every 200 miles
COMMUTATOR oil or vaseline every 200 miles.
HUB ON FAN, give grease cup one turn every 200 miles.
HAND LEVER CONTROL ARM, give bracket oil every 2000 miles.
UNIVERSAL JOINT, give grease few turns every 500 miles.
DRIVE SHAFT FRONT BEARING, give grease cup about two turns every 500 miles
DIFFERENTIAL
FILL WITH GREASE EVERY 1000 MILES.

Fig. 5. Lubrication chart for Ford car.

Greasing a Ford Car

This includes the filling of the grease cups, the universal joints, and the rear axle housing with grease. Cup grease, or grease containing graphite, can be used in the grease cups. **The rear axle housing** should not be filled too full. About 1½ pounds of grease is enough for the rear axle gears. If thrust washers are not worn, ½ lb. more can be added. A larger amount of grease will run out of the ends of the axles and spread over the wheels and tires.

The rear-axle housing should not be more than one-third full. The oil plug should be removed about every 1,000 miles and more grease added if necessary. If a fluid grease is used, the level should be approximately 1½" below the oil hole.

If grease or oil works out the rear hub-brake drums it is due to one of three causes: (1) too much lubricant in rear-axle housing; (2) thrust washers worn; (3) oil from engine working down drive shaft to rear-axle housing.

The universal joint should be packed with fresh grease. Fill the "dope" cups (grease cups) on the universal joint and drive-shaft front end bearing with grease and screw them down, refill, and repeat the operation several times until sufficient grease is forced **in** and the old grease is forced **out.**

The advantage of packing the universal joint with heavy grease is that it forms a packing which prevents oil from the engine crank case working down the drive-shaft housing and thinning the lubricant in the rear axle housing, thus working out the rear hub brake drums. See also page 1098.

Fan lubrication: The lubrication chart (Fig. 5) specifies grease every 200 miles. This applies to the old-style fan equipped with grease cup. The later-style fan should be lubricated by occasionally unscrewing the oil plug and filling the hub with heavy fluid oil.

CONSTRUCTION IN GENERAL

The Ford chassis is divided into units, such as: the **front axle** system; the **rear axle** system; the **engine** and **transmission** unit; and the **dashboard,** which includes the **steering column.**

It is well to remember these units when making repairs to cars, for it often is necessary to remove the entire unit from the car when a certain part is to be repaired.

For example, when repairing an axle shaft, it is necessary to remove the entire rear axle system, in order that the shaft may be removed.

The carburetor is a Holley or a Kingston instrument, having a hot-air fitting which clamps over the exhaust manifold, giving a complete supply of heated air for cold-weather evaporation. There is a dash carburetor adjustment controlling the needle valve.

Lubrication is by gravity, with the oil carried to the front end of the engine and the timing gears by means of the flywheel, through the oil tube, after which it returns by gravity to the flywheel casing in the crank shaft.

The clutch is a multiple disk in oil, delivering the drive to a two-speed planetary gearset in unit with the engine. From here the final drive is by means of a propeller shaft.

The propulsion stresses are taken through the radius rods, which are fastened by means of pivot connections at the outer ends of the rear axle and through the tube which surrounds the propeller shaft. The driving torque is taken through the torsion tube which surrounds the propeller shaft.

The springs are different from the usual construction on other cars (see illustration, Fig. 7).

The tire equipment is pneumatic, 30" x 3" in the front and 30" x 3½" in the rear when clincher wheels are used. When demountable rims are used, both front and rear tires are 30" x 3½".

The wheels are of the wood artillery type, with oval spokes. The foot brakes are on the transmission, and the hand brake is on the rear wheels.

The transmission drive-shaft brake is an external contracting type, and the hand brake is an internal type expanding on the rear wheel drums.

The steering gear is mounted on the left, and the control system is the standard Ford layout with three pedals and the brake lever.

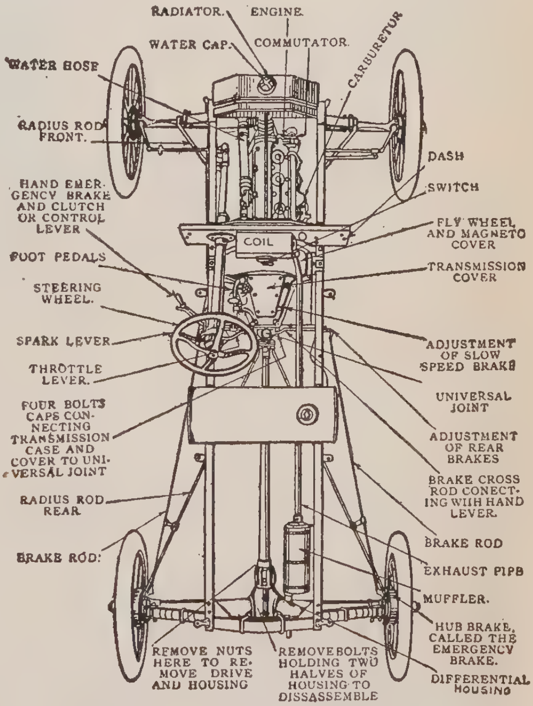

RADIATOR.
ENGINE.
WATER CAP.
COMMUTATOR.
CARBURETOR
WATER HOSE
RADIUS ROD FRONT.
DASH
SWITCH
HAND EMERGENCY BRAKE AND CLUTCH OR CONTROL LEVER
COIL
FLY WHEEL AND MAGNETO COVER
FOOT PEDALS
TRANSMISSION COVER
STEERING WHEEL.
SPARK LEVER
ADJUSTMENT OF SLOW SPEED BRAKE
THROTTLE LEVER.
UNIVERSAL JOINT
FOUR BOLTS CAPS CONNECTING TRANSMISSION CASE AND COVER TO UNIVERSAL JOINT
ADJUSTMENT OF REAR BRAKES
BRAKE CROSS ROD CONECTING WITH HAND LEVER.
RADIUS ROD REAR
BRAKE ROD
BRAKE ROD.
EXHAUST PIPE
MUFFLER.
HUB BRAKE, CALLED THE EMERGENCY BRAKE.
REMOVE NUTS HERE TO REMOVE DRIVE AND HOUSING
REMOVE BOLTS HOLDING TWO HALVES OF HOUSING TO DISSASSEMBLE
DIFFERENTIAL HOUSING

Fig. 7. Top view of Ford chassis. The crank shaft operates on three bearings and the cam shaft is driven by spur gears.

STEERING-GEAR SYSTEM

The Ford steering device is the "planetary gear" type. See also pages 11 and 1087.

The **steering reduction gears** are placed at the top of the steering column, instead of at the bottom (Figs. 8 and 9).

These gears increase the power and the sensitiveness of the control over the front wheels of the car. If these gears were not used, a slight turn of the steering wheel would send the car into the ditch, while road obstructions, or bumps, would wrest the steering wheel out of the driver's control.

The lower part of steering column merely has an arm (A) (Fig. 10) which is connected to rod (B) extending to the steering knuckle arm (SA) (Fig. 11).

The steering wheel has a short shaft, on which a drive pinion is mounted. This pinion is held in place by the cover and nut of the steering gear case.

The steering rod proper, on the end, is fitted with a flange (triangle shape under the gears), on which three studs project, which carry the three small gears. These gears mesh with the drive pinion and also with an internal gear cut on the inside of the steering-wheel case (see also Fig. 18).

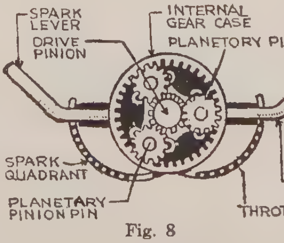


Fig. 8

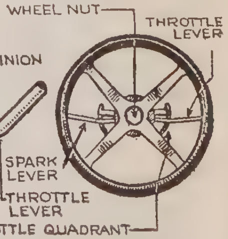


Fig. 9

To obtain access to the gears: Remove the small screw which holds the gear-case cover. Then unscrew the gear-case cover, and the steering wheel and the cover can be removed together as a unit. It is not necessary to remove the lower part of the steering wheel from its shaft to obtain access to the steering gears.

There are two small **retaining keys** in the top of the steering column. Keep these keys snug, for if they come loose, considerable play will result.

Removing the Steering Wheel

Unscrew the nut on the top of the post, and drive the wheel off the shaft, using a block of wood and a hammer. Do not batter the threads of the shaft, or it will be difficult to replace the nut. See Fig. 18.

Tightening the Steering Gear

A loose steering gear will make steering difficult and cause wear of tires. To tighten, see that the nut which holds arm (A) at the lower end of steering rod (R) (Fig. 10) is tight.

Ball and Socket Joints

There is a ball on the end of arm (A) which fits into a socket (C) (Fig. 13). If this is not kept oiled, play will develop.

There is also a ball on the end of the thrust rod (B), which connects the steering arm (SA) (Fig. 11).

If the ball and socket becomes worn from lack of oil, it can be ground by rubbing over emery cloth, or filing, as shown in Fig. 16.

Spring ball sockets which take up wear automatically are now supplied by specialty manufacturers.

Bushings in Front-Axle Spindles

There are bushings in the spindle arms (S) (Fig. 11). The "spindle arm bolt" works in the bushings. The bushings wear first, and, if worn should be replaced.

Removing bushings: Split expanding bushing removers are best for this purpose, or else the bushing can be threaded and fitted with a bolt and driven out. The bushings are short, and one is at each end of the spindle body.

New bushings should be pressed in with an arbor press or vise, or be carefully hammered in with a lead mallet, or with wood between hammer and bushing.

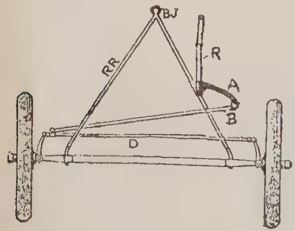


Fig. 10

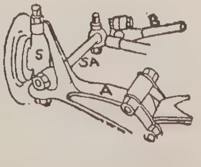


Fig. 11

Fig. 10. Arm (A) of the steering device is the only part connected to the steering, or drag rod (B), by means of a ball and socket joint (Fig. 13). The movement of the steering rod (R) moves (A), then (B), then the steering knuckles, thus causing the front wheels to move.

Both ends of rod (B) are fitted with ball and socket joints, as shown in Figs. 11 and 15.

After fitting, the bushings should be reamed out. Special reamers are made for this purpose. See "Ford tools" (farther on), and Index under "Reamers."

The bushings must fit snug, so that the bolts will turn and not the bushings.

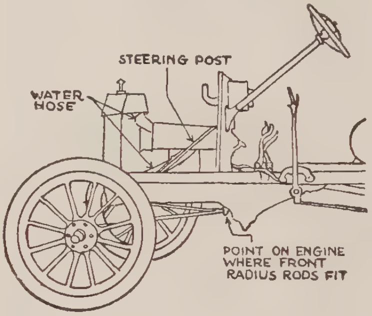


Fig. 12

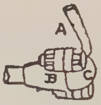


Fig. 13

Fig. 12. Note the ball joint (BJ) (Fig. 10) which fits into a socket on the engine base to support the front radius rods.

Fig. 13 is the part connecting (A) and (B) (Fig. 10).

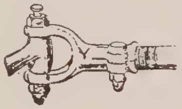


Fig. 14

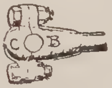


Fig. 15

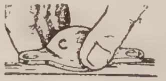


Fig. 16

Fig. 14. Yoke which connects each end of the tie rod (D) to the steering knuckle arms.

Fig. 15. The part shown at (B) (Fig. 11).

Fig. 16. Method of taking up wear on socket (C) which places the sockets closer together over the joint. The method is to emery the halves of the parts down, as shown.

Front Wheels

Removing the front wheels: Use the special hub-cap wrench to remove the hub-cap. Pull out the cotter pin; then take off the castle lock nut and lock washer. Unscrew the adjustable bearing cone. Then pull the front wheel off.

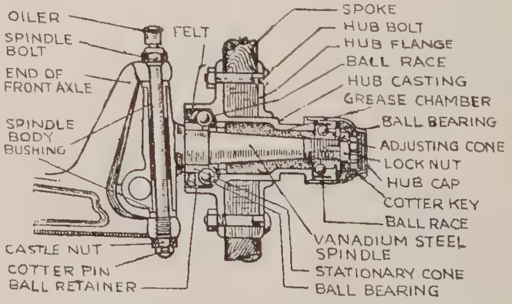


Fig. 17. Names of parts of **front wheel spindle assembly.** Note that the bushings do not extend entirely through the spindle body, but only at each end. Ball bearings shown above.

The cones and castle nuts must be replaced on the spindles from which they were removed. There are left-hand threads on the right spindle and right-hand threads on the other spindle. (Note. Turn the top of the nut toward the rear of the car to tighten. This holds good for all wheel nuts.)

If the cones or cups are worn, they should be replaced with new parts. While slightly longer service can be obtained by turning the cones half-

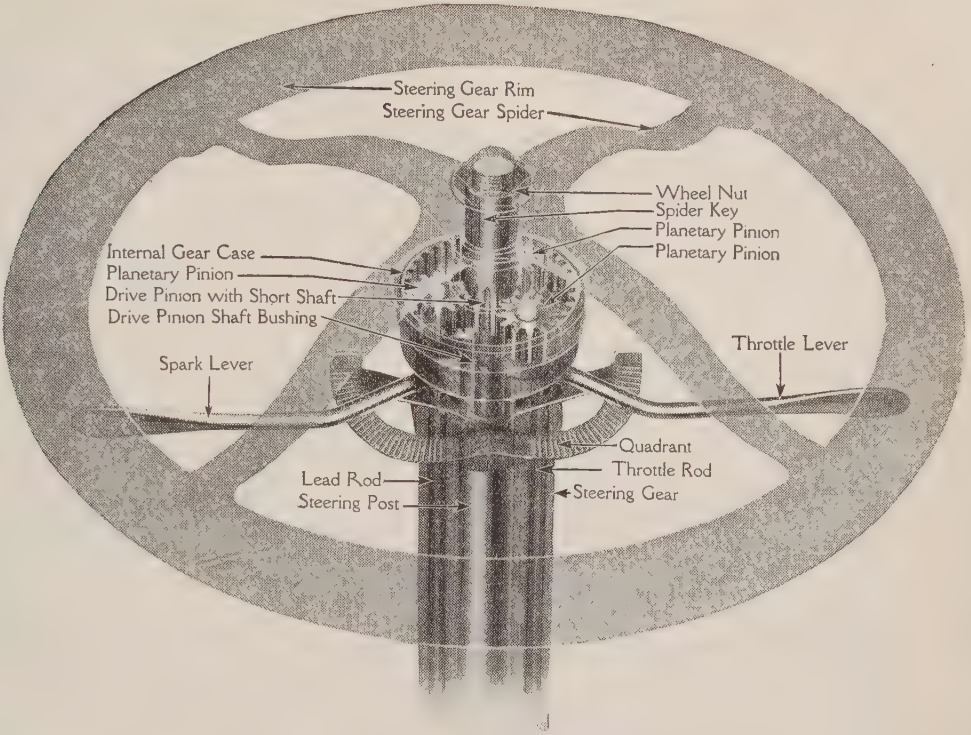


Fig. 18. The distinctive feature of the **Ford steering gear,** illustrated above, is the arrangement of the planetary reduction gears at the upper end of the steering post.

The steering wheel is keyed to a shaft about 4½″ long, which also forms the center or drive pinion. The three planetary pinions are carried on a spider at the upper end of the steering post and mesh with the drive pinion; also the internal gear case which surrounds them.

When the steering wheel is turned, the drive pinion must also turn. This causes the three planetary pinions to rotate on their axes, and as they mesh with the gear case, which is stationary, they also revolve around the drive pinion, thus forcing the steering post to turn. The difference in the number of teeth on the pinions and gear case gives the steering post but one-third of the turn of the steering wheel. This gear reduction gives the leverage required for easy steering.

way around, so that the wear comes on the opposite side of the cone, this permits a certain amount of looseness, and is not as good as the fitting of new parts.

If the balls are chipped, cracked, or pitted at all, they should be replaced by new ones. Chipped balls will break and ruin the other parts of bearings.

Testing the Wheels

The front wheels should be jacked up and tested for side play and smoothness of running. See page 905; "Testing front wheel bearings."

A sharp click, when running the front wheel, together with a momentary check in the motion of the wheel, indicates a broken ball, which should be immediately removed, before it causes trouble.

Adjustment of Front Wheels

The front wheels should be so adjusted that the wheels will come to rest—after spinning—with the tire valve at the lowest part of the wheel. Yet there should be no noticeable side play, when the spokes of the wheel are grasped with the hands and the wheel shaken.

When Timken roller bearings are used, they should be adjusted as follows: the threads on the outer bearings are the same as on the adjusting cones of the ball bearings. Tighten the outer bearing on the spindle until the wheel seems to bind, then back off one-quarter to one-half a turn so that the wheel revolves freely without end play.

Timken roller bearings can easily be installed on cars equipped with ball bearings.

Sedans, coupés, and trucks are now fitted with roller bearings.

Undue wear of the cones may be caused by adjusting the cones so closely that the bearings bind; or this may be due to lack of lubrication. The hub-caps should be filled with a soft grease every few thousand miles.

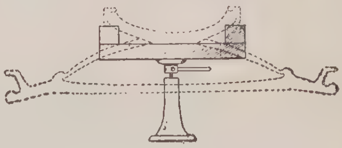


Fig. 19. One **method of jacking up the front of a car** with a block of wood. The illustration shows method and dimensions. The block should be narrow enough to go between the front axle and steering connection that crosses about 4½″ behind it.

Removing the Front Axle

Jack up the front of the car, by supporting the frame on a couple of boxes, or by chains or ropes, or as shown in Fig. 19. Remove both front wheels. Disconnect thrust rod (**B**) from arm (**SA**) (Fig. 11, page 1086). Disconnect the radius rod at the ball joint (as in Figs. 10 and 12). Remove the two spring shackle bolts at each end of the front spring.

To Disconnect the Front Radius Rod from Axle

Remove the cotter-pinned nuts. To remove the radius rod entirely, take the two nuts off the studs which hold the ball cap, and remove the lower half of the cap. See Figs. 10 and 12.

If the radius rod rattles, remove the lower half of the ball cap, and file some of the metal off the flat surfaces, or rub down (as shown in Fig. 16).

Straightening the Front Axle

In case the front axle or parts are bent, straighten them while cold. The application of heat will remove the effects of the heat treatment to which these parts have been subjected, and will dangerously weaken them.

Bringing the point of contact of the tire and ground more nearly under the spindle body bolt makes steering easier and tends to prevent tire wear. See the discussion of "camber" on page 906.

Transposing Tires

To use 30″ by 3½″ tires on the front wheels, a pair of rear wheels can be purchased and fitted in place of the original front wheels, on cars not equipped with demountable rims.

Springs

Care of springs: If the springs seem stiff, use a screwdriver to pry the leaves apart and place some graphite grease, or heavy oil, between the leaves.

Spring clips should be kept tight: If these clips are not kept tight, the strain will be put on the tie-bolt which passes through the center of the spring leaves and will break it. The tie-bolt is intended only for keeping the spring leaves from slipping out of position sideways. This is particularly true of the front spring, for if the front spring shifts sideways, it will endanger the steering of the car, and may cause an accident.

Making the Car Ride More Easily

One or more leaves can be removed from the rear spring of the runabout, to make the car ride more easily, as the same spring is used on both runabout and touring cars. The runabout does not carry so much weight. If one leaf is removed, it should be the second from the top. If severals leaves are removed, take out alternate leaves, so as to maintain the general shape of the spring as nearly as possible.

For truck use: Several leaves are sometimes added to increase the stiffness of the springs.

Alignment of Wheels

See page 903; "Alignment of wheels" for the reason why proper alignment of wheels is necessary. See also page 906 for "Alignment of Ford front wheels."

Adjustment of the front wheels can be made by turning the yoke at the left end of the drag rod, drawing the wheels into a parallel position. If inspection shows that the axle or the spindles are bent, it will be necessary to have those parts straightened or replaced before correct alignment can be secured.

THE FORD TRANSMISSION AND CLUTCH

This transmission serves the same purpose as a sliding gear or selective type of transmission, as explained under the instruction on "Transmissions."

It is mounted on a shaft which has a flange projection at one end, which bolts to the flywheel; the flywheel is bolted to a flange on the end of the crank shaft.

The planetary gears are shown as marked, (P1) (P) (K) and (S) (P) (G) (Fig. 20). These gears are mounted on studs projecting from the flywheel.

By means of bands, which are tightened around the drums, the rotation of these gears is governed as explained.

It is called a **planetary transmission,** from a fancied resemblance between the motion of the triple gears around the central shaft and the motion of the planets around the sun.

Low speed: Gear (D) is the driven member, keyed to the hub clutch drum (C), which in turn is secured to the driven shaft. By applying the brake band to drum (B), gear (F) is held stationary, pinion (P) rolls on it, and a smaller pinion (P1) causes gear (D) to turn slowly in the same direction as the flywheel, as explained later.

For high speed or direct drive, the friction clutch locks the clutch drum (C) to the engine crank shaft and the entire mechanism revolves as a unit.

For reverse: Applying the brake band to drum (V), gear (L) is held stationary, pinion (K) rolls on it, and pinion (P1) turns gear (D) slowly in the reverse direction, as explained later.

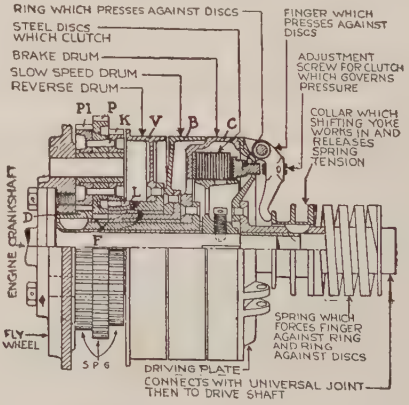

RING WHICH PRESSES AGAINST DISCS
STEEL DISCS WHICH CLUTCH
BRAKE DRUM
SLOW SPEED DRUM
REVERSE DRUM
FINGER WHICH PRESSES AGAINST DISCS
ADJUSTMENT SCREW FOR CLUTCH WHICH GOVERNS PRESSURE
COLLAR WHICH SHIFTING YOKE WORKS IN AND RELEASES SPRING TENSION
P1
P
K
V
B
C
L
D
F
ENGINE CRANKSHAFT
FLY-WHEEL
S P G
SPRING WHICH FORCES FINGER AGAINST RING AND RING AGAINST DISCS
DRIVING PLATE
CONNECTS WITH UNIVERSAL JOINT THEN TO DRIVE SHAFT

Fig. 20. Simplified illustration of the Ford transmission and clutch.

The clutch serves the same purpose as a cone or disk clutch, as described under the instruction on "Clutches," on page 20.

The clutch on the Ford is made of steel disks, as lettered. The pressure of clutch fingers (there are 3) through the ring which presses against the disks, causes the disks to take hold. When the clutch is "in," the car is on high speed (there are only two speeds forward on a Ford), and the entire transmission revolves, and the drive is then **direct** to the rear axle.

Principle of the Ford Transmission

The shaft **(S)** (Fig. 21) is connected, through the universal joint, to the drive shaft of the car. It is also fastened rigidly to the brake drum. Therefore any motion imparted to the brake drum will also be imparted to the rear axle and consequently to the rear wheels.

What Happens When the Transmission Is in Neutral

The flywheel (Fig. 21) and the shaded parts rotate. The clutch-release fork holds back the clutch spring from pressing on the clutch fingers.

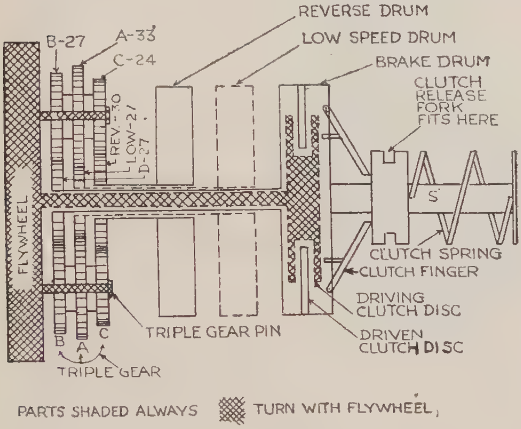


Fig. 21. Diagram of Ford Transmission.

Therefore the driving clutch disks will not be pressed against the driven clutch disks, and the brake drum will not be rotated. The low-speed drum and the reverse drum will rotate, but will have no effect.

What Happens When the Transmission Is in High

The release fork permits the clutch spring to press on the clutch fingers, thus pressing the driving clutch disks against the driven clutch disks. The brake drum will then be directly connected to the flywheel and the drive will consequently be direct. The low-speed drum and the reverse drum will rotate, but will have no effect.

The total gear ratio in high is therefore the ratio of the rear axle, which is 3.63, because the bevel-drive gear in the rear axle is so much larger than the pinion that the engine makes 3.63 revolutions for every turn of the rear wheels.

What Happens When the Transmission Is in Low

The release fork holds back the clutch spring and consequently the flywheel is not **directly** connected to the brake drum through the clutch disks.

A band is clamped around the low-speed drum (Fig. 21), thus holding the low-speed drum stationary. This drum is fastened to the gear **(LOW-21)** therefore **(LOW-21)** is stationary. Since the triple gear pins rotate with the flywheel, then triple gear **(A-33)** must rotate on the triple gear pin as it rolls around the gear **(Low-21)**.

The triple gears (A) (B) and (C) are all fastened together; consequently the rotation of **(A-33)** on the triple gear pin will cause **(B-27)** to turn on this pin. Since **(B-27)** is in mesh with the driven gear **(D-27)**, this latter gear will rotate, thus causing a slow motion of the brake drum to which it is attached. Since the brake drum rotates slowly, the car moves slowly.

Now refer to Fig. 22. Remember that gear **(D-27)** is fastened to the brake drum, and consequently to the drive shaft. The numbers on the gears correspond to the number of teeth on it, that is, **(A-33)** has thirty-three teeth, **(B-27)** has twenty-seven teeth, and so forth. The arm **(Ar)** represents the triple gear pin which is fastened to the flywheel and carries triple gears **(A-33)** and **(B-27)**. When the low-speed drum is stopped, gear **(LOW-21)** remains stationary, as just explained.

Let us see what takes place during one revolution of the flywheel. (1) The triple gear pin **(Ar)**, since it is part of the flywheel, will pass through one revolution as shown by the arrow **(S)**. (2) Consequently it will try to pull the driven gear **(D-27)** through one revolution in the same direction as shown by the arrow **(X)**. (3) Since gear **(LOW-21)** is stationary, one revolution of the triple gear pin **(Ar)** causes the gear **(A-33)** to turn in the direction shown by the arrow **(T)**. (4) But gear **(A-33)** has thirty-three teeth, while **(LOW-21)** has only twenty-one teeth; therefore gear **(A-33)** will not make quite one revolution, but will make only 21/33 of a revolution. (5) Gear **(A-33)** being fastened to **(B-27)** causes the latter to revolve the same amount, or 21/33 of a revolution, as represented by the arrow **(W)**. (6) Since **(B-27)** is in mesh with **(D-27)** and both have the same number of teeth, then **(D-27)** will try to revolve 21/33 of a revolution in the direction shown by arrow **(Y)**

As a result we find the effect on gear **(D-27)** to be as follows: The triple gear pin **(Ar)** tries to rotate **(D-27)** one revolution, as shown by the arrow **(X)**, whose length represents one revolution; the triple gears try to rotate **(D-27)** 21/33 of a revolution in the opposite direction, as shown by arrow **(Y)**, whose length represents 21/33 revolution. **Gear (D-27) will actually turn** the difference between the two, that is one revolution minus 21/33 of a revolution equals 12/33 of a revolution in the same direction as the flywheel as represented by the small arrow **(Z)**, whose length represents 12/33 of a revolution.

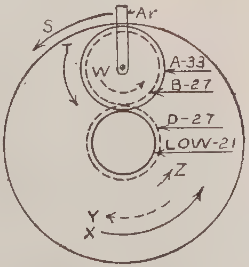


Fig. 22

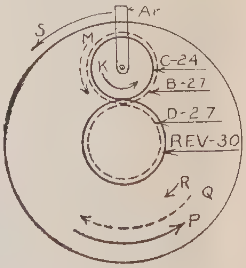


Fig. 23

Fig. 22. Diagram of Ford transmission in low speed.
Fig. 23. Diagram of Ford transmission in reverse.

The gear ratio in low is therefore 33 divided by 12, or 2.75. The rear axle has a ratio of 3.63, therefore the **total ratio** in low is 2.75 times 3.63, equals 9.98, or practically 10 to 1.

In general, owing to frictional losses in the transmission, and other causes, it may be assumed that the car will travel about three times as fast in high gear as in low. But the car will have about twice as much pulling force when low gear is used.

What Happens When Transmission Is in Reverse

The release fork holds back the clutch spring, and consequently the flywheel is not **directly** connected to the brake drum through the disks (Fig. 21).

A band is clamped around the reverse drum (Fig. 21), thus holding the reverse drum stationary. This drum is fastened to the gear (**REV**-30) therefore (**REV**-30) is stationary. Since the triple gear pins rotate with the flywheel, then triple gear (**C**-24) must rotate on the triple gear pin as it rolls around the gear (**REV**-30). The triple gears (**A**) (**B**) and (**C**) being all fastened together, the rotation of (**C**-24) will cause (**B**-27) to turn on the triple gear pin. Since (**B**-27) is in mesh with driven gear (**D**-27), this latter gear will rotate in a reverse direction, as explained later. The reverse rotation of (**D**-27) causes a reverse turning of the brake drum to which it is attached. Since the brake drum reverses, the car reverses.

Now refer to Fig. 23. Remember that gear (**D**-27) is fastened to the brake drum, and consequently to the drive shaft. When the reverse drum is stopped, gear (**REV**-30) remains stationary, as just explained.

Let us see what takes place during one revolution of the flywheel. (1) The triple gear pin (**Ar**) will pass through one revolution, as shown by the arrow (**S**). (2) Consequently it will try to pull the driven gear (**D**-27) through one revolution in the same direction as shown by the arrow (**P**). (3) Since the gear (**REV**-30) is stationary, one revolution of the triple gear pin (**Ar**) causes the gear (**C**-24) to turn in the direction shown by the arrow (**K**). (4) But gear (**C**-24) has only twenty-four teeth, while (**REV**-30) has thirty teeth; therefore gear (**C**-24) will make more than one revolution on the triple gear pin. To be exact, it will make 30/24 of a revolution, or 1 and 6/24 of a revolution. (5) Gear (**C**-24) being fastened to (**B**-27) causes the latter to revolve the same amount, or 30/24 of a revolution, as represented by the arrow (**M**). (6) Since (**B**-27) is in mesh with (**D**-27), and both have the same number of teeth, (**D**-27) will try to revolve 30/24 of a revolution in the direction shown by the arrow (**Q**).

As a result we find the effect on gear (**D**-27) to be as follows: The triple gear pin tries to rotate (**D**-27) one revolution, as shown by the arrow (**P**), whose length represents one revolution; the triple gears try to rotate (**D**-27) 30/24 of a revolution, as shown by the longer arrow (**Q**), whose length represents 30/24 of a revolution. **Gear (D-27) will actually turn** the difference between the two, that is 30/24 of a revolution, minus one revolution, equals 6/24 of a revolution, in the direction of the small arrow (**R**), whose length represents 6/24 of a revolution.

Notice that the arrow (**R**) points in the opposite direction to the arrow (**S**). Consequently (**D**-27) turns in the opposite direction from the flywheel, thus causing reverse rotation to the brake drum.

The gear ratio in reverse is therefore 24, divided by 6, which equals 4. Since the rear axle has a ratio of 3.63, the **total ratio** in reverse is 4 times 3.63, which equals 14.52 to 1, which is nearly 15 to 1. But owing to the number of gears transmitting the power when reverse is used, the actual available power in reverse is not as great as might be supposed. However, it is sometimes possible to use the reverse gear to pull the car out of a mudhole when even the low speed gear does not have sufficient power.

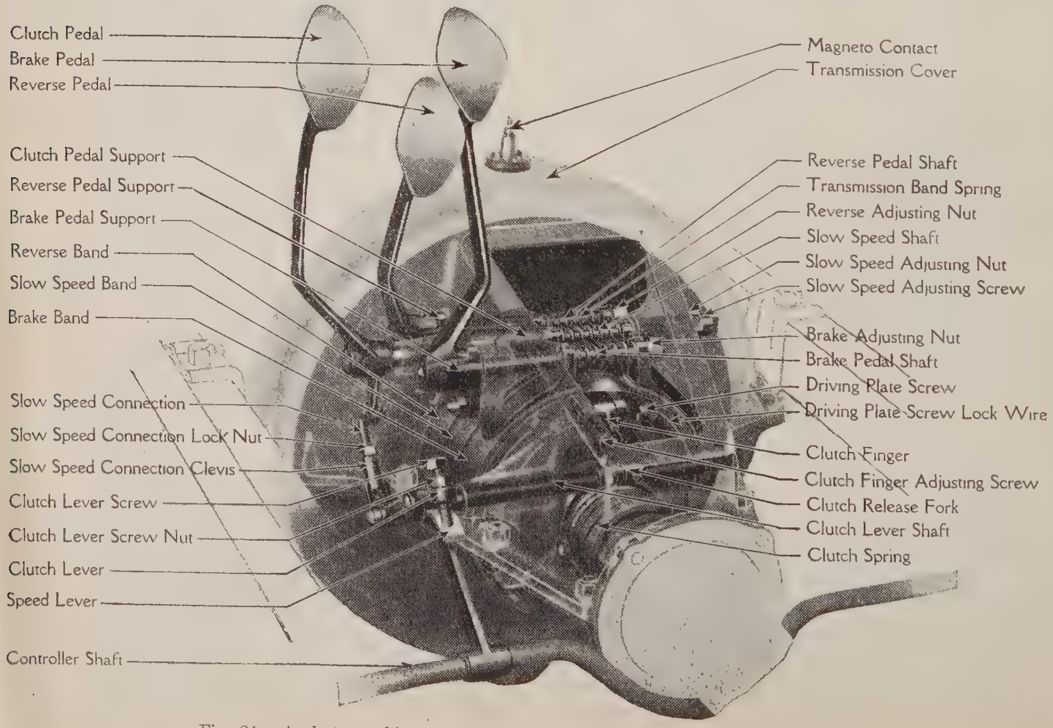


Fig. 24. A photographic view of the Ford **transmission and control pedals.**

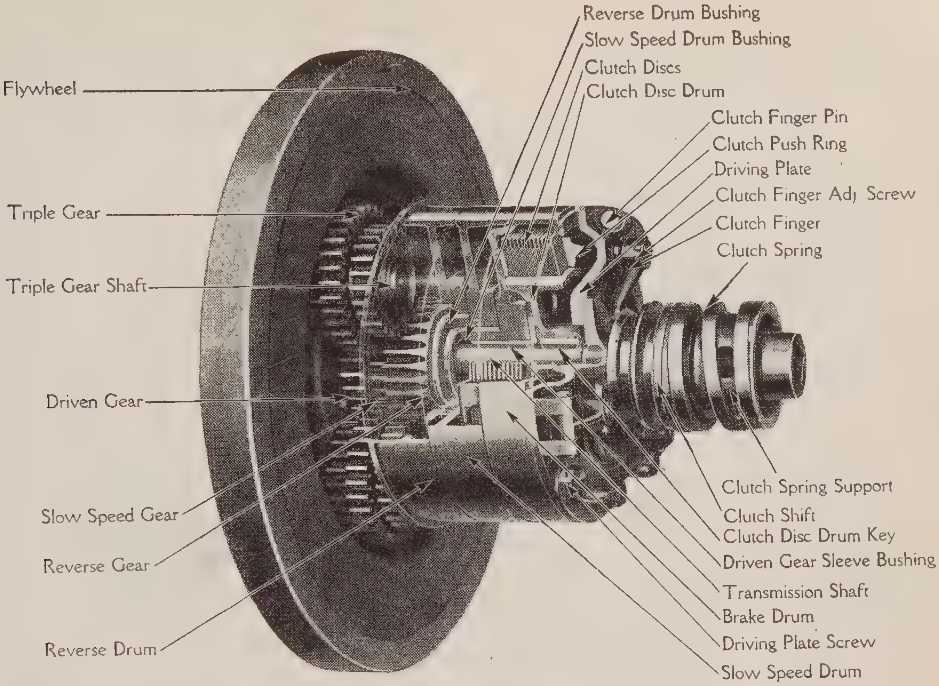


Fig. 25. A phantom view of the Ford **transmission and clutch,** showing how it is attached to the flywheel.

Clutch Control

The control of the clutch is by the left pedal at the driver's feet. If the clutch pedal, when pushed forward into slow speed, has a tendency to stick and not to come back readily into high, tighten up the slow-speed band, as directed farther on.

Should the machine have an inclination to creep forward when cranking, it indicates that the clutch lever screw (B) (Fig. 27), which bears on the clutch lever cam (C) has worn, and requires an extra turn to hold the clutch in neutral position.

When the clutch is released by pulling back the hand lever, the pedal should move forward a distance of 1¾″ in passing from high speed to neutral. See that the hub brake shoe and connections are in proper order, so that the brake will act sufficiently to prevent the car creeping very far ahead. Also be sure the slow-speed band does not bind on account of being adjusted too tight.

Clutch Slips or Drags

A slipping clutch may be due to worn main bearings, allowing the crank shaft to vibrate, or it may be due to the use of heavy oil in the engine.

When the clutch drags: This may be due to heavy or old oil. This oil collects between the clutch plates, and does not allow them to separate freely from each other, as they should, when the clutch is disengaged. An oil that is too heavy for the clutch plates is also too heavy for good use in the engine. Heavy oil will not penetrate into the closely fitted bearings, and if the oil does not get in, friction and rapid wear will result.

Heavy oils are sometimes used in Ford engines with the idea that the heavy oil will seal the gaps between worn pistons and cylinder walls, but the only effective remedy is to replace pistons and other worn parts as needed. **In winter, oil should have a low cold test,** that is, the oil should not congeal easily. If it does, the engine will be very hard to start on account of the **dragging of the clutch and the bands on the transmission drums.**

To Tighten Brake and Reverse Bands

Remove the transmission case cover and turn the adjusting nuts on the shafts to the right (Fig. 26).

The bands should not drag on the drums when disengaged, as they have a tendency to exert a brake effect, and to overheat the engine. The foot brake should be adjusted, however, so that a sudden pressure will stop the car immediately, or slide the rear wheels in emergency cases.

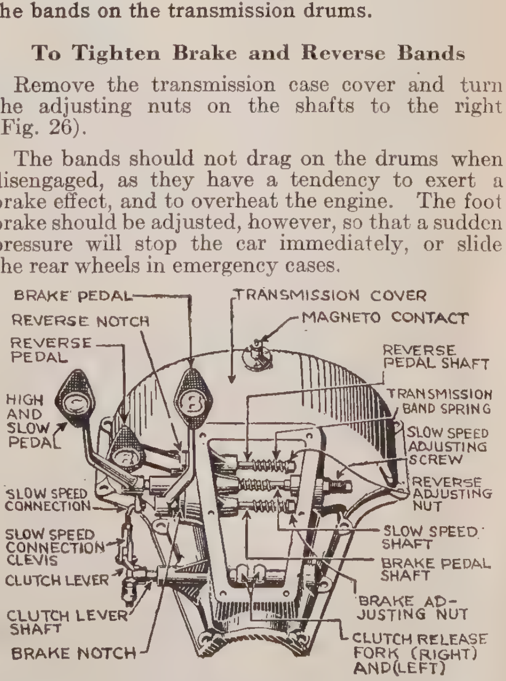


Fig. 26. **Transmission cover showing where adjustments are made.** The transmission-case cover (which bolts over the wedge-shaped opening) has been removed, thus exposing the reverse and the brake adjusting nuts.

To Tighten Slow-Speed Band

Loosen the lock nut at the right side of the transmission cover, and turn the adjusting screw (see Figs. 26 and 27) to the right.

If the reverse grabs and sticks at times, and the lining is in good condition, this is due to the adjustment on the foot pedal on the reverse, which allows the pedal to be pressed too far. This can be remedied by turning the reverse adjusting nut shown in Fig. 26.

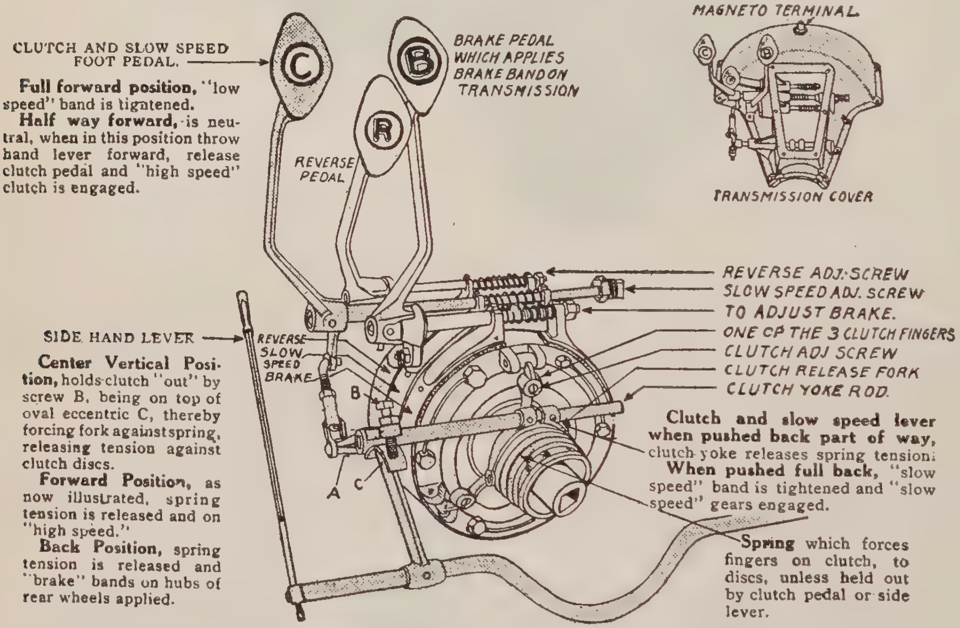
If the clutch slips in high speed, jack one rear wheel up, turn the engine so that the clutch fingers (Fig. 27) come in convenient position, remove the split pin, give half a turn clockwise to each clutch adjusting screw, and replace the pins. Do not drop the pins in the transmission case. After long wear, new disks will be needed. It will be necessary to remove the transmission cover, as explained later.

When the transmission band linings have become hard and glazed, they will not grip the drums until the pedals have been pushed very hard and all the oil has been squeezed from between the bands and the drums. Then the bands take hold with a series of jerks, and this causes a chattering and severe strains on both the transmission and the rear axle assembly.

Other evidences of worn transmission bands are:

1. The failure of the foot brake to hold in spite of all the adjustment that can be made through the cover on the top of the transmission case, without causing the bands to drag.
2. Or if the low-speed and reverse gears slip when the pedals are pushed, and the engine races, while the car does not travel as fast as it should.

On an average, the brake linings should give good service for about six months; with good driving, from ten months to a year of service may be had, counting on from five to ten thousand miles driving as a year of service.



Full forward position, "low speed" band is tightened. **Half way forward,** is neutral, when in this position throw hand lever forward, release clutch pedal and "high speed" clutch is engaged.

Center Vertical Position, holds clutch "out" by screw B, being on top of oval eccentric C, thereby forcing fork against spring, releasing tension against clutch discs. **Forward Position,** as now illustrated, spring tension is released and on "high speed." **Back Position,** spring tension is released and "brake" bands on hubs of rear wheels applied.

Clutch and slow speed lever when pushed back part of way, clutch yoke releases spring tension; **When pushed full back,** "slow speed" band is tightened and "slow speed" gears engaged.

Spring which forces fingers on clutch, to discs, unless held out by clutch pedal or side lever.

Fig. 27. Connections of **hand lever and foot pedals** to transmission and clutch.

Causes and Symptoms of Worn Transmission-Band Linings

Cause: When starting the car, the driver should press the pedal forward until the low speed begins to engage. Then the pedal should be pressed more slowly until there is no slipping of the band on the drum. When using the low-speed gear on long, steep hills, many drivers unconsciously relax the pressure on the pedal, so that the drums slip and wear the bands. Hold the pedals in firmly when the bands have once been engaged with the drums.

Another cause of rapid wear of the bands is the habit of some drivers of racing the engine at high speeds before attempting to engage the transmission bands. The best driver is the one who can use the gears and not speed up the engine any faster than will just avoid stalling. If the engine is not raced too fast, there will not be so much difference between the speed of the transmission bands and the speed of the drums. Then there will be less wear on the band linings and less strain on all parts of the car.

By driving on the throttle, as much as possible, instead of using the clutch so often, the bands will be made to wear longer.

Removing Transmission Cover

1. Remove the magneto wire.
2. Remove the starting motor.
3. Remove the 3/8" bolts holding on the transmission cover. (Use L-handle wrench No. 2322 for keeping the nuts from turning, while the bolts are turned from below, by using T-wrench No. 2320.)
4. Loosen and remove the two bolts which hold the universal ball cap to the transmission cover.
5. Loosen the lock nut on the low-speed screw and loosen the low-speed adjustment.
6. Push the emergency brake lever forward.

If the cover is hard to remove, then loosen the nuts on reverse and the brake-adjustment nut as far as they will go, and remove the slow-speed adjusting screw.

Removing Bands

Now the cover can be pulled off, and then the bands.

Place the band nearest the flywheel over the first of the triple gears. Turn the band around so that the opening faces downward. The band can then be removed by lifting up.

If the three sets of triple gears are so placed that one set is about 10° to the right of center at the top, the operation is considerably simplified. Each band is removed in the same way. It is important to shove each band forward on to the triple gears—as only at this point, is there sufficient clearance in the crank case to allow the ears of the transmission bands to be turned down.

Relining Bands

Instructions for relining the brake bands are given elsewhere. See page 893. The sizes of the linings are 5/32″ or 11/64″ thick, 1⅛″ or 1 3/16″ wide, and 23 5/16″ or 23⅜″ long.

Never use linings containing metallic reinforcements for the transmission bands. Special Ford linings should be used. Particles of wire, worn from ordinary band linings, are apt to cut through the insulation of the magneto, which is in the same compartment as the transmission. A short-circuited magneto necessitates pulling the engine out of the car for repairing.

At the Ford branches or agencies, transmission bands can be exchanged for 50 cents each. As the cost of the linings and rivets is about 40 cents, it usually pays to exchange the bands.

Use soft brass rivets: When relining the transmission bands, use soft brass rivets. If iron rivets are used, particles of iron, worn from the rivets, will be attracted to the magneto, and will tend to cause short circuits.

Iron rivets are so hard that they will cut and score the soft iron brake drums, thus making them liable to break.

To Install Bands

Simply follow the reverse of the procedure of removing the bands. When the three bands are placed in an upright position on the drums, placing the transmission cover on can be facilitated by passing a cord around the ears of the three bands, and holding them in the center. The pedal shafts can then be made to rest in the notches in the band ears.

The clutch release fork should also be placed in the rear groove of the clutch shaft.

Replacing Transmission Cover

First, tie the lugs of the three bands together tight, with a piece of wire or cord, or construct a band holder, as shown in Fig. 28.

Second, make sure that all the gaskets are in place and that none of them are defective. Broken gaskets will allow oil to escape when the engine is running. The oil is splashed around in the transmission case by the flywheel and transmission drums.

Third, loosen the nuts on the brake and slow-speed studs as far as they will go, without danger of falling off.

Fourth, compress the springs on these operating studs. This will make it much easier to replace the transmission cover.

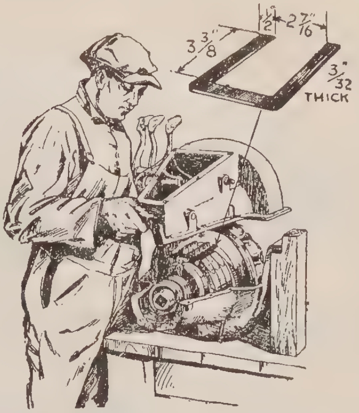


Fig. 28. **This clamp is used to hold the transmission bands together while replacing the transmission cover.** It is made of spring steel ½″ wide and 3/32″ thick, bent into the form of a U, having legs 3⅜″ long and 2 7/16″ across. One of these is clamped over the lugs on the transmission bands before replacing the cover, and is removed after the cover is bolted on. (*Motor World.*)

Fifth, replace the cover and all the bolts, and tighten them securely. It is not usually necessary to fit those around the sides with cotter pins. However, the bolts holding the universal ball cap must endure greater strains, so they should be fitted with cotter pins.

Remove the cord or wire, which was used to hold the bands in place while the cover was being installed.

Adjusting Bands

Adjust the bands so that the pedals can be pushed down to within a couple of inches of the floor boards, before the bands grip tightly. After running a couple of hundred miles, adjust the bands again, using the double-end wrench, No. 1917.

Transmission Gears

If the teeth of the triple gears are worn or chipped to such an extent that they do not properly mesh, they will cause a growling or grinding noise, especially when low or reverse gears are used.

Transmission Bearings

The transmission is supported at the rear end by a babbitt-lined bearing at the universal ball cap. If this bearing is worn, it will cause a knock in the transmission when the car is traveling over rough roads.

Worn bushings in the second speed and reverse drums throw the transmission shaft out of line; hence the gears become worn and noisy. It is advisable to install new bushings as soon as worn before they cause gear-teeth trouble, which means an ugly grinding noise.

A "chattering" noise in the transmission means that new band linings are needed. The same remedy applies when the car runs with a jerky movement.

To Remove Transmission

Take the upper part of the engine off the lower part of the crank case, as explained under "Removing power plant." Next remove the transmission cover (Fig. 28), and the crank-case cover. Then remove the four cap screws that hold the flywheel to the crank-shaft flange, using the special Ford flywheel cap-screw wrench No. 1929. The entire transmission may then be easily removed from the cylinder block assembly.

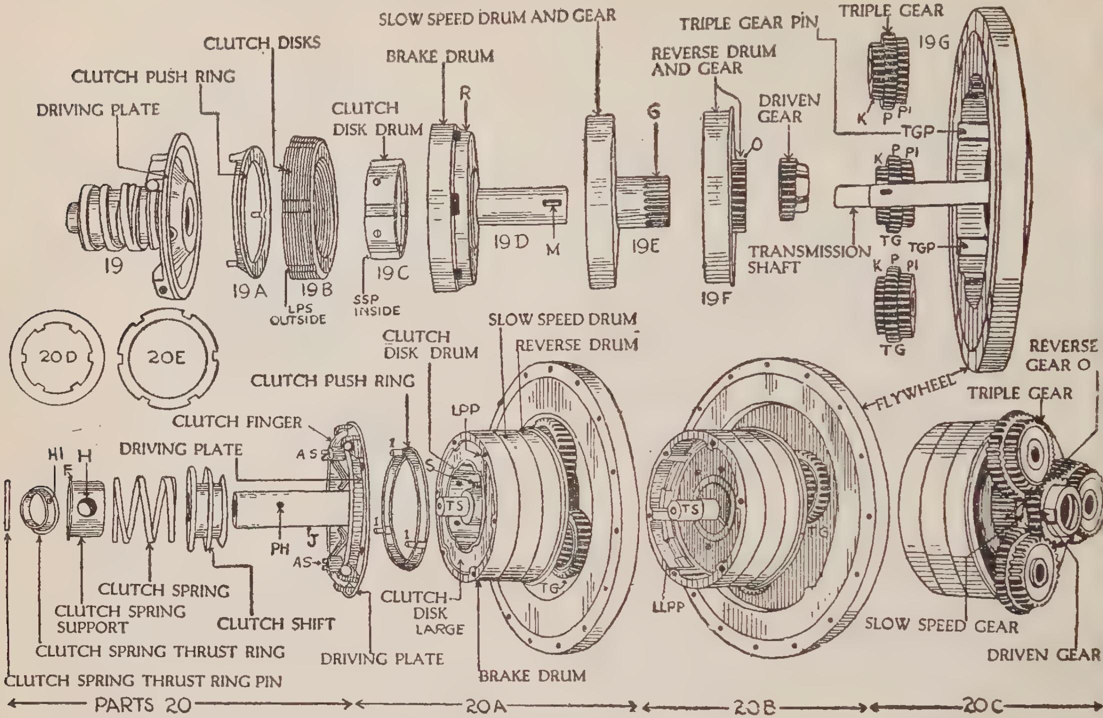


Fig. 29. **Parts of the Ford transmission:** The objects marked (19) to (19G) illustrate the parts of the transmission separated but in their respective order to be assembled.

Clutch: Note that the twelve small clutch disks or thrust plates (**20D**) and the thirteen large disks (**20E**) are placed together alternately (see 19**B**).

The projection on the small plates fits the slots of the disk-drum (19C), the latter being rigidly fastened to the transmission shaft (TS), whereas the slots in the large plates fit in projections (**LPP**) of the illustration (20**A**). The disk-drum (19C) is fastened to the transmission shaft by set-screw (S). The pressure of the "clutch push ring" (19A), due to the tension of the "clutch spring" (19) against the "clutch fingers," causes the large and small disks to grasp. The adjustment of the clutch fingers is made by screws (**AS**).

Transmission shaft (TS) and small plates (20**D**) run free in the brake drum, when the clutch is disengaged, in other words, the small plates revolve with the flywheel.

Slow-speed drum (19**E**) fits over the part (**R**) of the brake drum (19**D**). The driven gear is fastened to the hollow shaft (**M**) of the brake drum (19**D**) by means of two Woodruff keys.

Triple gears (TG), (K) are the reverse gears, (P) the slow-speed gears, and (P^1) the driving gears. These gears are fastened rigidly together in groups of three and are called triple gears on that account. There are three groups, and they revolve freely on pins (**TGP**) of the flywheel. (K) meshes with the gear on reverse drum (19F); (P) meshes with gear (G) on the hollow shaft of the slow-speed drum (19E); (P^1) meshes with the driven gear, and is keyed to the hollow shaft (M) on brake drum (19D), which projects past gear (G). The action can now be studied by referring to this illustration and the discussion of the principle previously given.

How to Assemble the Transmission

First, assemble the group of parts as shown in (20C) as follows: Place the brake drum (**19D**) so that the hub is in a vertical position; place the slow-speed drum (19E), with gear (G) up, over the shaft (**M**) of the brake drum. The slow-speed drum will then fit over (R).

Next, place the reverse drum (19F) over the hollow shaft of (19E), so that the reverse gear (O) on the drum surrounds the slow-speed gear (G).

Then fit two Woodruff keys in the shaft of the brake drum at (M), and place the "driven gear" (with teeth down) so that they will then come next to the slow-speed gear (G).

Triple gears (TG) (all three groups) should now be meshed with the driven gear, according to the punch marks on the teeth—the reverse gear or the smallest of the triple gear assembly being down.

When the triple gears are properly meshed, tie them in place with a string or cord passed around the outside of the three triple gears.

Second, assemble the parts to the flywheel as in (20B); place the flywheel on the bench with face down, and the shaft vertical.

Turn the group (20C) upside down, and place it over the transmission shaft, so that the three triple gear pins (TGP) on the flywheel will pass through the triple gears.

This will now leave the brake drum on top, as **shown in (20B), ready to take the clutch disks (19B).**

If the transmission is assembled, and if the triple gears, when in slow and reverse, growl, this is due to one of two causes: (1) The triple gears have a punch mark which should be in the center line with the driven gears. If the gears were rebushed, it is not likely that they will be placed back wrong, but if not, and the bushings are worn and loose, this may be the cause: (2) The bands may be adjusted too tight.

Assembling the Clutch

Third, fit the clutch-disk drum key in the transmission shaft; press the clutch-disk drum (19C) over the transmission shaft (TS) (20B), and put the set screw (S) in place to hold the drum.

Put a large clutch disk (20E) over the clutch drum, then a small clutch disk (20D) alternating with large and small disks until the twelve small and thirteen large disks are in place. A large clutch disk, or "thrust plate" as it is termed, will then be on top, as shown at (20A). Do not put a small disk on top.

Now place the "clutch push ring" (19A) over the clutch drum, so that it will be on top of the disks, with the pins (1) up.

Fourth group 20: Next bolt the "driving plate" in such a manner that the adjusting screws of the three "clutch fingers" will press against the "clutch push-ring pins" (1).

Fifth, it is now advisable to test by moving the clutch disks, and to see if they will move freely by hand. If properly assembled, the flywheel will revolve freely while any of the drums are held stationary.

Sixth, assemble the clutch-spring parts. Place the "clutch shift" (parts 20) over the driving plate hub **(J)**, so that the small end rests on the clutch fingers. The clutch-spring support is then slipped into the spring so that the flange **(F)** will rest on the upper coil of the spring; then insert the "clutch-spring thrust ring"[1] and press it into place. Insert the pin in the driving plate hub at **(PH)**, through the hole **(HI)** in the side of the thrust ring. This part of the work requires some "knack," but is simplified considerably by using a compressor similar to that shown on page 1137. The large holes **(H)** in the clutch-spring support facilitate the insertion of the pin.

Another easy method of compressing the clutch spring, so that the pin can be inserted, is to loosen the tension of the three clutch-finger adjusting screws **(AS)**.

When the clutch is tightened up again, the spring should be compressed to within a space of 2″ or 2 1/16″, to make sure the clutch spring does not slip.

The adjusting screws (AS) should be adjusted so that there is even tension all around the clutch disks. These screws are now provided with a slot, and it is necessary to turn them at least one half-revolution so that the slot comes in line with the cotter-pin holes; then insert the cotter pins.

Rebushing and Reaming of Transmission Drums and Gears

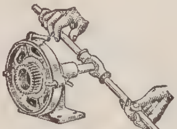
The bushings in drums and gears, when worn, can be replaced with new bushings and then reamed.

When reaming with an ordinary hand reamer, the gears are liable to wabble. Therefore, some sort of fixture should be used by which the drums can be accurately centered and located at fixed right angles, so that they may be reamed absolutely true, thus making a quiet transmission.

A reaming outfit with a centering device is shown in Figs. 30–33, which is a product of the K. R. Wilson Co., Buffalo, N.Y.

The bronze bushings in reverse gear (Fig. 30), the slow-speed gear (Fig. 31), the two bushings in the transmission brake drum (Fig. 32), and one bushing in each of the three triple gears (Fig. 33) should be replaced in case of wear.

The bushings are purposely made with the inside diameter a little smaller so that they can be reamed to an exact fit to the bearings on which they are to revolve.



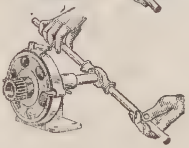
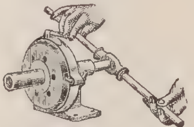


Fig. 30 (Upper)
Fig. 31 (Lower)



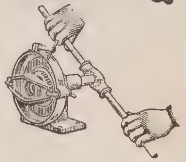


Fig. 32 (Upper)
Fig. 33 (Lower)

Fig. 30 shows a Ford **transmission reverse drum held in position in a reaming fixture,** especially designed. This fixture automatically locates the drum at right angles to the reamer, and with perfect centers. The reamers used in this machine are all especially designed, using a common standard-size arbor, the reamer proper being interchangeable on that arbor. The reamers are ground at a 45° angle in place of a long taper. This type of cutter plows through the bearing metal without being deflected off center, as in common practice with a long taper, where more cutting surface is exposed to the metal being cut.

Fig. 31 shows a Ford **slow-speed bushing being reamed** by the same process as that shown above.

Fig. 32 shows a Ford **transmission brake drum.** This drum has two bushings which must be reamed in perfect alignment. For this a special reamer with a pilot is used, the arbor being of the same size and interchangeable, as in the case of those used in Figs. 30 and 31.

Fig. 33. A Ford **triple gear being reamed,** correctly centered and at right angles; the clamp shown holds the center gear surface against the finished surface of the reaming fixture, thereby holding it in perfect alignment.

It is proper to use an arbor press for taking out or replacing bushings, as an even strain on all sides is applied. Many mechanics use a sledge hammer to force these bushings in place, with the result that they may batter over the ends of the bushings and, unless a self-centering reaming fixture is used, the reamer would have a tendency to be deflected off center, or in the direction of the least amount of metal to be removed, usually reaming out of alignment.

Bushings that are worn have no metal to ream out. Two or three years ago, there was put on the market a very powerful press for the purpose of compressing bushings, thereby making them tighter in the drums or triple gears, and also making the hole smaller. The low cost of bushings has prevented this idea from proving very successful, as the average mechanic prefers a new bushing. The cost of a press was nearly $200, a rather large investment for the ordinary repair shop for a tool doing only a limited amount of work, although it is a good investment if the business is large enough to warrant it.

Bushings should be renewed whenever they are loose and sloppy. If not renewed and properly fitted, as in the case of a planetary transmission, there will be excessive wear and noise due to imperfect meshing of the gear teeth in various positions of a revolution, with the result that the gears wear excessively and unevenly on the pitch diameters (or shoulders) of the gear, while, if held in perfect alignment by being properly fitted, they must wear evenly, as originally designed. Gears which have been allowed to become loose and sloppy on the bearings will be rounded off toward the end of the teeth, and in reality there is no special bearing surface on the gear with worn teeth.

---

[1] On the later cars the "clutch-spring thrust ring" is not used, its function being incorporated in the "clutch-spring support," the inner end of which is contracted and has four small lugs for the reception of the "thrust-ring pin."

REAR AXLE AND PARTS

The axle housing is made in two parts (Fig. 39). The later types of rear axle housings are much stronger than those made in earlier years.

Drive shaft and housing (Fig. 35): The housing or tubing encloses the drive shaft and also takes the torque or twist off the rear axle, when the car is being started or stopped, that is, in connection with the radius rods. This sometimes causes the tube to break near the rear axle.

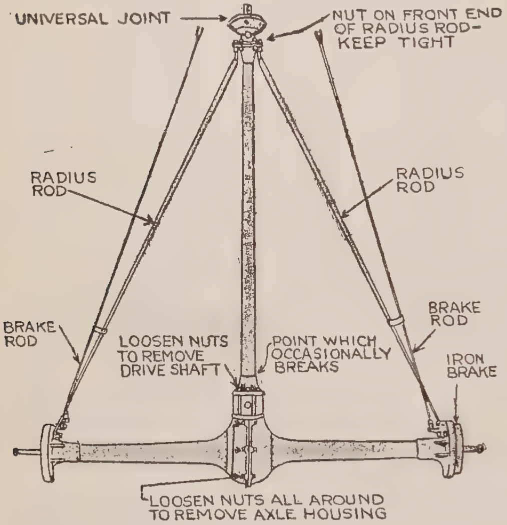

UNIVERSAL JOINT
NUT ON FRONT END OF RADIUS ROD-KEEP TIGHT
RADIUS ROD
RADIUS ROD
BRAKE ROD
BRAKE ROD
LOOSEN NUTS TO REMOVE DRIVE SHAFT
POINT WHICH OCCASIONALLY BREAKS
IRON BRAKE
LOOSEN NUTS ALL AROUND TO REMOVE AXLE HOUSING

Fig. 34. Rear axle assembly.

Drive shaft and its bearings (Fig. 36): There is a roller bearing to support the shaft and pinion, and a ball-thrust bearing above the roller bearing to take the thrust of the pinion against the drive gear.

The entire rear axle and drive shaft, shown in Fig. 34, must be removed when repairs are to be made to the differential, or the drive gears, or when new axle shaft is installed. The Ford rear axle is a "plain live" type of axle, see page 15.

To test for wear or play in the rear-axle drive system, jack up one of the rear wheels and notice if the rear wheel can be turned 4" or more. If so, it is likely that there is wear in the rear-axle gears, or in the universal joint, or both. They must be replaced. While working around the universal joint, **tighten all nuts** on the radius rod, front and rear.

To Remove Rear Axle

Jack up the car and remove the rear wheels. Take out the four bolts connecting the universal bolt cap to the transmission case. Then disconnect the brake rods. Remove the nuts holding the spring perches to the rear axle housing flanges. (It is sometimes easier to remove the shackles which connect the spring to the spring perch.) Raise the frame at rear, and remove entire axle. (See Fig. 34.)

Disconnecting Universal Joint

The two plugs from the top and bottom of the ball casting must be removed. Then turn the shaft until the pin comes opposite the hole. Drive out the pin and force the joint away from the shaft. (See Figs. 37 and 45.)

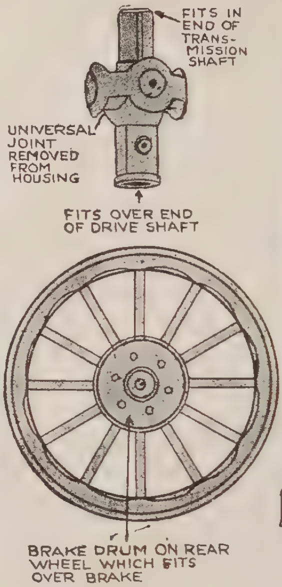

FITS IN END OF TRANS-MISSION SHAFT
UNIVERSAL JOINT REMOVED FROM HOUSING
FITS OVER END OF DRIVE SHAFT
BRAKE DRUM ON REAR WHEEL WHICH FITS OVER BRAKE

Fig. 37 (upper)
Fig. 38 (lower)

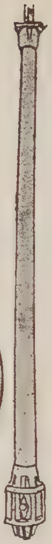


Fig. 35

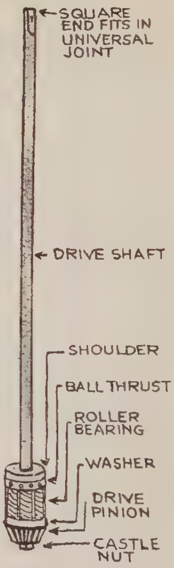


Fig. 36

Fig. 35. Propeller or drive shaft enclosed in a housing or tube; Fig. 36. Propeller or drive shaft and parts; Fig. 37. Universal joint; Fig. 38. Brake drum on rear wheel.

To Disassemble Rear Axle

See Figs. 34 and 39. Disconnect the universal joint first, then the radius rods at the front end; then loosen the nuts on the studs holding the drive shaft to the rear axle (Fig. 34). Next, remove the nuts holding the axle housing together over the differential, as in Fig. 39. The axle housing in two parts is then removed from the axle shafts.

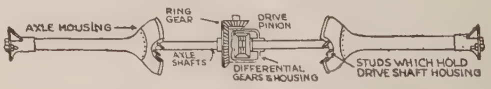

AXLE HOUSING
RING GEAR
DRIVE PINION
AXLE SHAFTS
DIFFERENTIAL GEARS & HOUSING
STUDS WHICH HOLD DRIVE SHAFT HOUSING

Fig. 39. Axle shafts, axle housings, and differential.

To Remove Axle Shafts

Follow the plan in the preceding paragraph, and as in Figs. 34 and 39. Take the inner part of the differential casing apart, by removing the bolts which hold the two halves together as in Fig. 40, and draw axle shaft through casing at the center.

When replacing the axle shaft, be sure the rear wheels are firmly wedged on at the outer end, and that the key is in proper position. With a new car the hub caps should be removed and the lock nut tightened. In fact, it is essential that the rear wheels be kept tight.

If the rear axle or wheel is sprung by skidding or striking a curb, or if the axle shaft is bent, replace it.

Removing Drive Pinion

The pinion end of the drive shaft, to which the pinion is attached, is tapered to fit the pinion tapered hole which is keyed on to the shaft, and then is additionally secured by a cotter-pinned "castellated" nut. Remove the castle nut, and drive the pinion off (Figs. 35 and 36).

No adjustment is provided. Fit new parts if worn.

The Differential

There is no adjustment on the Ford differential between the pinion and drive gear. New parts are usually fitted.

Removing differential gears: The gears are keyed on to the axle shafts, and are held in position by a ring or split washer, which is in two halves and fits in a groove in the rear axle shaft (Fig. 40).

Force them down on the shaft, away from the end to which they are secured; drive out the two halves of the ring in the grooves in the shaft with a screwdriver or chisel; then the gears can be forced off the end of the shafts.

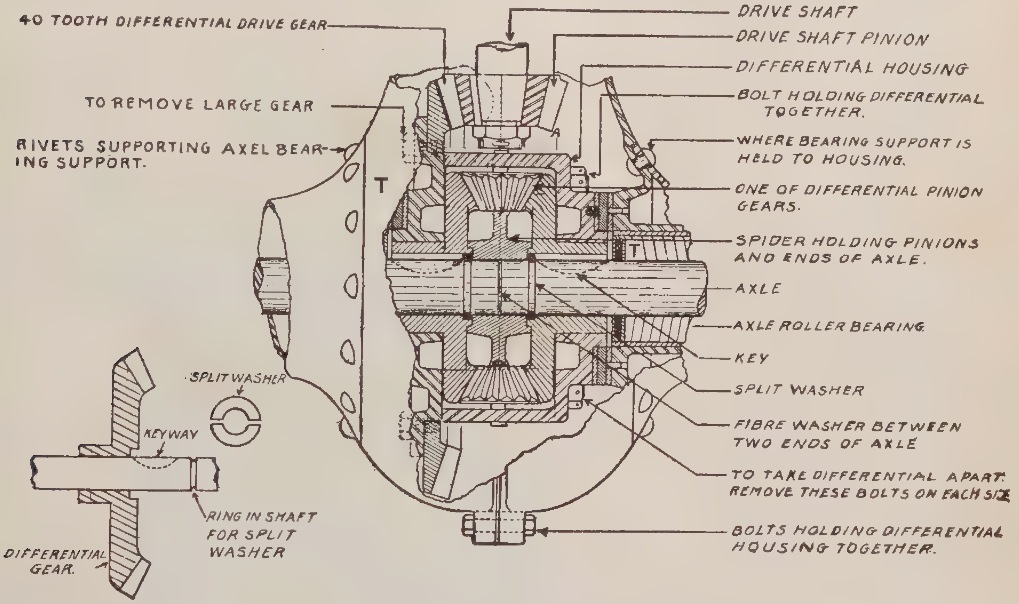

40 TOOTH DIFFERENTIAL DRIVE GEAR
TO REMOVE LARGE GEAR
RIVETS SUPPORTING AXEL BEARING SUPPORT.
T
T
SPLIT WASHER
KEYWAY
RING IN SHAFT FOR SPLIT WASHER
DIFFERENTIAL GEAR.
DRIVE SHAFT
DRIVE SHAFT PINION
DIFFERENTIAL HOUSING
BOLT HOLDING DIFFERENTIAL TOGETHER.
WHERE BEARING SUPPORT IS HELD TO HOUSING.
ONE OF DIFFERENTIAL PINION GEARS.
SPIDER HOLDING PINIONS AND ENDS OF AXLE.
AXLE
AXLE ROLLER BEARING
KEY
SPLIT WASHER
FIBRE WASHER BETWEEN TWO ENDS OF AXLE
TO TAKE DIFFERENTIAL APART. REMOVE THESE BOLTS ON EACH SIDE
BOLTS HOLDING DIFFERENTIAL HOUSING TOGETHER.

Fig. 40. Differential, drive pinion, and axle shafts.

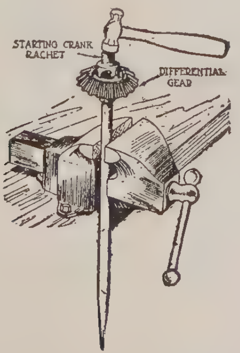


Fig. 41. **Removing the differential gear from the axle shaft.**

One method for doing this is shown in Fig. 41. The Ford differential gears can be removed from the shafts by placing an old starting-crank ratchet in the face of the gear, and driving it with a hammer till the gear is below the half-moon key. The key is then removed and the gear driven off.

Rear Wheels

The rear wheels are fitted with pressed-steel brake drums to which the emergency or hand brake operates. See Figs. 42, 34, and 38.

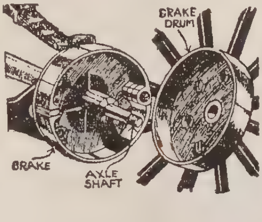


Fig. 42

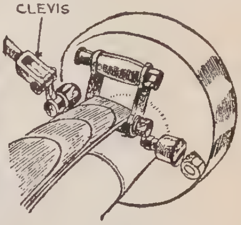


Fig. 43

To remove rear wheels, take off the hub cap, remove the cotter pin, unscrew the nut, and with a wheel puller remove the wheel from the tapered shaft to which it is locked with a key.

Hand Brakes

The cast-iron brake shoes will wear if used very much. This brake is usually used for holding the car when at rest on an incline, and not for slowing down the car.

Brake shoes, lined with asbestos fabric can be obtained from accessory dealers, and will last longer than plain cast-iron shoes.

To replace these brake shoes, (1) remove the rear wheels; (2) unscrew the nut and bolt on which the brake shoes are pivoted to the axle housing. The brake shoes can now be pulled off.

Put the springs in place on the new brake shoes; then place the open ends of the brake shoes over the cams, and swing the brake shoes into place.

Replace the wheels, and tighten the axle-shaft nuts securely, before putting the cotter pins in place.

Equalize the rear hub brakes, by removing the cotter pins and pulling out the clevis pins (see Fig. 43), and then turning the clevises on the brake-connecting rods until the two brakes grip equally. Be sure that the clevises catch enough threads on the brake rods to give strength.

Universal Joint and Shaft Bushing

The universal joint and the driving shaft front bushing (Fig. 44): When this bushing becomes worn (which will take a long time, if the grease cup is turned regularly), it will be necessary to have the new bushing forced in in the shop, and then reamed to fit the axle shaft.

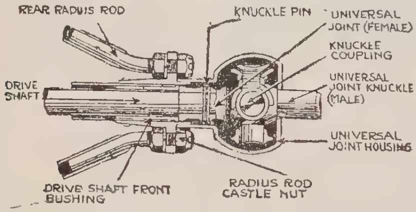


Fig. 44. The universal joint and parts.

Grease Leaks from Rear Axle

Grease leaks from the rear axle: These are the result of too much grease. One and a half pounds of grease is plenty, but a small amount should be added every thousand miles. See also page 1085.

Another reason for the leakage is, that in this construction Hyatt roller bearings are used, which tend to permit leakage of fluid or semi-fluid lubricants. The ring gear (or main differential gear) takes up too great a quantity and distributes it to the shafts. The centrifugal action of these shafts carries the lubricant to the outer end, and **if the felt washers are not in first-class condition,** the grease works out to the brake drums.

Worn thrust washers (T) (Fig. 40) allow the axle shafts and differential to shift from side to side and pump the grease out. This usually causes the grease to appear around the left wheel first, as that wheel is nearer the drive gear.

Worn thrust washers will cause the gears to grind. The noise will change as the car turns corners to right or left, and the weight of the car is shifted from side to side.

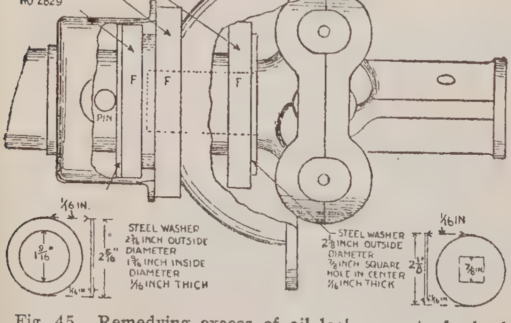

NO.2510-B-FELT WASHER
UNIVERSAL FRONT BALL CAP BACK COVER
UNIVERSAL JOINT
NO 2829
NO 2829
F
F
F
PIN
1/16 IN.
1 9/16
2 5/16"
STEEL WASHER 2 3/16 INCH OUTSIDE DIAMETER 1 9/16 INCH INSIDE DIAMETER 1/16 INCH THICK
1/16 IN
STEEL WASHER 2 1/8 INCH OUTSIDE DIAMETER 7/8 INCH SQUARE HOLE IN CENTER 1/16 INCH THICK
2 1/8"
7/8 IN
1/16 IN
1/16 IN

Fig. 45. **Remedying excess of oil leakage out of wheel bearings:** The oil from the transmission works down the drive shaft, through the universal joint, through the differential, out at the axle ends, causing an excess of oil on the brakes.

To overcome this, place a felt washer at **(F).** (Note the Ford stock numbers on these felt washers.) Then place steel washers (see illustration for size), as shown in the illustration.

To put these washers in place, remove the rear axle and rear half of the universal joint, then remove the front universal cover ball-cap cover. Put the felt and metal washer on, as shown, by placing them over the transmission shaft. Then put No. 2829 washer on after the cover is removed. Note the pin which will hold the washers in place. The washer 2510B and steel washer are easily applied when the universal joint is apart. Reassemble carefully.

Worn thrust washers require that the rear axle be removed from the car and taken apart before new washers can be inserted. Ball-bearing thrust washers are now made for Ford rear axles, and it is claimed that they wear longer. They should give less friction, and should therefore be useful for speedsters and racing.

The felt washers become worn and hard with use. They can be replaced—after removing the wheels—without taking the axle system off the car.

Two felt washers should be pushed on the axle shaft near the roller bearing next to the differential. A third felt washer should be placed near the outside end of the axle shaft, just inside of the outer roller bearing. These felt washers are cheap, and easily replaced, and, if only one pound of grease is used, will usually cure the rear-axle grease leakage.

If light grease or oil is used it will leak out rapidly. If the grease is too stiff and heavy, the gears will simply cut a groove through the grease and the bearings will not be lubricated. Mobilubricant is often used for Ford rear axles, as also Kaoga No. 2.

A Special Transmission

A four-speed transmission is made for Fords by specialty concerns. One concern supplying these is the Laurel Motors Corpn., Anderson, Ind.

Gear Ratios and Special Gears

The standard ratio is 3 7/11 to 1 on high gear or direct drive. Changes can be made by purchasing the differential ring gear and drive pinion (Fig. 46) from Laurel Motors Corpn., Anderson, Ind., or from Detroit Radiator Specialty Co., Detroit, Mich., or from Fulton-Houston Co., 1146 S. Michigan Ave., Chicago. It is necessary to change both gears.

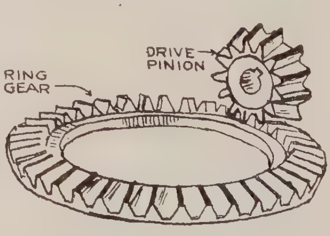


Fig. 46. Special gears for Ford rear axle.

For racing use 2 4/7 to 1; **for fast roadsters** use 2¾ to 1; **for general use** for level country, use 3 to 1; **for general use** in average country, use 3 7/11 to 1; **for trucks,** use 4 to 1, or 4.2 to 1.

For racing on dirt tracks, where a quick pick up is required, the 3 to 1 is recommended. The 2¾ to 1 and 3 to 1 are interchangeable. The number of teeth are as follows for various ratios:

2¾ to 1; gear 36 teeth, pinion 13.
3 to 1; gear 39 teeth, pinion 13.
3 7/11 to 1; gear 40 teeth, pinion 11.
4 to 1; gear 40 teeth, pinion 10.

Average speeds: 2¾ to 1; 60 to 65 m.p.h.; 3 to 1, 50 to 60 m.p.h.; 4 to 1, varies according to weight; average 25 to 35 m.p.h.

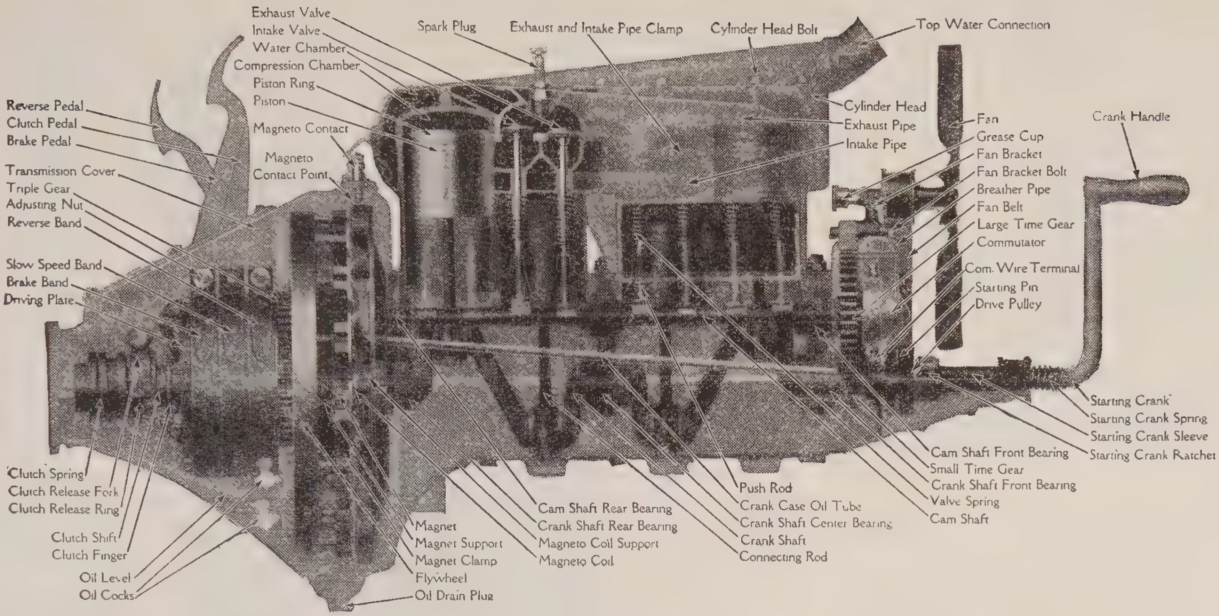


Fig. 47. Ford power plant, consisting of engine, transmission with clutch, and magneto in one unit, thus termed a **"single-unit power plant,"** as used on the model "T" Ford car and truck.

Specifications of Ford Engine

Engine: 4-cylinder, L-head type, with mechanically operated valves on the side. Bore $3\frac{3}{4}''$; stroke $4''$; $22\frac{1}{2}$ h.p. Cylinders are "in block" type.

The cooling is by means of thermo-syphon circulation.

Ignition: Source of electric supply is an inductor type of magneto, one part being attached to the flywheel and the other part stationary. The current is carried to a commutator, thence to four high-tension coils, thence to the spark plugs. (The Ford electric starting and lighting system is explained farther on.)

Lubrication: Gravity and splash. The flywheel, in revolving, picks up the oil and throws it by centrifugal force into the catch basin; from here it is led by $\frac{3}{8}''$ copper piping (the crank-case oil tube as shown above) to the timing gears and then to the oil splash trough under the front cylinder.

Location of valves: The front valve to the left of the fan, is No. 1 cylinder exhaust; then No. 1, inlet; then No. 2, inlet, No. 2, exhaust; No. 3 exhaust is next, then No. 3 inlet; then No. 4 inlet and then No. 4 exhaust. Note that the exhaust valves are next to the water jackets and nearest to the port openings, where the cooling action is most effective.

Gasoline feed system is gravity.

Carburetion: The Holley model "G," and sometimes Kingston model "Y" and "L-4."

FORD POWER PLANT; INTERNAL AND EXTERNAL PARTS

Internal Parts of the Ford Power Plant

By referring to Figs. 47, 48, and 49, the complete **internal construction of the Ford engine** will be made clear, and will be found fully explained.

Engine: Note in Figs. 48 and 49 that there are four pistons. The crank shaft is of the 180° type. When pistons Nos. 1 and 4 are up, Nos. 2 and 3 are down.

The Ford **engine fires** 1, 2, 4, 3—that is, if, say, No. 1 was starting down on the firing stroke, No. 2 would be coming up on compression and would fire next; No. 4 would be going down on suction, because it would fire after No. 2; No. 3 would be coming up on the exhaust (see table, Fig. 49).

Cam-shaft speed: The cam shaft runs at half the speed of the crank shaft, because the cam-shaft gear is twice the size of the crank-shaft gear (see timing gear Fig. 48; note the small gear on the end of the crank shaft and the larger cam gear on the end of the cam shaft).

The cam-shaft gear has 42 teeth and is 5⅓″ in diameter. The **crank-shaft gear** has 21 teeth, and is 2 2/3″ in diameter.

Transmission: Of the planetary type. It gives two speeds forward and one reverse. When driving on high speed, the drive is direct and the entire transmission revolves with the drive shaft. When running on low speed, the gears inside of the low-speed part of the transmission are in action; the same when reversing.

The transmission is attached to the end of the crank shaft, and is enclosed in a housing which covers transmission, flywheel, and magneto.

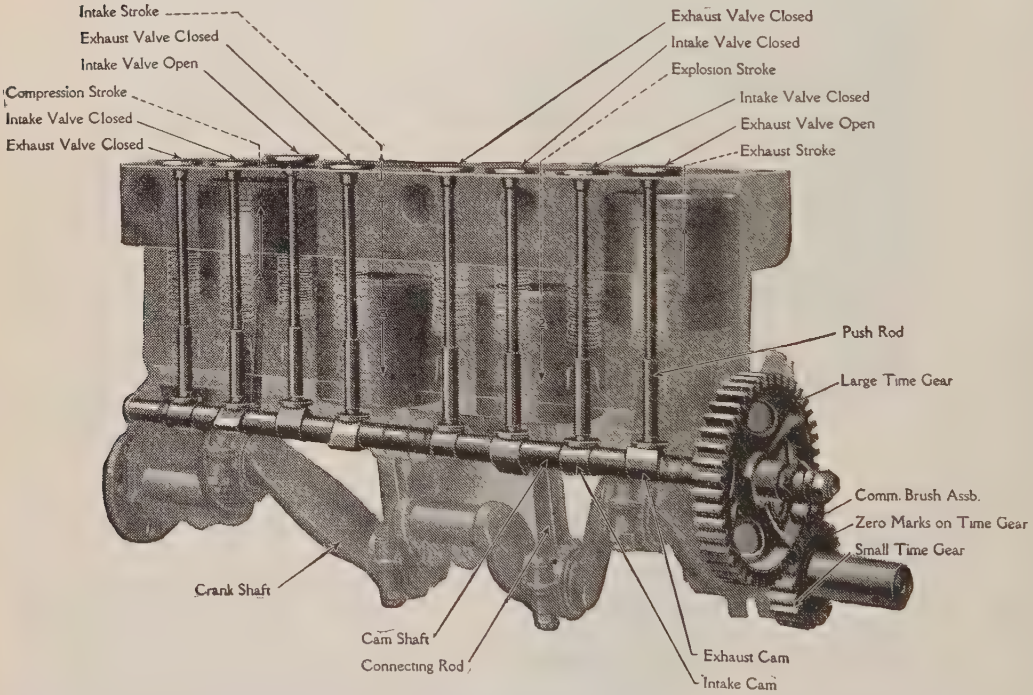


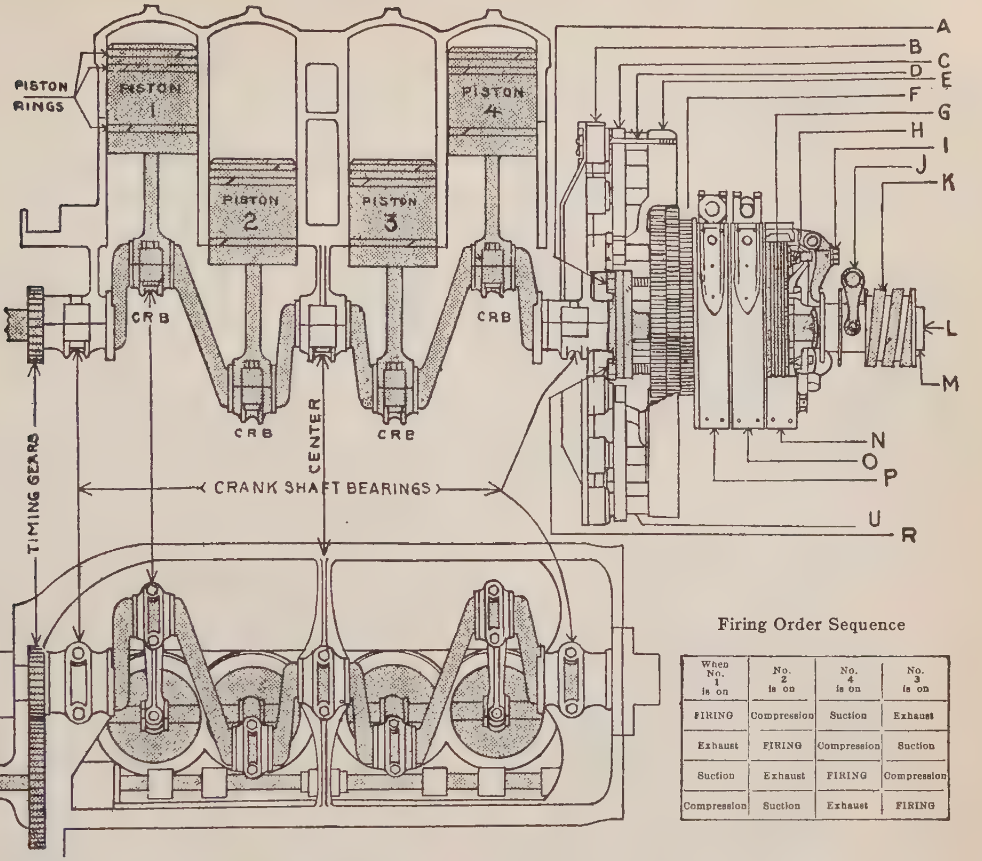
Fig. 48. **A view of the relation of the Ford crank shaft and small timing gear** which drives the cam shaft through the large timing gear, also the cam shaft, cams, and valves. As the large timing gear is twice the size of the small driving gear, **the** cam shaft will, of course, revolve at one-half the speed of the crank shaft.

The firing order is 1, 2, 4, 3. No. 1 cylinder is next to the gears, or the front of the engine. **No. 2 piston is going down** (see arrow point) **on the explosion stroke.** Note that the nose of the cam does not raise either of the valves, therefore the intake and exhaust valves are closed.

No. 4 piston is almost at top of its compression stroke and will be the next cylinder to fire, and the piston will then go down on the explosion stroke. Note that both valves are closed.

No. 3 piston is going down on the intake stroke, drawing in a charge of gas, as the inlet valve is open, but the exhaust valve is closed. The piston of No. 3 will go up on the compression stroke, at which time the inlet valve will be closed and will fire after No. 4.

No. 1 has almost completed its exhaust stroke. The exhaust valve is open. The intake valve is closed. Immediately that the exhaust valve closes, which is exactly on top, then the inlet valve will open and it will go down on the intake stroke next, then on the compression stroke up, then on the explosion stroke. **Therefore No. 1 will fire after No. 3.**



Firing Order Sequence

When No. 1 is on	No. 2 is on	No. 4 is on	No. 3 is on
FIRING	Compression	Suction	Exhaust
Exhaust	FIRING	Compression	Suction
Suction	Exhaust	FIRING	Compression
Compression	Suction	Exhaust	FIRING

Fig. 49. **View of the Ford engine, explaining the firing order and the location and names of parts as follows:** (A) Flange on the end of the crank shaft, bolted to the flywheel. (B) Magneto coils or spools, of which there are sixteen. They remain stationary. (C) Magnets on the flywheel, of which there are also sixteen. They revolve with the flywheel. (D) Bolts supporting the magnets. (E) Flywheel, bolted to the flange on the crank shaft. (F) Planetary gears, called the "sun and planet" type. (G) Clutch disks. (H) Ring which presses against the clutch disks when the fingers are pressed on by yoke (J), which causes the clutch adjusting screw (I) to press against ring (H), thereby pressing the clutch disk plates (G) together, which then causes the drive shaft (L) to transmit power through the drive shaft to the rear axle. (I) Adjusting screw for pressure of the finger against the ring and clutch. There are three of these and three fingers. (J) Yoke which throws the clutch "in" and "out" by movement of the side hand lever (Fig. 27). (K) Spring which forces the collar against the fingers. (L) Transmission shaft connecting with the universal joint, thence to the drive shaft. (M) Collar supporting the thrust of the rear of the spring. (N) Transmission brake band, applied by movement of the foot lever, marked (B) (Fig. 27). (O) Slow-speed band applied by the foot lever marked (C). The same lever operates the clutch. (P) Reverse band applied by the foot lever, marked (R). **Note that in Fig. 49** there are only four cams shown on the cam shaft. There are eight cams, as in Fig. 48. (Error in drawing.)

Removing the Ford Power Plant

1. Remove the hood.
2. Drain the radiator.
3. Loosen the bolts holding the top hose connection.
4. Loosen the bolts holding the side hose connection to the cylinder block.
5. Loosen the radiator-to-dash stay rod.
6. Remove the nuts and washers from the two bolts holding the radiator to the chassis.
7. Remove the radiator.
8. Loosen the cap screw holding the commutator. Place the commutator case and wires to one side.
9. Remove the spark plug and magneto wires.
10. Remove the spark plugs.
11. Remove the cylinder head. (This makes the engine lighter and easier to lift.)
12. Remove the four bolts holding the universal ball cover.
13. Turn off the gasoline and disconnect the feed pipe from the carburetor.
14. Remove the nuts from the studs holding the inlet and exhaust manifolds.
15. Take off the inlet manifold, with the carburetor attached.
16. Take off the exhaust manifold, with the exhaust pipe complete.
17. Remove the two bolts holding the pans to each side of the base, and knock the pans down out of the way.
18. Loosen the nuts holding arm (A) (Fig. 10, page 1086) on the lower end of the steering post.
19. Remove the three bolts holding the steering column to the chassis.
20. Loosen the dashboard, and pull the dash and steering column up out of way. (Note. It is not necessary to loosen the dash or steering gear on 1917 and later cars. The engine is brought forward until clear of dash; then lifted up to the right, to clear the steering post.)
21. Remove the nuts from the front radius-rod ball joint (see Fig. 12, page 1086).
22. Loosen and remove the bolts holding the engine to the frame at the front end.
23. Loosen and remove the bolts which hold the side crank-case arms to the frame, and then the power plant can be lifted out.

External Parts of the Ford Power Plant

The illustrations, Figs. 47, 48, and 49, on preceding pages gave internal views of the Ford power plant. The following illustrations (Figs. 50, 51, 52, and 53) show the **external construction** and the location of parts.

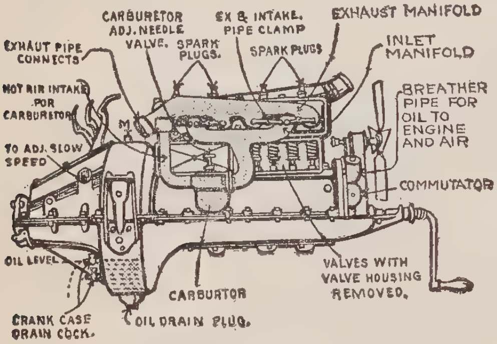


Fig. 50. **Right side of Ford model "T" unit power plant.** Showing inlet and exhaust manifold and valves.

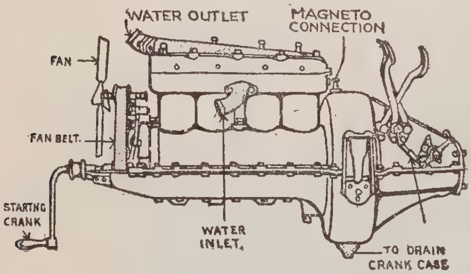


Fig. 51. **Left side.** Showing cooling water inlet and outlet. Note cylinders are "in-block" a typical unit power plant.

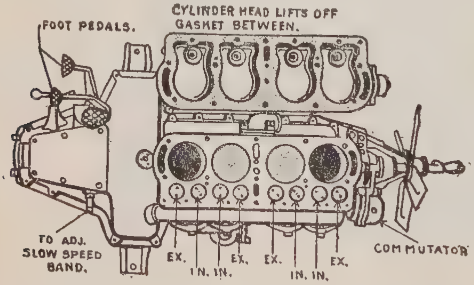


Fig. 52. **Top view.** Cylinder head removed showing cylinder bores, pistons, and heads of valves in their seat. Note which are exhaust and which are inlet valves.

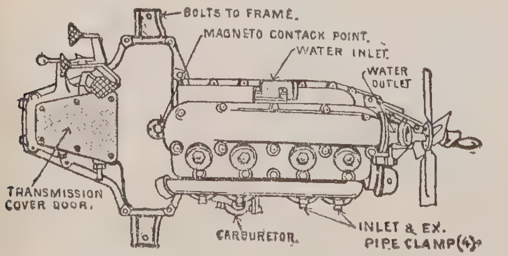


Fig. 53. **The cylinder head is detachable** and can be removed by taking off fifteen 7/16" x 2 9/16" cap screws on top of the cylinder. Underneath the head there is a gasket.

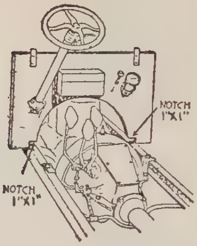


Fig. 54. To remove the Ford engine from the frame without raising the body from the frame, take a hacksaw and cut out a square 1" by 1" on each side of the dash. (*Motor World.*)

Ford Pistons and Rings

The subjects of Ford pistons and rings are treated elsewhere in this book.

See pages 811, 812 for "Questions and Answers on Ford pistons," also "Measurements of Ford pistons," "Piston replacement," and "Ford piston rings." See also page 823 for "Reboring Ford cylinders," and page 812 for "Ford oversize pistons and rings."

"Running in" the Engine

After the engine and car have been overhauled, new rings fitted, etc., it is a good plan to jack up the rear wheels, in the manner shown in Fig. 55, and to put about 1¼ gallons of lubricating oil in the crank case. Put water hose in the radiator and run the engine for several hours in order to work the rings and bearings "in." Note that when "running in" an engine, the water should be kept running constantly.

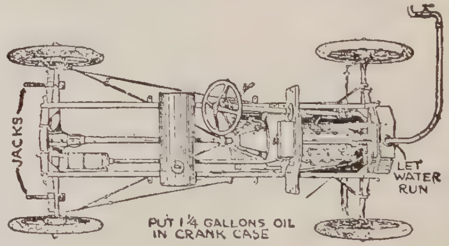


Fig. 55

When doing this work, the engine is usually out of the frame of car. Therefore another plan would be to place the engine on a stand made for the purpose, and to run the engine from a belt from the line shaft. This is a suggestion for a repair shop with considerable work. See page 789.

Note on page 785 that there are different methods described for fitting main bearings to the crank shaft as follows:

1. By spotting-in and scraping.
2. By boring, then reaming, then spotting-in and scraping, then running-in in oil.
3. By boring, reaming and burning-in, then running-in in oil.
4. By boring, then reaming, then running-in in oil.

Note on pages 821, 817 that there are different methods described for enlarging cylinders and fitting oversize pistons, as follows:

1. By boring.
2. By reaming.
3. By lapping.
4. By grinding.

COMPRESSION AND THE VALVES

If the compression is poor, and the pistons and rings fit well, the valves may need grinding or adjusting. The compression can be tested when the engine is warm, by pulling up slowly on the starting crank. The compression should be springy and elastic, but not as lively as that of other cars, on account of the drag and friction in the Ford transmission. See pages 766, 765, "Testing compression."

Removing Valves for Grinding

Drain the radiator. Remove the cylinder head and the valve covers on the right side of the engine. Use the valve-lifting tool (Fig. 35, page 770) to compress the valve springs, and pull the pins out of the ends of the valve stems. The valves can then be pulled out.

Valve Grinding

This subject is fully dealt with elsewhere. See pages 56, 57, 770: "Valve grinding."

When the valve seat is worn badly or seamed, it is then advisable to have it reseated with a valve-seating tool. Care should be exercised against making too deep a cut, otherwise the retiming of the valve will be necessary. See pages 773, 57; "Reseating valve seats."

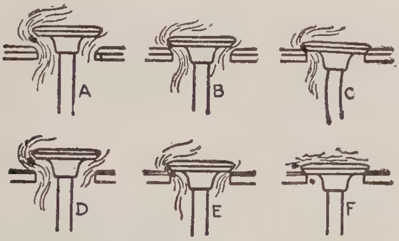


Fig. 56. **An ideal valve seat is a narrow edge,** as it is more easily ground and will last longer than a wide one. The illustrations show the action of the valve on a piece of carbon which might locate on the seat. **A wide seat holds the carbon,** which will soon burn and warp the valve, while a **narrow seat** cuts the carbon, keeping the seats clean. (A) grain of carbon passing through exhaust valve with wide seat; (B) the exhaust valve with a wide edge has just closed, the grain of carbon lodging between valve and seat; (C) the exhaust valve with a wide edge is closed, and the grain of carbon warps the valve and stem. (D) grain of carbon passing through the exhaust valve with a narrow seat. (E) exhaust valve with a narrow edge has just closed, the grain of carbon trying to lodge between valve and seat; (F) narrow edge of valve seat cuts grain of carbon, one part passing into the exhaust manifold, the other remaining in the combustion chamber to be burned during the next power stroke, or removed during the next exhaust stroke.

Oversize Valves and Worn Valve Guides

The play between the valve stem and the valve guide may be checked by placing the valve in the valve guide of the cylinder block, raising it about ¼″ and moving it from side to side. If there is very little play and the valve stem shows considerable wear, try a new valve with a standard stem. If this does not take up the play sufficiently, ream the valve guide for a 1/64″ oversize valve stem (Fig. 57) with a 21/64″ reamer (Fig. 58).

Fig. 57

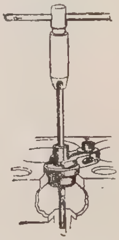


Fig. 58

Fig. 57. For valve 1/64″ oversize. See page 773; "Ford valves" for sizes of standard valves.

Fig. 58. A valve-guide reamer. When reaming the valve guides it is necessary to ream true; therefore a guide is necessary. The guide is shown clamped to the cylinder head. The reamer is then passed through the guide and turned by a hand tap wrench.

CHECKING VALVE TIMING BY PISTON TRAVEL

When valves are ground, the engine should be checked for valve timing.

The method of determining when the valves open and close is as follows: With the spring assembled, close the valve. When it is closed, hold it with the fingers,

Twist back and forth on the head while someone cranks the engine slowly. The instant the valve will turn, it has started to open. In the same way the valve may be closed, the valve turning until it has seated.

Another way to check the opening and closing is to insert a .001″, or less, feeler, or a thin piece of paper, between the stem and push rod. The instant the feeler will not move the valve has opened. The instant it will move after being held tight the valve has closed.

On a new engine, the valves in No. 1 cylinder may be checked by the **piston travel,** and the rest of the valves may be checked by the **air gap clearance** between the end of the valve stem and the tappet rod. This gap should be between .022″ to .028″, the distance being measured with a feeler or thickness gauge.

On the 1913 and later model "T" Ford engines, the valves open and close as in Figs. 59, 60, 61, and 62. (See next page.)

Prior to 1913, the inlet opened 7/64″ past top and closed ⅜″ past bottom. The exhaust opened ⅜″ before bottom, and closed 1/64″ past top. These figures may vary slightly on different engines, especially on old engines with worn parts.

The intake valve should be timed accurately on the opening, and the exhaust should be timed on the closing, since, in an engine whose cam shaft may be worn, it is not always possible to have both the opening and closing check accurately with the figures given.

On old engines, the valve tappet rods (also called push rods) become worn in the center (Fig. 63) (see next page) owing to the continual tapping against the valve stem.

If the engine were timed by the gap alone, it might be considerably out of time, as the feelers (thickness gauge) would bridge the actual point of contact on the tappet rod.

All valves on a worn engine should therefore be timed or checked by the **piston travel.**

Inlet valve opens 1/16 in. (piston travel) after top center on 1st stroke (as piston is 5/16 in. above cyl. when at top — it is now ¼ in. above.)

Inlet valve closes 9/16 in. after bottom center on 2d stroke. Measurement from top of cyl. to top of piston being 3⅛"

Exhaust valve opens 5/16 in. before bottom center on 3d stroke. Measurement from top of cyl. to top of piston being 3⅜"

Exhaust valve closes on top center of 4th stroke.

Note when piston is at top of stroke it is 5/16 in. above cyl. casting.

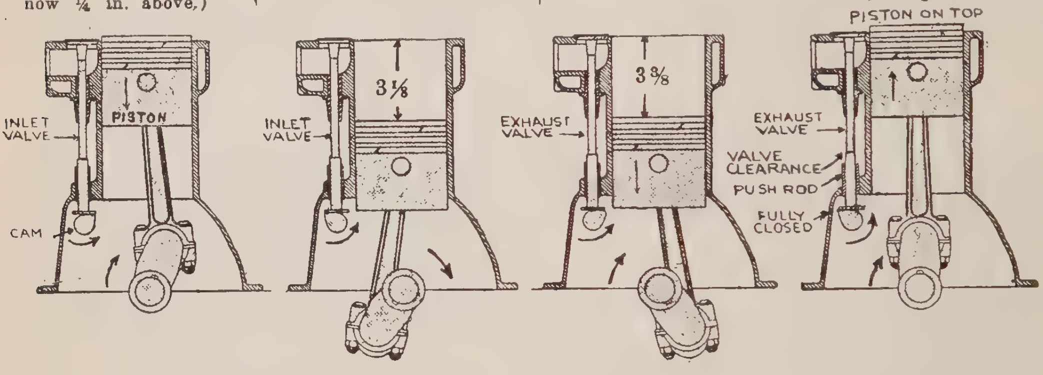


Fig. 59 Fig. 60 Fig. 61 Fig. 62

Figs. 59 to 62. **Illustrating the positions of the pistons when the valves open and close.** A method of checking the valve timing by the **piston travel.**

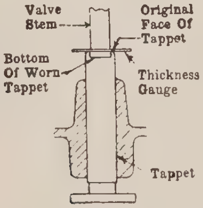


Fig. 63. Showing how the tappet rod becomes worn in time.

It is possible to tell if the tappet rods are worn by removing the springs and feeling the top of the tappet rod. New rods are straight across the face. Worn rods have a depression in the center of the face, as in Fig. 63.

Worn tappet-rod guides cannot be replaced on the Ford engine. The remedy is to ream out the worn guide and to install an **oversize** tappet rod. Worn guides cause a great deal of noise, as each time the cam strikes the lower end of the tappet it slaps the tappet against the worn guide.

VALVE TIMING AND VALVE CLEARANCE

Valve Timing

The method of accurate valve timing on a Ford model "T" engine is to time the valves by the **piston travel.** The measurements are given in Figs. 59 to 62.

As the valves are properly timed at the factory it is not necessary to retime them **unless the cam shaft, time gears, or valves were removed in overhauling.**

In this case, the time gears must be meshed properly, as follows: Place the top of the piston of No. 1 cylinder within approximately ⅝" of the top of the cylinder block by turning the crank shaft in the direction of rotation.

Turn the cam shaft (with gears out of mesh), until the exhaust cam is at a point where the exhaust valve is near closing (Fig. 64); the exhaust cam should point away from the (0) mark on the camshaft and crank-shaft gear, which is directly opposite or in line with the center of the point or nose of the cam. At this point, the tooth of the crank-shaft gear, indicated by the (0) mark, will mesh **between** the two teeth of the cam-shaft gear (large gear) at the (0) mark.

After meshing the gears in this manner, the inlet valve of No. 1 cylinder should be closed and the exhaust valve open.

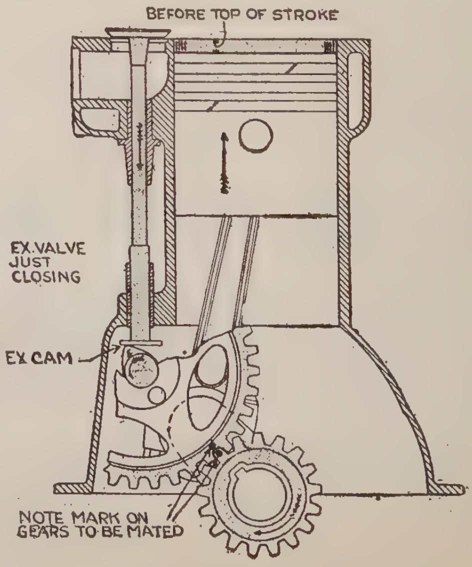


Fig. 64. **Meshing of timing gears by zero marks.**

When the gears are meshed as described, the exhaust valve of No. 1 cylinder (Fig. 64), is just at the point of closing, but is not fully closed; but by the time the piston reaches the top of its stroke the exhaust valve will be fully closed, as in Fig. 62.

When the gears are meshed as above with the zero marks together, the piston will be ¾″ from top dead center; or, in other words, since the piston is 5/16″ above the block when at top dead center, when the zero marks on the timing gears are together the top of the piston should be 7/16″ below the top of the cylinder block.

As the exhaust valve of No. 1 cylinder is just closing, as shown in Fig. 64, and will be closed just as soon as it completes its exhaust stroke, then No. 1 piston will start down on the **suction** stroke.

By referring to the table at the lower right-hand corner of Fig. 49, page 1101, it will be noted that when No. 1 piston starts down on the suction stroke, then No. 4 will be the next cylinder to **fire** (No. 4 will fire with the spark lever retarded when No. 1 is about ⅛″ down on the suction stroke). Therefore if No. 4 is the next to fire, the roller of the commutator should be set on No. 4 segment, or just ahead of the No. 4 segment, with the spark lever fully retarded (if the spark lever was fully advanced, the roller would be well on to the segment.)

Setting the commutator: There should be no difficulty in setting the commutator roller in the proper position on the cam shaft, as it is held in place by a retaining pin similar to a nail, and the pin can be inserted only when the hole in the roller lines up with the one in the shaft. As the hole in the cam shaft is not drilled clear through, there is only one place where the roller can be set, and the pin inserted.[1]

The retaining pin is held in place by a collar which fits over the head, and is in turn held by the lock nut on the end of the cam shaft. See page 1113 for the method of timing ignition.

If the cam-shaft gear is removed at any time from the shaft, in replacing the gear see that the dished side is out and that the first cam (exhaust cam) points in the opposite direction from the (0) mark on the cam-shaft time gear, as in Fig. 64.

To check valve timing, when the cam shaft or the gears have not been removed, first remove the cylinder head and check the inlet valve opening and exhaust valve closing of each cylinder by following the measurements in Figs. 59 to 62.

These measurements may not check accurately. If they are out to any great extent, see if the camshaft, bearings, push rods, or valves are worn. If not, and the gears are meshed correctly, then the variance may be in the manufacturing limit. See **that the valve clearance** is properly adjusted before checking the valve timing.

Spiral or helical tooth timing gears are now used.

Valve Springs

A weak valve spring can usually be detected by the following method: Remove the valve plate (Fig. 65) and insert a screw driver between the coils of the spring while the engine is running. If the extra tension thus produced causes the engine to pick up speed, the spring is weak and a new one should be replaced.

Valve springs consist of 11¼ coils of No. 104 music wire, complete spring is 2⅞ inches long and 31/32 inch outside diameter.

If the valves fail to seat properly, it may be due to weak or broken springs. Weak inlet springs would probably not affect the running of the engine, but weak exhaust valve springs cause uneven action, which is difficult to locate.

It will cause a lag in the engine due to the exhaust valve not closing instantly, and the result will be, a certain percentage of the charge under compression escapes, greatly reducing the force of the explosion.

Valve Clearance

The correct clearance between push rod and valve stem is .022″ to .028″. The gap should be measured, of course, when the cam point, or nose of the cam is not lifting the valve, but when the push rod is on the heel of the cam, that is, when the push rod is at the lowest point. The correct clearance is naturally half-way between these two measurements.

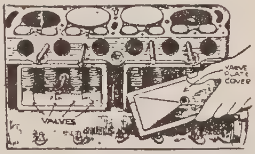


Fig. 65. Removal of valve cover to adjust clearance.

If clearance is greater, the valve will open late and close early, resulting in uneven running of the engine. In this case, **the push rod is worn or the valve stem is too short,** and a new valve should be substituted, and a push rod (tappet) also, if necessary. The old valve can be "drawn out" by peening the lower end to lengthen it, but this is not considered the best practice. Valve adjusters may be used, as shown in Fig. 66.

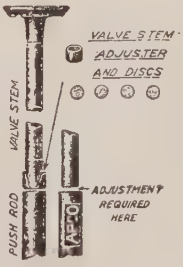


Fig. 66. **Valve clearance adjusters:** When the space between the end of the push rod and the end of the valve stem is more than 1/32″, a clicking noise is the result. As the Ford valve has no means of adjustment, it is remedied by either installing new valves and push rods or using adjusters as shown. (Apco Co., Providence, R.I.)

A reamer, 29/64″, is used to ream the push rod or tappet guides 1/64″ **oversize.**

If the clearance is less, the valve will open early and close late, or if there is no clearance at all, it will remain partially open all the time. In this case, the stem is **too long,** and a small amount of stock should be ground from the end of the valve stem.

When fitting new push rods, new valves should also be fitted.

When fitting new valves, they should be ground in. See page 770: "Grinding valves."

Valve clearance on Ford engine is non-adjustable.

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[1] In the older models the hole in the cam shaft is drilled clear through. In this case, place the roller on the No. 4 segment, as directed above, and insert the retaining pin, paying no attention to the hole in the opposite side of the shaft.

CONNECTING-ROD BEARINGS

The connecting rod in the Ford engine is clamped tight to the wrist pin, and is termed the "oscillating type." See also page 795: "Adjusting connecting rods."

Loose connecting-rod bearings cause a rattle, or light knock, especially at light loads and high speeds. Heavier loads seem to steady the connecting rods.

Long wear, pounding due to carbon, a spark too far advanced, or forcing the engine to labor on high gear, as well as a lack or poor quality of oil, are the chief causes of loose connecting-rod bearings. If this condition continues, the crank shaft will eventually crystallize, and may break.

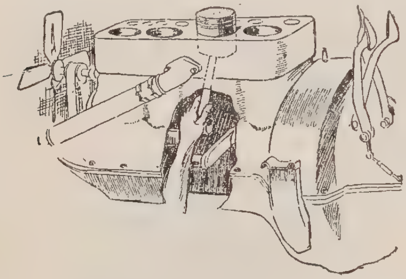

Fig. 67. **Removing the connecting rod and piston.** One method of getting at the piston is to take off the cylinder head, remove the cover from the bottom of the crank case, and, by reaching through this, remove the bolts holding the connecting-rod lower bearings in place. After the connecting-rod bearing caps are removed, the piston can be pushed up through the top of the cylinder.

The method of removing the piston is clearly illustrated.

To remove the piston pin, loosen the connecting-rod clamp screw.

Adjusting Connecting-Rod Bearings

The connecting-rod bearings may be adjusted without taking out of the engine, as follows: (1) drain off the oil; (2) remove the crank-case lower cover plate on the bottom of the crank case, exposing the connecting rods; (3) punch or file a mark on one side of the bearing cap, so that it may be replaced in the same position; (4) remove the first connecting-rod bearing cap and draw-file the ends, just a little at a time; (5) replace the cap, being careful to see that the punch or file marks are on the correct side, and tighten the bolts until it fits the shaft snugly; (6) test the bearing for tightness by turning the engine over by the starting handle; (7) now loosen the bearing and proceed to fit the other bearings in the same manner; (8) after each bearing has been properly fitted and tested, tighten the cap bolts.

There is a possibility of getting the bearings too tight, and under such conditions the babbitt is liable to cut out quickly, unless the engine is run slowly at the start. After adjusting the bearings, jack up the rear wheels and let the engine run slowly for about two hours (keeping it well supplied with water and oil) before going out on the road.

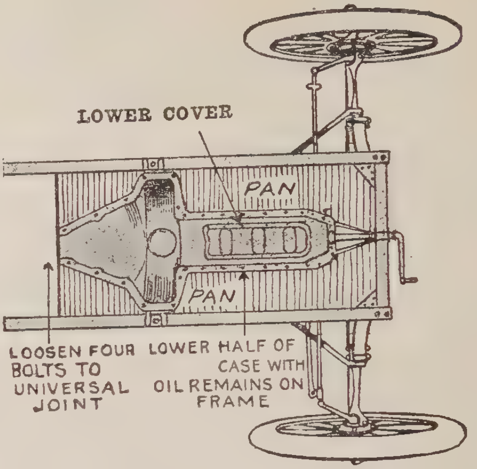
LOWER COVER
PAN
PAN
LOOSEN FOUR BOLTS TO UNIVERSAL JOINT
LOWER HALF OF CASE WITH OIL REMAINS ON FRAME

Fig. 68. All parts of the Ford engine can be removed in one unit, and the **lower part or the oil pan can be left on the frame,** as it seldom needs to be removed.

To remove the lower crank-case cover, it is necessary to take out fourteen capscrews (5/16" x 7/16"). Be careful not to destroy the gasket, and watch for oil in pockets under the connecting rods. Note that the lower crank-case cover is the part to which the upper arrow points.

Removing No. 4 Connecting-Rod Cap

Bring the No. 4 connecting rod about half-way up on the up-stroke. Remove the cotter pin and nut from the right connecting-rod bolt. Now turn the crank shaft over, by means of the starting crank until the connecting-rod cap is about half-way down on the other side. Pull out the other cotter pin and remove the nut from the bolt. The Ford socket wrench No. 2322 can be used, if a couple of inches are cut off from the handle; or the Walden wrench No. 5810 is specially made to reach this nut, and is very useful for this purpose.

Be careful that the nuts and parts do not fall into the transmission case, and mark the connecting-rod cap with a center punch before taking it off, so that it can be replaced in exactly the same position.

It is a good plan to stuff a rag into the transmission case while removing or replacing connecting-rod nuts and cotter pins. If they are accidentally dropped, they may then be easily recovered. The rag used should be free from lint or grit.

When the connecting rods become worn, they may be returned, prepaid, to the nearest Ford agent or branch house for exchange at a price of $1.00 each to cover the cost of rebabbitting. It is not advisable for any owner or repair shop to attempt the rebabbitting of connecting rods or main bearings, for without a special jig in which to form the bearings, satisfactory results will not be obtained. The constant tapping of a loose connecting rod on the crank shaft will eventually produce crystallization of the steel, with the result of a broken crank shaft; and possibly other parts of the engine may be damaged.

CRANK-SHAFT MAIN BEARINGS;[1] CAM-SHAFT REMOVAL, ETC.

Crank-Shaft Main Bearings

Wear of the main bearings of the crank shaft will be evident by a rather heavy pound or thud, especially when the engine is pulling hard under a heavy load.

Wear of these main bearings may be due to long use; not enough, or poor quality of oil, allowing the engine to knock; carrying the spark too far advanced, or carbon in the cylinders; a sprung crank shaft; or failure to drain out the old oil regularly.

The rear main bearing carries the heaviest load and is usually the first to show signs of wear. This rear bearing supports the flywheel, the magneto, and one end of the transmission, in addition to supporting the crank shaft against the thrust of the pistons.

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[1] See also pages 787, 789 on fitting Ford engine bearings.

Looseness in the rear main bearing may be detected by running the engine on No. 4 cylinder and having the throttle wide open. This will show up a loose main bearing.

The rear main bearing cannot be tightened without taking the engine out of the car, as explained under Fig. 69. The middle bearing can be tightened without taking the engine out of the car, but it seldom needs adjusting unless the other bearings need it also.

Unless the bearing is burned out or badly worn, the center and front bearing can be taken up by removing the bottom cover without removing the engine. Remove the cotter pins from the bolts between No. 2 and No. 3 cylinders, and while one man has a wrench on the nuts, another man beneath the car turns the bolts out. If there are shims, loosen the bolts just enough to pull the shims out with a pair of pliers. If there are no shims, remove the cap, and file. Be sure to mark the caps, if they are removed.

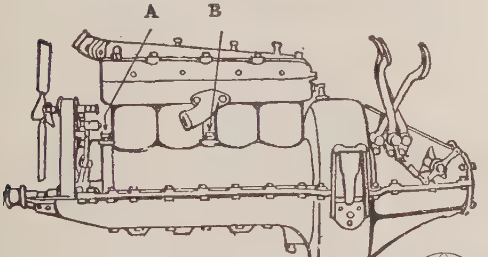

Fig. 69

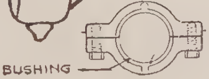

Fig. 70

Fig. 69. **To remove the center and front main bearing,** remove nuts at **(A)** and **(B)**, and draw the long crank-shaft bearing bolts (½" x 6 1/16" x 20 threads) out from the bottom, when the lower bearing caps can be removed. It is not necessary to remove the engine from the frame.

To remove the rear main bearing, it is necessary to remove the engine from the frame. If a special Ford wrench No. 1929 is used, one flywheel bolt, holding the flywheel to the end of the crank shaft (see Fig. 49, page 1101) can be removed without further dismantling; then remove the two bearing nuts from the lower part and the bearing cap will lift off.

To remove the cylinder head: Disconnect the water hose from the top plate, after first draining the radiator; disconnect the spark-plug wires. Remove the cap screws holding the head to the cylinders, and lift off. This can be done without removing the engine from the frame. (See also Fig. 52, page 1102.)

Fig. 70. Illustration showing the **main bearing cap** and **bearing bushing,** which is babbitt lined. Shims between the bearing cap and upper bearing not shown. The three main bearings on crankshaft are babbitted. On the old 1910 models, the upper halves of the main bearings were plain iron and not babbitted.

Adjusting Main Bearings[1]

First: Take the engine out of the car. Remove the crank case, transmission cover, cylinder head, pistons, connecting rods, transmission, and magneto coils. Remove the three babbitted caps and clean the bearing surfaces with gasoline. Prussian blue is then applied, or red lead, to the bearing surfaces of the crank shaft, which will enable one to determine whether a perfect bearing surface is obtained when fitting the caps.

Second: Put the rear cap in position first, and tighten it up as much as possible, being careful not to strip the bolt threads. The bearing, when properly fitted, will permit the moving crank shaft with one hand. If it cannot be turned with one hand, contact between the bearing is too close, and the cap requires shimming up, one or two thin shims usually being sufficient.

If the crank shaft moves too easily with one hand, the shims should be removed or the steel surface of the cap filed off, thereby causing it to set closer.

Third: After the cap has been removed, note whether the blue or red "spottings" indicate a full bearing the length of the cap. If "spottings" do not show a true bearing surface, the babbitt should be scraped and the cap refitted until it fits properly. (See Index under "Adjusting main bearings.")

Fourth: The rear cap can now be laid aside and the adjustment of the center bearing can be made in the same manner. The operation can be repeated with the front bearing.

Fifth: After you have obtained the proper adjustment of each bearing, the babbitt surface should be cleaned carefully and a little lubricating oil placed on the bearings and on the crank shaft; then draw the caps up as close as possible—making sure that the necessary shims are in place. There is no danger of getting the cap bolts too tight, as the shim under the cap and the oil between the bearing surfaces will prevent the metal being drawn in too close a contact. Put oil on the bearing surfaces, otherwise the babbitt is apt to cut out when the engine is started before the oil in the crank case can get into the bearing. When the crank case and transmission-cover on the engine are replaced, a new set of felt or cork gaskets should be fitted to prevent oil leaks.

Note. **If the upper main bearings are worn considerably,** and adjustment is made by drawing them up tight against the worn surface, by filing and fitting the bearing caps, this may cause the crank-shaft gear to mesh tighter with the cam-shaft gear, thus resulting in a singing noise in the gears.

Crank-Shaft End Play

As a result of wear by the end thrust on the outer end of the rear main bearing, this will in time cause sufficient play to permit the magnets to strike the magneto coils.

The remedy is a new main bearing; or, refer to this subject elsewhere; see page 786: "End play in main bearings."

To Remove Crank Shaft

First remove the connecting rods and the main bearings; disconnect the bolts holding the flywheel to the flange of the crank shaft, using the Ford special wrench No. 1929.

Removing the Cam Shaft

It is sometimes necessary to remove the cam shaft in order to install new push rods, or to replace worn cam-shaft bearings, as the bearings are sometimes the source of knocks that are difficult to locate.

It is a comparatively easy matter to remove the cam shaft when the engine is out of the car, but, contrary to the opinion of many owners of Ford cars, it is also fairly easy to remove the cam shaft without removing the engine.

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[1] See also page 784 on "Adjusting Bearings."

Procedure for cam-shaft removal: Remove the pin which holds the fan-belt pulley on the crank shaft (see Fig. 71). Drive the fan-belt pulley forward. Remove the cap screws which hold the cylinder front cover to the cylinder block. Remove the commutator brush assembly, after driving out the pin which holds it to the cam shaft. Now the cylinder front cover can be removed. Next, remove the two cap screws in the side of the cylinder block which hold the cam-shaft bearings in place.

It may now be possible to pull out the cam shaft with its bearings, but if not, the plate on the lower part of the crank case should be removed, after the cap screws which hold this plate to the crank case have been taken out.

Then a drift, or brass bar can be used to drive the cam shaft out from below, holding the end of the brass bar against one of the cams and striking the other end of the bar with a hammer. Care should be taken not to punch a hole through the cast-iron cylinder block while doing this part of the work.

After the cam shaft has been removed, the push rods will drop down and can be removed through the opening in the bottom of the crank case. Be sure to remove all the push rods.

Installing New Push Rods (Tappet Rods)

Place the new push rods in the guides. Small holes, near the top of each push rod, will now be noticed. After putting the push rods in place, slip nails, or a piece of wire, through these holes, to keep them in position while the cam shaft is being replaced. Then the cam shaft and its bearings can be driven in, and the cap screws (which hold the bearings) tightened.

The marks on the small crank-shaft gear and on the large timing gear should be placed together, and the valves tested to make certain that the valves open and close at the proper time. Then the front cylinder cover plate should be replaced, and the timer brush assembly, and also the timer cover; then the fan-belt pulley and the starting-crank pin, and finally the fan belt. (*Fordowner.*)

Removing Starting-Crank Ratchet

Drive out the pin which passes through the starting crank and ratchet (see Fig. 71). Pull the starting crank forward and out of the ratchet. It may be necessary to support the crank by a block and to drive off the ratchet by means of a drift placed against the shoulder of the ratchet.

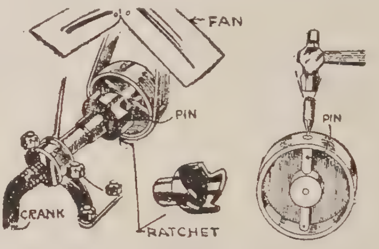

Fig. 71. Method of drawing out pin in fan-belt pulley with which the starting-crank ratchet engages.

Removing Fan Pulley

Remove the ratchet, as explained above. Drive out the pin in the fan-belt pulley, as shown in Fig. 71. Move the pulley forward off the crank shaft.

CAUSES OF ENGINE KNOCKS; CARBON; OVER-LUBRICATION

Causes of Engine Knocks

1. **Carbon** is the most frequent cause of engine knocks.
2. **The spark too far advanced** will waste power and cause a knock.
3. **Loose connecting-rod bearings** will cause knocks.
4. **Worn crank-shaft main bearings** cause knocks.
5. **Piston slap,** due to a loose piston, will cause knocks.
6. **Worn or broken piston rings** will cause a light knock.
7. **The piston striking the cylinder-head gasket.**
8. **Loose cam-shaft bearings.**
9. **Valve tappets out of adjustment,** or badly worn, will cause noise.

How to Distinguish Knocks

1. **The carbon knock** is a clear, hollow sound, most noticeable in climbing sharp grades, particularly when the engine is heated. It is also indicated by a sharp rap immediately on advancing the throttle.
2. **Too advanced a spark** will be indicated by a dull knock in the engine.
3. **The connecting-rod knock** sounds like the distant tapping of steel with a small hammer, and is readily distinguished when the car is allowed to run idly down grade, or upon speeding the car to twenty-five miles an hour; then, when suddenly closing the throttle, the tapping will be very distinct.
4. **The crank-shaft main bearing knock** can be distinguished when the car is going uphill, as a dull thud.
5. **The loose piston knock** is heard only upon suddenly opening the throttle, when the sound produced might be likened to a rattle. (See also pages 777, 460: "Engine knocks.")

Overheating of Engine

This subject is fully treated under the "Digest of Troubles," page 460, and under the discussion of the "Cooling" subject, page 152.

Water Pump for Ford Engine

Overheating of the engine as a result of long runs or where there are many hills to climb, or a tendency on the part of the radiator to steam, can be remedied in many instances by attaching a water pump which will more rapidly circulate the water in the cooling system.

The **Cluley water pump** for the Ford operates from a double-flanged pulley on crank shaft, and independent of the fan. There are several good features to this particular pump. It can easily be attached. (Address Cluley Auto Supply Co., Fullerton Bldg., St. Louis, Mo.)

Before and After Carbon Cleaning

First: Drain the water off by opening the pet cock at the bottom of the radiator; then disconnect the wires at the top of the engine and also the radiator connection attached to the radiator. Remove the fifteen cap screws which hold the cylinder head in place. Take off the cylinder head and, with a putty knife or screwdriver, scrape from the cylinder and piston heads the carbonized matter (as in Fig. 72), being careful to prevent the specks of carbon from getting into the cylinders or other openings.

If carbon gets into cylinder-head cap-screw holes, it might prevent the cap screws from drawing up the cylinder head tightly, or it might cause the cap screw to be broken off. To avoid this, put the cap screws back in the holes before removing the carbon.

In replacing the cylinder-head gasket, turn the engine over so that No. 1 and No. 4 pistons are at top center; place the gasket in position over the pistons and then put the cylinder head in place. Be sure to draw the cylinder head cap screws down evenly (i.e., give each one a few turns at a time); do not tighten them at one end before drawing them up at the other. See Fig. 66, page 733.

Removing Carbon

Carbon removal is most easily done with a putty knife, after the cylinder head has been removed.

The flexible putty knife follows the surface better than the stiff and narrow blade of a screwdriver.

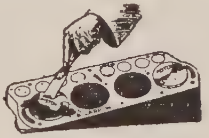

Fig. 72. Removing carbon.

Do not get the carbon in the openings into the water jacket. This would tend to impede the flow of the water and might cause overheating of the engine. The openings into the water jackets and the holes for the cylinder-head bolts can be plugged with wooden plugs, or pieces of cloth, until the scraping has been completed. (See also page 763.)

Over-Lubrication of Cylinders

When the spark plug is constantly oily or fouled and constantly missing, and an excess of smoke is emitted out of the exhaust, this indicates that too much oil is working past the piston rings, or at least that too much oil is passing into the combustion chamber from the crank case.

Causes of Over-Lubrication

1. The oil level in the crank case may be carried too high. It should not be above the upper petcock in the crank case. (See Fig. 3, page 1083.)
2. The front spring may be sagged. If the front end of the engine is lower than the rear, the oil will not drain back into the sump until there is too much oil under the front piston. A heavier pad between the front spring and the frame will level the engine.
3. The cylinder bore may be worn oval by the side thrust of the connecting rods on the pistons, or the cylinder walls may be grooved and scored. All four cylinders should be rebored at the same time, and fitted with oversize pistons.
4. The points of the spark plugs may be too close together, thus allowing oil to short-circuit them too easily. Bend the points slightly farther apart (not over 1/32″), and bend the side electrode upward, so that the oil will drain off to one side and not collect between the points.
5. For leaky piston rings see pages 828 and 815.

A broken piston ring will be indicated by a click or light knock, by loss of compression, and by smoke from the oil filler pipe or crank-case breather.

Well-fitted pistons and rings will almost invariably cure trouble caused by over-lubrication of the cylinder. If it does not, and none of the foregoing is the cause, then the engine is afflicted with what is termed "piston pumping oil," which is explained on page 168, and the remedy is to doctor the rings and piston.

GASKETS FOR FORD POWER PLANT

Cylinder-Head Gaskets

There is a copper-asbestos gasket between the cylinder head and the cylinder block. There is practically no water pressure on this gasket, but there is a cylinder pressure, of from 60 lbs. on the compression stroke, to 250 lbs. on the firing stroke, which must be withstood by the gasket.

As the cylinder-head bolts contract when cool, and expand when hot, there are varying degrees of pressure on the gasket; so the cylinder head must be securely seated to keep the cylinder head gasket from blowing out. (See also page 733: "Gaskets.")

The gasket is composed of asbestos fabric, between sheets of brass and copper. (See also Index under "Gaskets.") If examined closely, one end of the gasket will be found to have a different curve from the other. When the gasket is placed on the cylinder block, with its edges coinciding with the edges of the block, the right side of the gasket will be turned upward, and no further trouble will be experienced.

Shellac should not be used on either side of the cylinder-head gasket, or on any of the other gaskets on the engine. If shellac is used, it will not be possible to remove the gasket without spoiling it. But if grease is used, the grease will hold the gasket in place when the parts are being assembled, and it will cause no trouble when the engine is again taken apart. In this manner the cylinder-head gasket can be used several times.

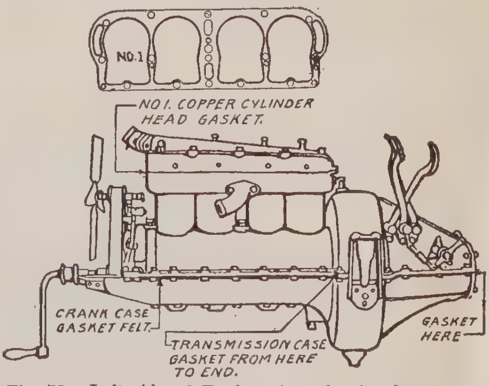
NO.1
NO. 1 COPPER CYLINDER HEAD GASKET.
CRANK CASE GASKET FELT.
TRANSMISSION CASE GASKET FROM HERE TO END.
GASKET HERE

Fig. 73. Left side of Ford engine, showing location and kinds of gaskets used.

The metal surfaces between which any of the gaskets are clamped **should be clean and free from grit.** A small lump of dirt will tend to cause a leak and spoil the gasket.

Asbestos can be substituted for the head of the cylinder if copper cannot be secured. Use sheet asbestos, 1/16″ thick x 7″ x 20″.

Ford Gasket Sets

Sets of gaskets and felt washers for Ford cars are shown in Fig. 75 and their location can be seen in Fig. 74.

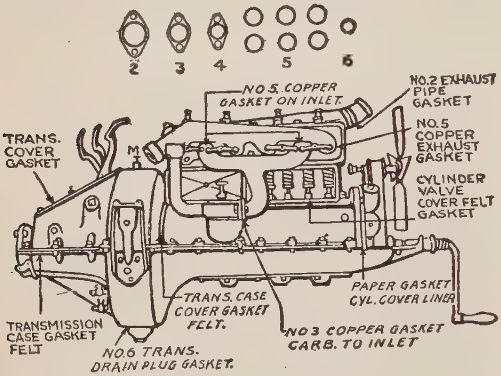
2
3
4
5
6
NO.5 COPPER GASKET ON INLET
NO.2 EXHAUST PIPE GASKET
TRANS. COVER GASKET
M
NO.5 COPPER EXHAUST GASKET
CYLINDER VALVE COVER FELT GASKET
PAPER GASKET CYL. COVER LINER
TRANS. CASE COVER GASKET FELT.
TRANSMISSION CASE GASKET FELT
NO.3 COPPER GASKET CARB. TO INLET
NO.6 TRANS. DRAIN PLUG GASKET.

Fig. 74. Right side of Ford engine, showing different location and kinds of gaskets used.

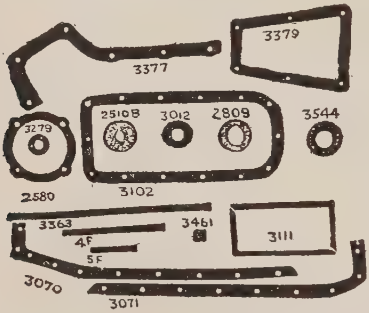

Fig. 75. Gaskets used on the Ford car, enumerated as follows:

2580: universal ball cap gasket.
3070: crank case and cylinder gasket (L.H.)
3071: crank case and cylinder gasket (R.H.)
3102: crank case lower cover gasket.
3111: cylinder valve cover gasket.
3363: transmission cover front gasket.
3377: transmission cover gasket.
3379: transmission sloping door gasket.
3461: control bracket felt.
4-F: transmission cover strip 7¾" x ½" x 3/64".
5-F: crank-case arm strip 3½" x ½" x 3/64".
3544: steering bracket.
2510B: for rear axle, 2 7/16" x ⅞" x 5/16".
2809: for front hub, 2½" diameter.
3012: for cylinder cover, 2" x 1 3/16" x ⅜" (goes between gear case and cylinder block).
3279: for magneto contact, 1½" x ¾" x 3/64".

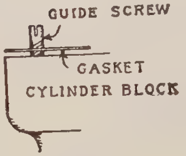

Fig. 76

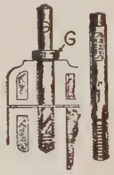

Fig. 77

Fig. 76. **Guide screws are handy for correct replacement of cylinder-head gasket.** They are made from cap screws with the head cut off and slotted. Place one at the front and rear diagonally opposite. Then place the gasket over the guide screws and replace the cylinder head. The screws can then be removed.

Fig. 77. **Cylinder-head cap screws are sometimes broken off when being tightened.** Ordinarily, this involves the removal of the cylinder head and the attempt to drill out the broken part of the bolt. It is not easy to hold the drill perfectly true, so that the threads will not be damaged, but by the use of the drill guide (G) furnished with the set, the drill can be held perfectly central, without the necessity of removing the cylinder head. Then the threads can be cleaned out with the 7/16" tap, and the new bolt installed. The cylinder bolts must be kept rather tight, or water may escape around the cylinder-head gasket. (See also page 716 for "Ezy Out").

If the cylinder-head cap-screw threads become stripped, it is not advisable to drill a hole in the head for an "oversize" screw; drill a cylinder-block tap and set in not less than a ⅝ x 18 thread blind plug, then drill and tap for a standard cap screw (7/16 x 14). 7/16 means the size of screw, and 14 means the number of threads to the inch.

FORD IGNITION

The electric system of a Ford model "T" car can be classified into two divisions:

1. The ignition system.
2. The starting and lighting system.

The ignition system consists of:

1. A low-tension magneto of the inductor type, which is the source of electric current for the ignition.

   Note. When the Ford is equipped with a starting and lighting system, the current is taken from either the battery, generator, or magneto.

2. A high-tension coil which transforms the low-tension current to a high-tension current.
3. Spark plugs, of which there are four.
4. An ignition commutator.

Ignition Circuit

The ignition circuit, when the magneto is used as a source of electric supply, is shown on page 249 and in diagram IV, page 1126.

The Ford magneto is fully described elsewhere in this book; therefore see page 248: "Ford magneto." The magneto is located as shown in Fig. 78 below.

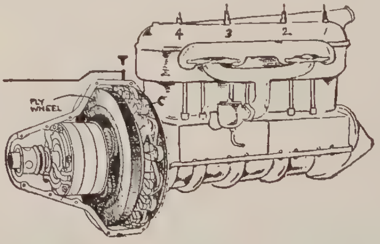

Fig. 78. An exaggerated illustration showing the magneto location. Note the coils (C) which are stationary, and the magnets (A) which rotate. When the flywheel revolves, the sixteen magnets revolve in front of the sixteen coils.

The Ignition Coil Box

The coil box contains four high-tension (vibrator type) coil units. The units can be removed from the box in case one is damaged. Connections to the coils are in the rear in Fig. 79.

The principle and construction of this coil is clearly shown and explained on page 222.

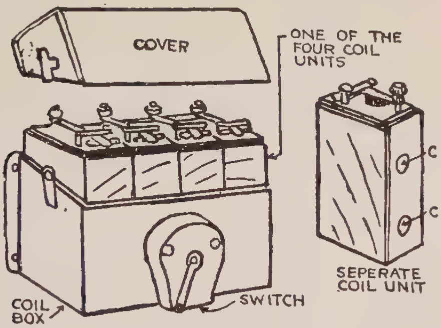

Fig. 79. The coil box containing four high-tension coil units. A separate unit is shown to the right.

The Ignition Commutator

The commutator is of the roller type. It is placed on the end of the cam shaft, that is, the roller mechanism is attached to the end of the cam shaft and revolves with it. Therefore the roller revolves at half the speed or revolutions of the crank shaft.

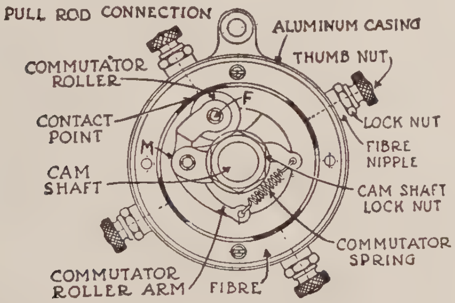

Fig. 80. The ignition commutator.

The roller makes contact with the insulated contact points, of which there are four, and which do not revolve. When the roller comes in contact with one of the four insulated contact points, the coil unit connected with it becomes operative. As the roller leaves the contact, the coil becomes inoperative.

To advance or retard the time of spark, the housing is connected at the "pull-rod connection" (Fig. 80) with the spark lever on the steering wheel.

Ignition Troubles

Ignition troubles on the Ford may be divided into four classes.

1. Spark-plug troubles.
2. Commutator troubles.
3. Coil units out of order.
4. Magneto out of order.

Spark-Plug Troubles

This subject is fully treated on pages 233–239.

When tightening spark plugs, never draw a spark plug down tight into a hot cylinder head. When the cylinder head is hot, the diameter of the spark-plug hole is slightly enlarged, while the spark plug which is comparatively cooler is nearer its normal diameter. When the engine becomes cool, the cylinder head shrinks on to this plug, making it almost impossible to remove it. Correspondingly, if the repairman finds a tight spark plug he may be able to remove it by running the engine until it becomes thoroughly warm.

If considerable trouble is experienced with plugs sticking, it is advisable to wipe the threads with some flake graphite which has been mixed with a little oil, before screwing them into the cylinder head.

Ignition Commutator Troubles

If misfiring occurs when running at high speed, and is not due to the spark-plug gap, inspect the commutator.

Removing commutator: Remove the cotter pin from the spark rod and detach the latter from the commutator at the "pull-rod connection" (Fig. 80).

Loosen the cap screw which goes through the breather pipe on top of the timer gear cover. This will release the spring which holds the commutator case in place, and this part can be removed.

Unscrew the cam shaft lock nut; withdraw the steel brush cap and drive out the retaining pin. The brush can then be removed from the cam shaft.

Inspection and Repair of Ignition Commutator and Wiring

The surface of the circle around which the roller travels should be clean and smooth, so that the roller makes a perfect contact at all points. If the roller fails to make a good contact on any one of the four contact points, its corresponding cylinder will not fire. In case the fiber, contact points, and roller of the commutator are badly worn, the most satisfactory remedy is to replace them with new parts. Or possibly the trouble is caused by short-circuited commutator wires.

The spring should be strong enough to make a firm contact between the roller and contact points, even though slightly worn or dirty.

Other causes of misfiring may also be an improperly seated valve, or a short circuit in the commutator wiring.

Weakness in the valves may be easily determined by lifting the starting crank slowly the length of the stroke of each cylinder in turn, a strong or weak compression in any particular valve being easily detected. It sometimes happens that the cylinder-head gasket (packing) becomes leaky, permitting the gas under compression to escape, a condition that can be detected by running a little lubricating oil around the edge of the gasket and noticing whether bubbles appear or not. Another source of leakage is around spark plugs. Test in the same way (see page 239).

How a short circuit in the commutator wiring may be detected: Should the insulation of the primary wires (running from coil to commutator) become worn to such an extent that the copper wire is exposed, the current will leak out (i.e., a short circuit) whenever contact with the engine pan or other metal parts is made. A steady buzzing of one of the coil units will indicate a "short" in the wiring. When driving the car, the engine will suddenly lag and pound on account of the premature explosion. Be careful not to crank the engine downward against the compression when the car is in this condition, as the "short" is likely to cause a kick-back.

How an "open" (broken wire or loose contact) in the commutator wiring may be detected: Take a dry cell or storage battery and connect one lead from it to ground of the car. Connect the other lead to the **battery terminal** of the coil box (see Fig. 81) and turn the ignition switch to (B) side.

Note. In cars equipped with a starting and lighting system, this procedure is unnecessary; just turn the ignition to the battery.

Now short one commutator thumb nut (see Fig. 80) to the engine by means of a piece of wire. If the coil buzzes, it indicates that this wire is in proper condition. Short the remaining thumb nuts one at a time. If the coil fails to buzz, it indicates that there is an "open" in the circuit leading to this thumb nut. Examine the contacts at both ends of this wire, and also examine the spring contacts inside the coil box. If these items prove satisfactory, the wire is broken at some point. **Be careful if the engine is warm,** as the shorting of one of the thumb nuts may cause the engine to start.

To repair wiring, when a short is discovered, tape may be used to insulate the bare spot, but it is usually better to install a complete new set of timer wires, as they are quite inexpensive. The price of timer wires for cars not equipped with a starting and lighting system is 60 cents; for cars with a starter the price of timer wires is 90 cents.

If a broken wire is discovered, it is best to install a new set of timer wires. However, if you are out on the road and cannot obtain a new set, a separate wire may be run from the terminal of the coil that fails, to its respective thumb nut on the commutator (see method of wiring given below).

To install timer wires: When a broken, badly shorted, or oil-soaked timer wire is discovered, it is best to install a new set. (1) Remove the old timer wires by disconnecting them from the coil terminals and the commutator thumb nuts; (2) thoroughly clean the contacts at the commutator thumb nuts; (3) take a new set of wires and connect them to the coil terminals according to the color scheme shown in Fig. 81; (4) connect the other ends of the wires to the commutator thumb nuts, as shown in Fig. 81, according to the same color scheme, that is, the black wire on No. 1, the red on No. 2, the green on No. 4, and the blue on No. 3; (5) note that all four wires pass under the priming rod, that Nos. 1 and 3 pass behind the commutator spring, and that No. 3 passes behind the commutator pull rod, thus protecting them from the fan belt and excess chafing; (6) to connect the light wires see Fig. 100 for cars not equipped with starters, and see Fig. 102 for cars with starters.

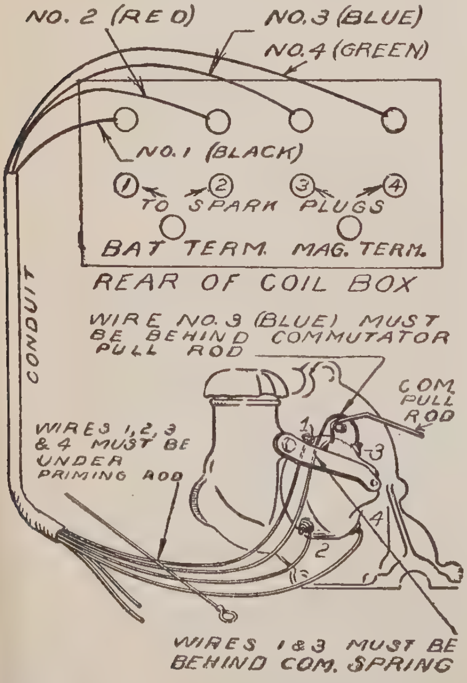
NO. 2 (RED)
NO. 3 (BLUE)
NO. 4 (GREEN)
NO. 1 (BLACK)
① ② ③ ④
TO SPARK PLUGS
BAT TERM.
MAG. TERM.
REAR OF COIL BOX
CONDUIT
WIRE NO. 3 (BLUE) MUST BE BEHIND COMMUTATOR PULL ROD
COM PULL ROD
WIRES 1, 2, 3 & 4 MUST BE UNDER PRIMING ROD
1
3
4
2
WIRES 1 & 3 MUST BE BEHIND COM. SPRING

Fig. 81. **Method of wiring the Ford commutator** (when the car is equipped with a starter and lighting system, the coil box has no battery terminal. The change is made in the lighting and ignition switch).

The parts of a commutator most likely to get out of order are: the roller, the spring, or the fiber lining and contacts in the commutator shell.

Replacing the brush (commutator roller assembly): See "Timing of ignition" on page 1113.

Cold weather effect on a commutator: It is a well-known fact that in cold weather even the best grades of lubricating oil are apt to congeal to some extent. If this occurs in the commutator, it is very apt to prevent the roller from making perfect contact with the contact points imbedded in the fiber. This makes difficult starting, as the roller-arm spring is not stiff enough to brush away the film of oil. To overcome this, as well as any liability of the contact points to rust, we recommend a mixture of 25 per cent kerosene with the commutator lubricating oil, which will thin it sufficiently to prevent congealing, or freezing, as it is commonly called. You have probably noticed in starting your car in cold weather that perhaps only one or two cylinders will fire for the first minute or so, which indicates that the timer is in the condition described above; as a consequence a perfect contact is not being made on each of the four terminals.

Ignition Coil Units

The four coil units on the Ford are contained in a metal box with a slanting cover (see Fig. 79) which enables them to be taken out of the box, without removing it from the dash. Some of the 1914 and 1915 metal coil boxes had straight covers, but when this type is used on a cowl dash (1916 or 1917 body), the units cannot be taken out without taking the box off the dash.

The earlier wood box coils were much inferior to the present type, and the Ford Motor Co. makes an exchange proposition on these wood box coils which should be carefully considered before replacing defective coil units in wood-coil boxes or installing new points.

Adjusting vibrators: With the spring held down, the gap between the vibrator points should be slightly less than 1/32". Then set the lock nut so that the adjustment will not shake loose. Each coil unit should be adjusted to take about 1½ amperes, as measured by an ammeter. See also the K.W. Ford coil adjustment (Fig. 2, page 222, and also page 188).

Hard starting, due to vibrator adjustment: If there is **too much tension** on the vibrator springs' the weak current generated by the magneto at cranking speeds will not be sufficient to cause the vibrators to buzz, and it will be difficult to start the engine. **Too little tension** will not let the vibrators respond quickly, and the engine will run unevenly.

A defective coil unit: This can be detected by noticing if the vibrator buzzes without producing a spark at the plug. Then the suspected unit can be exchanged with another unit to make sure that the trouble is actually in the coil unit. A punctured condenser is indicated by a heavy spark at the vibrators and a weak spark at the spark plug.

If the engine has a tendency to miss when driving over rough roads, this may be due to the coil units not fitting tightly in the coil box. The bouncing of the car makes the coil units touch the metal cover of the box and causes misfiring.

Sometimes, misfiring is due to the wooden lining of the metal coil box being damp and allowing the electric current to leak across from one terminal to another.

Testing coil units and dressing contact points is fully treated on pages 222, 223, 224, 225.

Timing the Ignition

We will assume two conditions under which to time the ignition:

1. Engine in disassembled condition.
2. Engine in assembled condition.

Timing Ignition; Engine Disassembled

This should be done immediately after meshing the timing gears and **checking the valve timing,** as explained under Fig. 64, page 1104.

The next operations are:

1. Replace the timing gear cover.

2. **Place the commutator roller assembly in position on the end of the cam shaft.** This roller can be placed in only one position on the cam shaft on the later models (see Fig. 82 below), that is, the slot in the roller assembly should line up with the hole in the cam shaft which is drilled only part way into the shaft. In the earlier models the hole was drilled clear through the cam shaft, thus permitting two positions of the roller. In this case, be sure that the roller points downward when the zero marks on the timing gears are together. In the later models, this is the only position in which it is possible to replace the roller.

3. Insert the retaining pin.

4. Replace the steel brush cap over the roller assembly hub.

5. Screw the lock nut on the cam shaft.

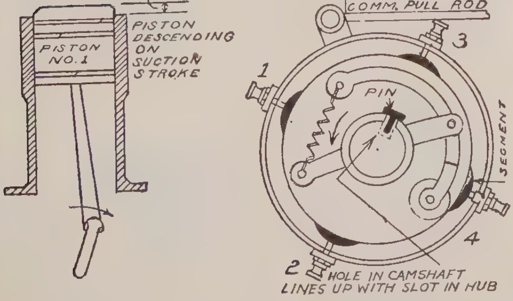
3"/16
PISTON NO. 1
PISTON DESCENDING ON SUCTION STROKE
FAN BRACKET BOLT
1/4"
COMM. PULL ROD
3
1
PIN
SEGMENT
4
2
HOLE IN CAMSHAFT LINES UP WITH SLOT IN HUB

Fig. 82. Timing or setting the Ford ignition. The commutator case is shown in a retarded position.

By reading the matter on page 1104 (Fig. 64), it will be noted that when the zero marks on the timing gears are together, No. 1 piston has not quite reached the top of the exhaust stroke, and the exhaust valve is just at the point of closing; consequently No. 4 piston has not quite reached the top of the compression stroke, and in this position (which is ¾" before top dead center) No. 4 is not quite ready to fire as yet. Therefore, when the zero marks on the timing gears are together, the commutator roller should nearly, but not quite, make contact with No. 4 segment on the commutator case after the latter is replaced.

6. **Adjusting the position of the commutator case:** Place the commutator case with wires attached over the roller assembly.

7. Clamp in position by means of the commutator spring shown in Fig. 81.

8. Turn the engine over slowly by means of the crank until No. 1 piston passes upper dead center and then descends ⅛" on the suction stroke. The top of the piston will then be 3/16" above the cylinder block, as shown in Fig. 82. No. 4 piston will then be in a similar position on the power stroke. With spark retarded, No. 4 should now fire.

9. Turn the commutator case until the roller just makes contact with No. 4 segment, as shown in Fig. 82. If the ignition switch is turned on the battery, the coil will buzz when contact is made.

10. The length of the commutator pull-rod can be adjusted by turning the ball-and-socket joint on its thread, or by bending the rod itself. This length should be adjusted so that the pull rod will fit into its hole in the commutator case (when the spark lever is fully retarded, up) without disturbing this position of the case. Insert the cotter pin in the commutator pull-rod.

When the spark lever is advanced, the roller will make contact when the piston is ⅜" from top dead center on the up or compression stroke.

Timing Ignition; Engine Assembled

When the engine is in an assembled condition, the ignition may be timed as follows:

1. In the earlier models, turn the crank shaft until the exhaust valve on No. 1 cylinder just starts to close. Place the commutator roller in position so that it points downward. In the later models, this is not necessary, as the roller can only be placed on the cam shaft in one position.

2. Install the commutator case with wires.

3. Place the spark lever three notches down (almost retarded).

4. Adjust the length of the pull-rod so that the pull-rod connection is ¼" to the left of the fan bracket bolt, as shown in Fig. 82.

Ford Magneto

How magnets are located on the flywheel: The like poles of the magnets are placed together, that is, N to N, and S to S, as shown in Fig. 83 (see also page 248).

Before assembling the magnets (if disassembled), test them and chalk mark the N poles. After assembling, test their correctness by passing a compass around the flywheel, close to the outside of the magnets. The needle should reverse as each pair of poles is passed. If they are placed wrong, the needle will turn cross-wise and tremble.

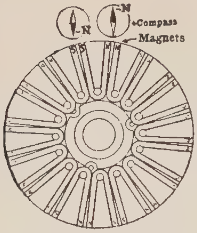

Fig. 83. **The magnet poles of the magneto** are placed with **like** poles together, and are mounted on the flywheel.

To test: The S pole of the magnet will attract the N pole of the compass needle, and the N pole of the magnet will attract the S pole of the compass needle.

Cause of Weak Magnets

1. Dirty contact as in Fig. 84.
2. End play in bearings, caused by a worn crankshaft bearing which permits the magnets to rotate at too far a distance, which makes the current weak.
3. A grounded magneto coil will weaken the current.

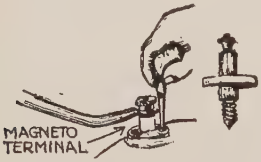

Fig. 84. Dirt on the magneto terminal contact will cause dim lights and misfiring. It can be removed and cleaned.

Indications of Weak Magnets

See the tester described on page 1117.

(1) Dim lights. (2) Frequent backfires, or explosions in the muffler when running—possibly blowing the muffler up.

The magneto is often blamed for trouble that lies elsewhere in the electrical system. A weak current will often be caused by dirt or waste collecting beneath the terminal contact spring on the crankcase cover. To clean, remove the three screws holding the binding post, remove the post and spring, and clean as shown in Fig. 84.

Check up the wiring for short circuits or grounds.

To reach the magnets, it is necessary to remove the engine from the car. The common method of doing this is to remove the radiator, dash, and steering gear, and to lift the engine out complete. By this method the base of the engine is left in the chassis, and the dash and steering gear are left undisturbed. Two experienced men can readily remove an engine and place it on the bench in thirty minutes by this method.

Note. **Before removing the engine,** make sure that the trouble lies in the magneto. This may be done by trying to run the car on the battery ignition, when cars are equipped with storage batteries. When cars are not equipped with batteries, use dry cells, connecting one lead to ground and the other to the battery terminal of the coil box (Fig. 81); then turn the ignition switch to the (B) side. If the engine will now run, it indicates the trouble to be in the magneto, but if the engine will not run, the trouble may be elsewhere.

To Remove the Engine without Removing the Crank Case[1]

1. Drain the radiator.
2. Remove the four bolts at the universal joint.
3. Remove the rear spring shackles and pull the rear axle back. (The rear of the car must first be blocked up.)
4. Disconnect the radiator stay rod.
5. Remove the two bolts holding the radiator to the frame, and remove the radiator.
6. Unsnap the commutator and place it to one side.
7. Remove the spark-plug wires.
8. Shut off the gasoline and remove the feed line from the carburetor.
9. Disconnect the exhaust manifold from the exhaust pipe, and remove both intake and exhaust manifolds from the engine.
10. Remove the fan-shaft bracket and timing gear case.
11. Remove the two bolts holding the pans to each side of the base, and knock the pans down out of the way.
12. Remove the base bolts.
13. Remove the transmission case after loosening the reverse, low, and brake-transmission bands, and removing the starting motor, if so equipped.
14. Lift the engine from the frame and place it on the bench. The lifting may be done with a hoist. It is quicker and easier, however, if three men take hold of it and lift it out by hand. One should straddle the engine at the rear and the other two should be at each side at the front.

To Find Amount of End Play in Crank Shaft

Before removing the transmission from the engine, test for crank-shaft end play as follows:

1. Force the transmission as close as possible to the engine.
2. Place a thickness gauge between the core of coils and the face of the magneto clamps.
3. Pull the transmission as far as possible away from the engine block.
4. Measure again with the thickness gauge.
5. The difference between the two measurements is the amount of end play of the crank shaft.

When there is more than .008″ end play, a new bearing cap should be fitted.

End play up to .015″, while detrimental to a smooth-running engine, should not cause a weak magneto.

Tearing Down the Engine and Testing the Magneto[2]

1. Clamp the engine on the bench.
2. Test the magnets on the flywheel, as shown in Fig. 85. The block of steel should just hang by a corner. The weight of this test block happens to be the same as that of the Ford cam-shaft gear. Failure to hold indicates weak magnets.

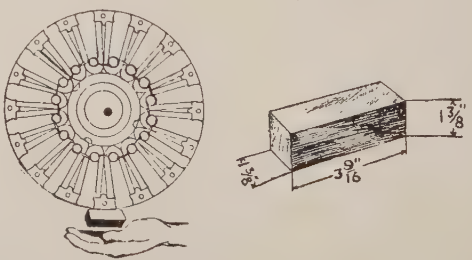

Fig. 85. Method of testing strength of Ford magnets.

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[1] For another method of removing the engine see page 1101.

[2] See the tester described on page 1117.

3. Remove the bolts holding the flywheel and transmission to the crank shaft.
4. Remove the flywheel, magnet, and transmission unit, placing the latter face down on the bench.

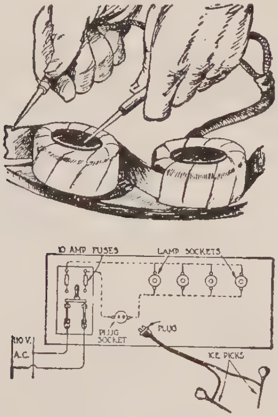

Fig. 86. Testing Ford magneto coils for grounds.

5. If trouble is suspected in the magneto coils, these may be tested, as shown in Fig. 86. The two test points are connected to a 110-volt alternating current line (Fig. 86). The main ground of the coils is disconnected, and each coil is tested for shorts, grounds, or open circuit (see also Fig. 87).
6. Chisel the heads from the ends of the brass magnet-retaining screws at the rear of the flywheel; when reassembling, use new screws.
7. Turn the flywheel transmission assembly over and set it upright in a square box placed on the bench.
8. Remove the wires holding the central magnet-retaining bolts.
9. Using a bit brace screwdriver, unscrew the outside magnet screws.
10. Using a bit brace socket wrench, unscrew the central retaining bolts. Clean all parts.

Fig. 86 shows a testing outfit using four 32 c. p. carbon lamps.

Testing Magneto Coils for Grounds

Connect five or six dry cells to a 6-volt lamp (Fig. 87). Attach one end of the terminal from the lamp to the magneto terminal (T).

Then unsolder the grounded end of the winding at coil (C-2) and raise it so that it will not be in contact with the magneto frame.

With the other wire from the battery, touch the iron frame (Y); if the lamp lights, then somewhere there is a ground of one of the spools in contact with the frame.

The next step will be to find out in what particular portion of the winding the ground exists.

Attach the test wire (W) to the metal part. This can easily be done by inserting the end under nut (Y), or by temporarily making a soldered joint at the point where the permanent ground was formerly attached. If there is a ground, the lamp will then light.

Loosen the coils, one at a time, and shake them vigorously, or move them up and down. This will cause the light to flicker, or go out and on when you reach the coil or section where the ground is located.

The ground can sometimes be removed by cleaning out the dirt and metallic particles and revarnishing with a special oil-proof varnish which can be obtained of Ford agents. Common shellac will not do.

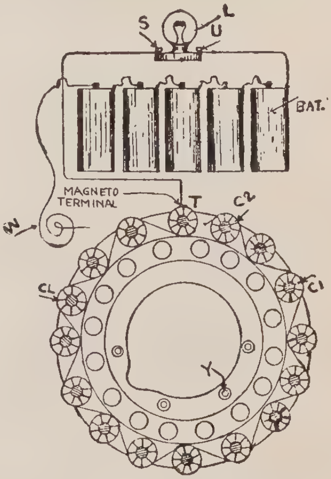

Fig. 87. Testing magneto coils for grounds.

In replacing the defective magneto coil with another from an old magneto, soak it well in oil-proof varnish and press it firmly on the stud. Let it dry thoroughly before installing in the engine. It is to be understood that the replacement of a single coil is an emergency measure only, as it is better practice to replace the entire set.

Note. The illustration (Fig. 87) shows the coil plate reversed. The bolt holes and recess for the cam shaft should be on top.

Building up the Magnets

If the magnets are found to be weak by the test shown in Fig. 85 (see also the tester described on page 1117), new magnets should be installed.

1. Place the new magnets on the flywheel in the same order that they were in the box in which they were shipped from the factory, that is, so that the legs that do not attract each other are together. This means that like poles, or N and N and S and S poles are placed together (see Fig. 83, page 1114).
2. Catch all the central retaining bolts in place, but do not tighten.
3. Slip the outside spools under the magnet ends.
4. Drop the magnet clamps on to the magnet ends, and catch the brass screws into their threads.
5. Using a brace screwdriver, bring all the screws down snug.
6. Pinch the ends of the magnets in with a pair of pliers until the sides of the magnets rest against the spacer on the clamps.
7. Tighten the outside brass screws.
8. Tighten the central retaining bolts.

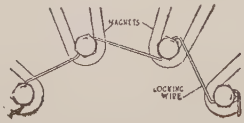

Fig. 88. Method of locking bolts by running a wire through the heads.

9. Using stovepipe or brass wire, lock the central bolts in position. The wire should be inserted as shown in Fig. 88 (when the holes are about in the position shown), as this creates a tendency to tighten instead of to loosen the bolts.
10. Knock the four corners of each magnet clamp down over the magnets, so that they cannot interfere with the coils later.
11. Test the magneto clamps for high spots. To do this, lay a straight-edge (such as a steel rule) across any three clamps. If the straight-edge "rocks," the center clamp is high. Move the straight-edge around the magneto so that each magneto clamp will at one time be in middle, thus testing each clamp.
12. Turn the assembly over, and head the brass screws at the rear of the flywheel. Before assembly, the engine should be inspected for loose or worn bearings, and if any are found, they should be cleaned and adjusted.
13. Inspect the magneto coils for high spots in a manner similar to that described for magnets under (11).

Dead Points on Old-Type Magneto

On the older model Fords which did not have the ¾″ magnets, there were certain dead points where, if the spark lever was placed in certain notches in the quadrant, the engine would not respond with increased speed. On the late magnetos, as the magnets pass from one end to the other as it revolves, there is no dead point.

Later Magnets ¾ Inch

To install ¾″ magnets of the latest type so that electric lights can be used, as the crank-case and the transmission cover are similar, the necessary parts include No. 3250-D magneto-coil assembly, one set of ¾″ magnets, sixteen magnet clamps No. 3277, and sixteen magnet clamp screws. (Former magnets were ⅝″.)

Assembling the Magneto

1. Test the crank-shaft flange for burrs or high spots.
2. Replace the flywheel-transmission assembly on to the crank-shaft flange, and secure it with the two opposite flange bolts. Draw these bolts up snug.

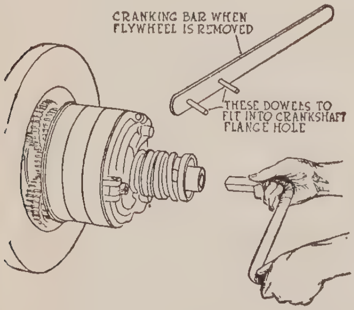
CRANKING BAR WHEN FLYWHEEL IS REMOVED
THESE DOWELS TO FIT INTO CRANKSHAFT FLANGE HOLE

Fig. 89. Cranking the engine with the transmission in place.

3. Using the crank as shown in Fig. 89, turn the flywheel and note whether the magnets interfere with the coils. The magnets are set 1/32″ from the coils.
4. The clearance or air gap between the coils and magnets should be .030″, which is almost 1/32″. However the allowable limits are from .025″ to .040″. **If the gap is too wide,** put the necessary shims behind the coil support. **If the gap is too narrow,** take out some shims. The steel shims are .015″, and the paper ones are .005″. The clearance may be measured with a thickness gauge.
5. Replace the two other flange bolts.
6. Tighten all the flange bolts. A short piece of round stock, wedged through one of the holes in the coil flange and caught behind the magnets, holds the crank so that the bolts may be drawn tight.
7. Again using the crank, as shown in Fig. 89, crank the engine quite fast. While cranking, short-circuit the magneto-contact point with the cylinder block, using a screwdriver. A fat blue spark shows the magneto to be in proper condition.
8. Place the locking wires in the crank-shaft flange bolts.

Replacing the Engine

Before replacing the engine in the base, the base should be thoroughly cleaned. The rivets holding the supports to the base should be tested to see that they are tight. All bolts should be inspected.

1. Place the standard Ford felt packing on each side of the engine base, setting it in heavy oil.
2. Lift the engine up, and set it in place. Be careful not to slide it around any more than necessary. Three men can do this easily.
3. Line up the holes in the base with a small drift.
4. Replace the front gear cover.
5. Drive all the base bolts through their holes, from the bottom up, and catch the nuts on to the threads. Two men, one with a speed wrench on the nuts and the other holding the bolts, can quickly fasten the engine to the base.
6. Slide the transmission bands in place.
7. Bring the lugs all together at the top, and wire them together tightly with a single strand of stovepipe wire, or use a clamp similar to that shown in Fig. 28, page 1093.

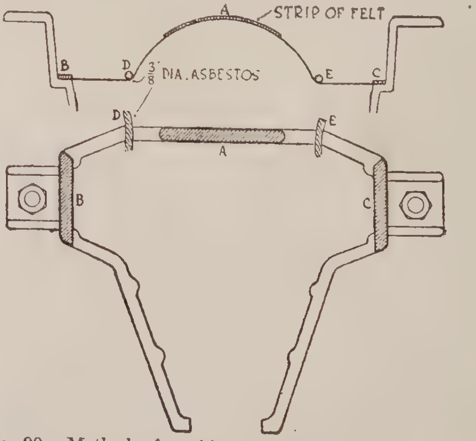

Fig. 90. Method of packing transmission-case joints to prevent leakage of oil.

8. Place the short lengths of felt gasket at (A) (B) and (C), as shown in Fig. 90. Place ⅜″ asbestos wicking and grease in the corners at (D) and (E).
9. Then place the standard Ford felt transmission gasket in place. The double-thickness felt and the asbestos wicking stop up the points that tend to leak.

10. Slide the transmission housing in place. Using a screwdriver, pry the bands into place.
11. Knock the housing down flush, and tighten the two rear retaining bolts.
12. Using a thin socket, or check-nut wrench, tighten the transmission bands.
13. Replace the balance of the housing bolts, and bring them up snug.
14. Slide the rear axle and drive shaft back into place, and secure them there.
15. Assemble the engine fittings, such as fan, commutator, wiring, and manifolds.
16. Replace the radiator assembly, hood, and floor boards. (*Motor World.*)

To Test the Air Gap with a Ford Magneto Tester

Another method for testing the strength of the magneto, which also determines the air-gap space, can be found very easily with the **tester** shown in Figs. 91 and 93, as explained below.

To test the air gap space and strength of the magneto on a car:

1. Test the output of the magneto with the tester (Fig. 91), with the engine running at moderate speed.
2. Remove the transmission cover and place a thickness gauge, 1/32″, between the magnet and the coil core. If the gap is 1/32″, but the magneto has tested out as **weak,** the magnets need recharging.
3. After remagnetizing the magnets (which can be done without taking the engine down; see below), test the magneto again with the engine running at moderate speed. The tester should show **strong;** if it does not, the probabilities are that the magneto coil is short-circuited.

If some of the magneto coils become short-circuited, or if the magnets are weak, the tester will read low. In other words, it tells you instantly, without removing the magneto from the engine, if the magneto is in proper condition. If not in proper condition, it is time to take the magneto out and to remedy the trouble. If it tests satisfactorily, it is time to look elsewhere for the trouble, and you will thereby save the time and trouble of removing the magneto in error.

The meter scale is very simple. It has two readings (see Fig. 91). One is marked "1914," meaning that on all magnetos before 1915, the needle should come to this mark. The other is marked "1915," meaning that on all cars after 1915, the needle should reach this mark. (The Ford magnets were enlarged in 1915.)

Example of a Ford Magneto Tester[1]

The Ford magneto generates "alternating" current. An ordinary "direct"-current ammeter, as used for testing batteries and generators, will not operate. Therefore a special meter, as shown in Fig. 91, is designed for testing the Ford magneto.

If the engine will not run at all, and the ignition is the fault, an easy way to determine if the trouble is due to the magneto, is to connect a storage battery, or five or six dry cells, to the battery side (**B**) of the coil (Fig. 92), and to turn the switch to (**B**), or to the right side.

If the engine then starts, and runs satisfactorily, but will not start on the magneto, with the switch to the left, or (**M**) side, you may know that the magneto is not supplying current. This may be due to dirty or loose magneto terminals (**T**) or to a weak magneto, due to weak magnets, or to grounded magneto coils.

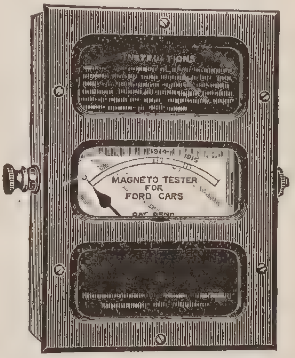

Fig. 91. Ford magneto tester. Note how the scale is marked. See text.

The Ford magneto can be tested with a special magneto tester, as shown in Figs. 91 and 93. This instrument is nothing more than an ammeter, but one provided with a "reactance coil" (**R**) (Fig. 93), which enables the meter to indicate a constant current at all engine speeds. In other words, the meter is so designed that it will indicate if the magneto is giving its proper output at any speed of the engine, while testing.

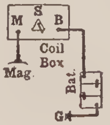

Fig. 92

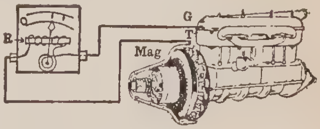

Fig. 93

Fig. 92. Method of connecting the battery to the ignition coils.

Fig. 93. Method of connecting Ford tester.

This instrument can be used to test the strength of the magneto while the engine is being run on a battery, if the engine fails to start on the magneto.

If engine starts on the magneto, but continually misses, and if the trouble is not due to other causes, then the tester can be used to see if the magneto is delivering its proper current, while the engine is being operated on the magneto.

The connection for testing would be the same in both cases (Fig. 93), except that, when the engine is running on the battery, the wire from the ignition coil to the magneto is removed, and the switch is placed on (**B**) side (Fig. 92).

The clearance or air gap of Ford magnets is the distance the magnets are from the core of the magneto coils. This should be as stated on next page. If they are farther away, the amperage and voltage will be less; if closer, the amperage and voltage will be greater, but there is danger that the magnet will strike the coil core.

The tester is a great help when assembling the magneto on the bench. The "air-gap" can be adjusted to the point of greatest output, if you have the meter to test with as you assemble. The flywheel can be turned by hand fast enough, so that the instrument will give a steady reading.

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[1] This tester can be secured of A. L. Dyke, Granite Bldg., St. Louis, Mo. Price $11.00.

Adjusting air-gap clearance: The clearance, or air gap, between the coils and magnets should be .030″, which is almost 1/32″. The allowable limits are from .025″ to .040″. **If the gap is too wide,** put the necessary shims behind the coil support. **If the gap is too narrow,** take out some shims. The steel shims are .015″, and the paper ones are .005″.

If the needle fails to reach this mark, remagnetize the magnets.

If then the magneto fails to test up to this mark, and the missing still occurs, and is not due to loose terminals, and runs satisfactorily with a battery, then you may know you have a "grounded" magneto coil. The magneto must be removed, the defective coil located, another put in place, and the "air-gap" clearance must be given as described above.

Remagnetizing Ford Magnets

There are various methods of remganetizing Ford magnets. The usual and proper method of remedying weak magnets is to replace them with new ones. The Ford Co. does not advise everyone to attempt this work. This however necessitates taking down the engine and then reassembling. This makes a costly job, and is a big job. Therefore different methods of recharging magnets without removing them from the car will be given.

Remagnetizing by electromagnet and battery:[1] It is not necessary to remove the flywheel from the engine when remagnetizing Ford magneto magnets with the device shown in Fig. 94. Simply remove the transmission-case cover so that the ends of the magnets are available. Use a compass to determine the N pole of each magnet, and chalk them; also chalk the S pole of the remagnetizer. Place the S pole of the remagnetizer so that it will be on the N pole of the magnets.

Turn the flywheel over after remagnetizing one magnet, and remagnetize each magnet separately.

After remagnetizing, check the polarity of all magnets with the compass again.

The connections are shown in Fig. 94. The storage battery can be either a 6 or 12-volt battery. It is possible to use 6 or 8 dry cells, if connected as in Fig. 95.

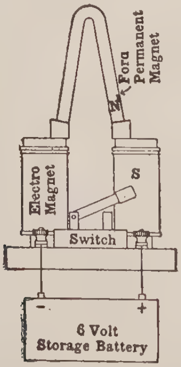

Fig. 94. Electromagnet using a storage battery for remagnetizing Ford magnets.

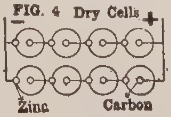

Fig. 95. Dry cells can be used instead of a storage battery, if connected as shown.

Magnets of all types of magnetos can be charged with this remagnetizer. When remagnetizing magnets which are separated from the magneto, it is important to place a "keeper" across the magnets until placed on the magneto. It is also advisable to rap the magnet a few times with a piece of wood while being remagnetized. See also page 312: "Remagnetizing Magneto Magnets."

Remagnetizing with storage batteries: Five or six, 6-volt storage batteries should be about right. Refer to Fig. 96.

To prepare the magneto for recharging, first disconnect the wire (A) which goes from the magneto terminal on the transmission cover to the coil on the dash.

Next remove the transmission cover (B), so that you can look at the magneto. Locate the brass studs on the rim of the fly wheel which hold the magnets in place, and have someone turn over the engine very slowly until one of these brass studs is in line with an imaginary line drawn about 1″ or so from the magneto terminal, to the left of the latter and paralleling the frame.

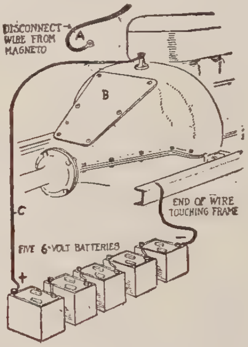

Fig. 96. Remagnetizing Ford magnets with storage batteries.

Another method is to place an ordinary small compass on the transmission cover about 1″ from and to the left of the magneto terminal, at the same time turning the engine slowly until the needle of the instrument is parallel with the engine.

The N pole end of the needle should point toward the engine when in this position.

Connections: Connect a wire from the positive (+) terminal of the battery to the magneto terminal on the engine, as shown at (C) (Fig. 96).

Next connect a wire from the negative terminal on the battery, and make and break the circuit by striking the free end of the wire on some metal part of the engine.

Permanent connection should not be made, but only thirty or so momentary contacts, which, it is said, will recharge the magnets much more satisfactorily than if permanent contact is made. (*Motor Age.*)

Dry cells can be used if necessary. Use 48 connected in series-multiple, as shown in Fig. 97. Connect the positive (+), or carbon poles, with the terminal.

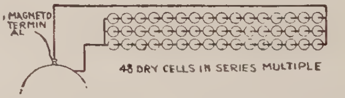

Fig. 97. Remagnetizing Ford magnets with dry cells.

Resistance wire can be used. Use 13 ft. of nichrome No. 16 wire, or 8 ft. of No. 18. If German silver, use 35 ft. of No. 16 or 22 ft. of No. 18—in series, as shown in Fig. 98.

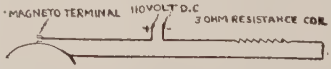

Fig. 98. Method of remagnetizing Ford magnets with 110-volt direct current and resistance.

110-volt direct current can be used. To use this it will be necessary to use a resistance lamp bank, as shown in Fig. 99. Use twenty-eight 32 c.p. carbon filament lamps. Connect the positive pole with the magneto terminal. Connected as shown, this gives 27½ amperes. To find the positive pole, or polarity of any circuit, see page 564, "Polarity, how to find."

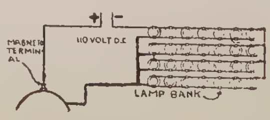

Fig. 99. Method of remagnetizing Ford magnets with 110-volt direct current and lamp bank.

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[1] Can be secured of A. L. Dyke, Granite Bldg., St. Louis, Mo. Price $9.50 with Ford attachment and full instructions.

LIGHTING CIRCUITS ON FORD CARS NOT EQUIPPED WITH STARTERS

Two lamps can be connected in series to operate from the magneto, as shown in Fig. 100 below.

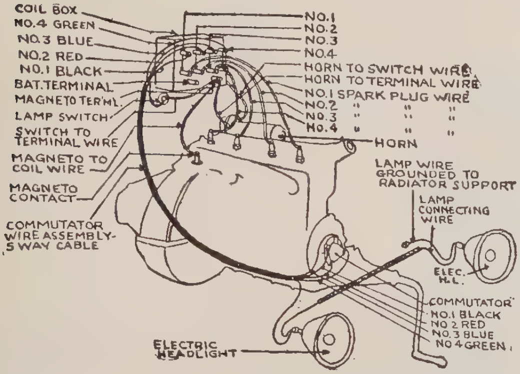


Fig. 100. **The wiring** above shows the ignition and also two lamps in series which take current from the magneto **on Fords that are not equipped with a starting and lighting system.** The horn switch or button is on the steering post.

The lamps are 9 volts, therefore, two being in series, they would require 18 volts, which voltage is taken from the magneto. Note that the lighting circuit is from the magneto contact or terminal to a connection on the rear of the coil, thence to the lamp switch, thence to the two lamps in series, thence to ground. **A complete lighting circuit where the starting and lighting system is used** is shown in Diagram V, page 1127. All details are shown in the illustration.

The bulbs supplied on present Ford cars for the electric head lamps are 9 volts, 2 amperes, and best results will be obtained by securing lamps of this voltage and amperage when replacement is necessary. (See Fig. 100.)

If a lamp burns out, it will be necessary to replace it by removing the lamp door.

Should the door be removed, care should be exercised not to touch the silver-plated reflector or the bulb with anything but a soft, clean rag, preferably flannel.

To focus the lamps, turn the adjusting screw in the back of the lamp in either direction until the desired focus is obtained.

21 or 27 c.p. is standard for headlights. For side lamps, 4 c.p.; for dash or tail lamps, 2 c.p.

The model "T" Fords are fitted with an 18-volt magneto, and therefore a 9-volt lamp in series would really last longer than 8-volt lamps in series, but the light would not be quite so bright. The older model magnetos gave 12 to 16 volts; therefore 6 to 8-volt lamps were used—connected in series.

Nitrogen bulbs, type C, are best (see pages 432, 433), but are more expensive.

When lamps are connected in parallel, 12 to 16-volts, one ampere, 15 c.p., type B bulbs can be used.

Proper voltage: You should get good lights at eight miles per hour, and the bulbs should come up to full candle-power at about twelve miles per hour.

If the bulbs do not come to full candle-power, and cast a yellowish light, you should use a bulb of smaller voltage.

If the bulbs burn too brightly, throwing an exceedingly white light at slow speeds, the bulbs are of too low a voltage, and a higher voltage should be used. In this case, the life of the bulb would be very short.

Dry cells for starting: The (B) side of the switch can be used for batteries (dry or storage) for starting and after starting, the switch is placed on the (M) or magneto side (see Fig. 92). The Ford Co. claims, however, that the magneto gives current at a very low speed and that batteries are not necessary. (If dry cells are used, use five or six.)

Storage battery for ignition and lights can be connected in place of dry cells as shown in Fig. 92.

In connecting a storage battery, **the battery terminal should never be connected to the magneto terminal** post on the dash, as this will demagnetize the magnets.

Wiring: The timer and light wires are enclosed in a loom as furnished by the Ford Co. Extra wires used should be No. 16 flexible lamp cord, run through metal tubing or flexible loom.

To Install a Storage Battery when a Ford Is not Equipped with a Starting and Lighting System

For ignition, horn, and lighting, one terminal of the storage battery can be connected to the battery terminal in rear of the coil box (see Fig. 81). The other terminal is grounded to the frame of the car or engine (make clean contact and draw tight with a bolt).

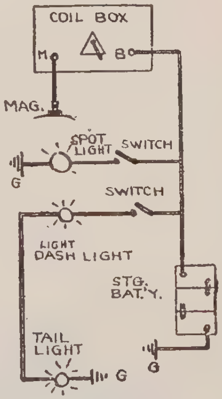


Fig. 101. Method of wiring a storage-battery system to Fords not equipped with starting and lighting system.

The wire to the (B) connection on the coil should have three branches (see Fig. 101). One branch should connect, through a single-pole switch, to a 3-volt lamp on the dash. Then the wire from this dash lamp should proceed to a 3-volt tail-lamp at the rear of the car. The remaining wire from the tail-lamp should be connected to the metal of the chassis frame. This places the dash and tail-lamp in series, so that if the tail-lamp should burn out or become disconnected, the dash lamp would also be extinguished, thus warning the driver.

Another wire should be connected, through a single-pole switch to the spot-light, the remaining wire from the spot-light being grounded.

The third branch wire from the battery should be connected to the binding post on the left-hand corner of the coil box, looking from the radiator toward the dash. When the switch on the coil box is turned toward the binding post, to which the battery wire is connected, the battery will be con-

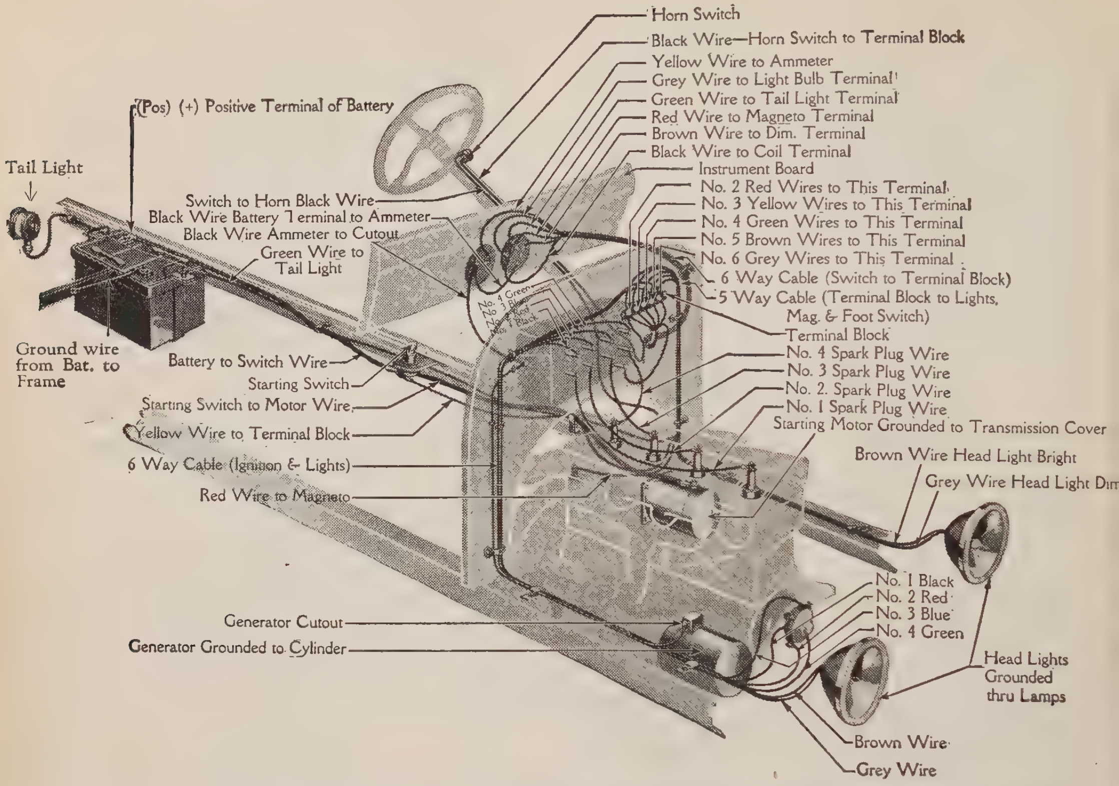

Horn Switch
Black Wire—Horn Switch to Terminal Block
Yellow Wire to Ammeter
Grey Wire to Light Bulb Terminal
Green Wire to Tail Light Terminal
Red Wire to Magneto Terminal
Brown Wire to Dim. Terminal
Black Wire to Coil Terminal
Instrument Board
No. 2 Red Wires to This Terminal
No. 3 Yellow Wires to This Terminal
No. 4 Green Wires to This Terminal
No. 5 Brown Wires to This Terminal
No. 6 Grey Wires to This Terminal
6 Way Cable (Switch to Terminal Block)
5 Way Cable (Terminal Block to Lights, Mag. & Foot Switch)
Terminal Block
No. 4 Spark Plug Wire
No. 3 Spark Plug Wire
No. 2. Spark Plug Wire
No. 1 Spark Plug Wire
Starting Motor Grounded to Transmission Cover
Brown Wire Head Light Bright
Grey Wire Head Light Di
(Pos) (+) Positive Terminal of Battery
Tail Light
Switch to Horn Black Wire
Black Wire Battery Terminal to Ammeter
Black Wire Ammeter to Cutout
Green Wire to Tail Light
No. 4 Green
No. 3 Black
No. 2 Red
No. 1 Black
Ground wire from Bat. to Frame
Battery to Switch Wire
Starting Switch
Starting Switch to Motor Wire
Yellow Wire to Terminal Block
6 Way Cable (Ignition & Lights)
Red Wire to Magneto
No. 1 Black
No. 2 Red
No. 3 Blue
No. 4 Green
Head Lights Grounded thru Lamps
Generator Cutout
Generator Grounded to Cylinder
Brown Wire
Grey Wire

Fig. 102. **Wiring diagram of the Ford model "T," including the Ford electric starting and lighting system.** This diagram is of value to the repairman when installing new wires. See pages 1125–1127 for two-color wiring diagrams showing the different circuits.

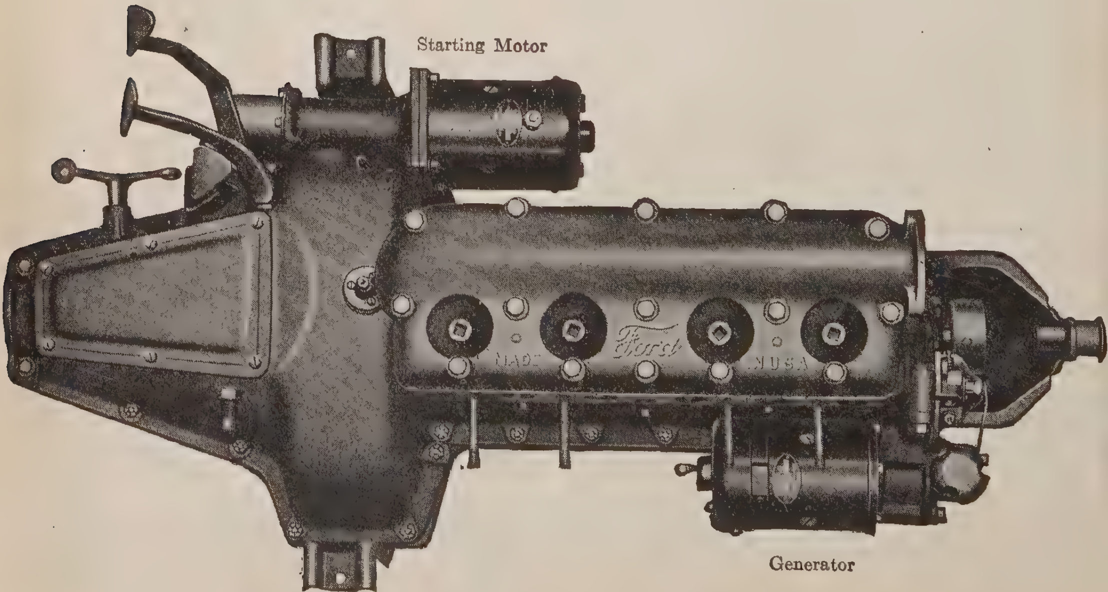


Fig. 103. Top view of Ford single-unit power plant, showing the location of the starting motor and generator.

nected for easy starting, and no other switch need be used.

The bulb for the spot light should be rated at 6 volts. The bulbs for the dash and tail-lights should be each rated at 3 volts. If desired, the bulb for the dash may be rated at 2 volts, and the bulb for the tail light at 4 volts. But they must be of the same amperage. Only two switches will be needed.

The usual voltage of storage batteries is 6 volts; therefore lamps of this voltage should be used.

The number of hours a battery will operate depends upon the number and size of lamps used and the ampere-hour capacity of the battery (see page 522).

When the battery is exhausted, it must be taken to a charging station and recharged. There is a device known as the Warner battery charger, which, it is claimed, will rectify the magneto current from alternating to direct, and the battery can be charged from the magneto with it (see page 1139).

THE F. A. STARTING AND LIGHTING SYSTEM AS INSTALLED ON FORD SEDANS AND COUPES

Parts and Location

The starting and generator system is a two-unit type, and consists of the following parts: generator, cut-out, combination switch, fuse, terminal block, ammeter, starting motor, storage battery, wire, headlamps with headlight bulbs and dimmer bulbs. The combination switch, ammeter, and priming rod are mounted on the cowl (Fig. 102).

The Starting Motor

The starting motor is mounted on the left-hand side of the engine and bolted to the transmission cover (Fig. 103). When in operation, the pinion on the Bendix drive shaft (Fig. 104) engages with the teeth on the flywheel, which is a ring gear with teeth cut in it and bolted to the flywheel and held in place by the brass screws which hold the magnets (see Fig. 105).

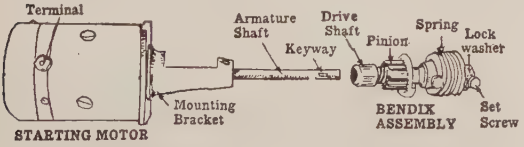


Fig. 104. Starting motor with Bendix drive parts removed from the armature shaft.

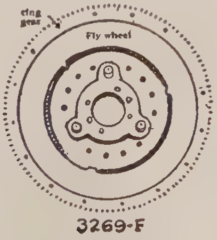


Fig. 105. Steel ring gear bolted to the flywheel for the starting motor.

To Start the Engine

The spark and throttle levers should be placed in the same position on the quadrant as when cranking by hand, and with the ignition switch turned on. Current either from a battery or magneto may be used for ignition. When starting, especially if the engine is cold, the ignition switch should be turned to "battery." As soon as the engine is warmed up, turn the switch back to "magneto." The magneto was designed to furnish ignition for the model "T" engine, and better results will be obtained by operating in this way. Special attention must be paid to the position of the spark lever, as a too advanced spark will cause serious backfiring, which in turn will bend or break the shaft in the starter.

The starting motor is operated by a foot button, conveniently located in the floor of the car at the driver's feet. With the spark and throttle levers in the proper position, and with the ignition switch turned on, press on the push button with the foot. This closes the circuit between the battery and starting motor, causing the pinion of the Bendix drive shaft to engage with the teeth on the flywheel, thus turning over the crank shaft.

When the engine is cold it may be necessary to prime it by pulling out the carburetor priming rod, which is located on the instrument board. In order to avoid flooding the engine with an over-rich mixture of gas, the priming rod should be held out for only a few seconds at a time.

If Engine Fails to Start

If the starting motor is turning the crank shaft over and the engine fails to start, the trouble is not in the starting system. In this event, release the button at once so as not to discharge the battery unnecessarily, and inspect the carburetor and ignition system to determine the trouble.

If Starting Motor Fails

If the starting motor fails to act, after pushing the button, first inspect the terminal on the starting motor, the two terminals on the battery, and the two terminals on the starting switch, making sure that all of the connections are tight; then examine the wiring for a break in the insulation that would cause a short circuit. If the wiring and connections are correct, and the starting motor fails to act, test the battery with a hydrometer. If the hydrometer reading is less than 1.225, the trouble is no doubt due to a weak or discharged battery. See also pages 562, 556: "Testing a storage battery."

Operation of Generator

The generator is mounted on the right-hand side of the engine and bolted to the cylinder front-end cover. It is operated by the pinion on the armature shaft, engaging with the large time gear (spiral gear) (see Fig. 106).

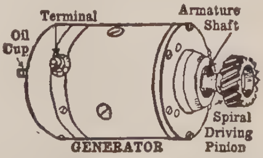


Fig. 106. Generator for Ford.

The charging rate of the generator is set so as to cut in at engine speeds corresponding to 10 m.p.h. in high speed, and reaches a maximum charging rate at 20 m.p.h. At higher speeds the charge will taper off, which is a settled characteristic of battery charging. See also page 516.

Cutout Action

This operation of cutting in and cutting out at suitable speeds is accomplished by the cut-out.

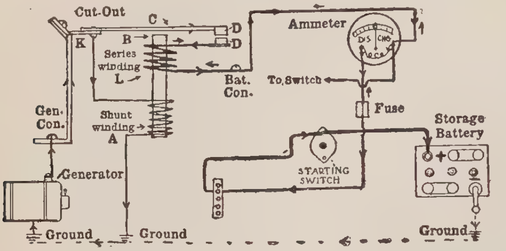


Fig. 106A. **When the engine is started and running slow,** the current flow from the generator begins to build up magnetic strength in the iron core (B), through fine wire shunt winding (A). Note that connection to the battery is open at (D).

When the car speed reaches 10 m.p.h. on high gear, the generator current is then strong enough for the shunt winding (A) to magnetize core (B), and blade (C) is drawn to (B), which closes contact points (D). The generator voltage is then 6.8 volts, or slightly more than that of the battery (battery is 6 volts). Therefore the generator **charges the battery** with current passing through the coarse wire series winding (L), through the ammeter to the battery. The generator current is now passing through (L) and (A) in the same direction.

When the engine slows down to less than 10 m.p.h., the generator voltage is then less than the battery voltage. Therefore the battery current begins to flow, or to **discharge** in the **opposite** direction (see outside arrows), through series winding (L), and this is why it is called a "reverse-current" cutout. This action **opposes** the generator current passing through shunt winding (A), which is weak, with the result that core (B) loses its magnetism, or is demagnetized, and releases blade (C), through the tension of spring (K), thus opening the circuit between the generator and battery. This action is repeated over and over as the engine speeds up and slows down, and (C) vibrates accordingly. See also pages 519, 520.

Oiling Starting Motor and Generator

The starting motor is lubricated by the Ford splash system, the same as the engine and transmission. The generator is lubricated by a splash of oil from the time gears. In addition, an oil cup is located at the end of the generator housing, and a few drops of oil should be applied occasionally. Do not use too much oil.

Ignition System

See pages 1125, 1126, which give details and circuits.

Note. The introduction of a battery current into the magneto will discharge the magnets, and whenever repairing the ignition system or tampering with the wiring in any way, do not fail to disconnect the positive wire from the battery. The end of this wire should be wound with tape to prevent its coming in contact with the ignition system or metal parts.

The Ampere Meter

The ammeter is located on the instrument board or cowl, and the reading is 20-0-20, 0 or zero being in the center, and 20 to the left indicating the "discharge" side, and 20 to the right or "charge" side (Fig. 107). The needle is on the "charge" side when the generator is charging the battery, and on the "discharge" side when the lights are burning and the engine is not running above 10 miles per hour.

At an engine speed of 15 miles per hour or more, the meter should show a reading of 10 to 12 amperes, even with lights burning.

If the engine is running above 15 miles per hour and the meter needle does not go to the "charge" side, first inspect the terminal posts on the meter, making sure that the connections are tight. Then disconnect the wire from the terminal on the generator, and, with the engine running at a moderate speed, take a pair of pliers or a screwdriver and short-circuit the terminal stud on the generator to the generator housing. If the generator is in proper order, a good live spark will be noted. (Do not run the engine any longer than is necessary with the terminal wire disconnected.) Next inspect the wiring from the generator through the meter, to the battery, for a break in the insulation that would result in a short circuit.

Next short-circuit around the cutout by connecting the battery lead directly to the generator terminal. If the ammeter now shows charge, the trouble is in the cutout, and a new one should be installed. Repairing Ford cutouts has not proved a satisfactory practice.

If, after these tests, the trouble is not remedied, then remove the dust cap from the end of the generator. Procure a fine grade of sandpaper which has been slightly oiled. Do not use emery cloth, as emery is a conductor of electricity. With the engine running, hold the sandpaper against the commutator with the fingers until all dirt has been removed and a bright surface attained. See also page 491: "Cleaning commutator."

Lighting System

The lighting system consists of two headlights and a tail-light operated by a combination lighting and ignition switch (Fig. 108) located on the instrument board. The headlamp bulbs are of 6–8 volt, **double filament** type. The major filament is 18 c.p., and the minor filament is 2¾ c.p. The small bulb used in the tail-light is of 6–8 volt, single-contact, 2 c.p. type.

All of the lamps are connected in parallel, so that the burning out or removal of any one of them will not affect the other. Current for the lamps is supplied by the battery.

Do not connect the lights to the magneto, as it will result in burning out the bulbs and might discharge the magnets. (See Diagram V, page 1127.)

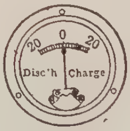


Fig. 107

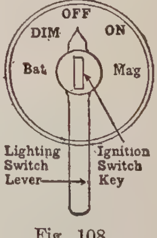


Fig. 108

The ignition and lighting switch is shown in Fig. 108. **The ignition switch** is a key, and **the lighting switch,** a lever.

How to Remove Starting Motor

When removing the starter to replace the transmission bands, or for any other reason, first remove the engine pan on the left-hand side of the engine, and with a screwdriver remove the four small screws holding the shaft cover to the transmission cover.

Upon removing the cover and gasket, turn the Bendix drive shaft around so that the set screw on the end of the shaft, as in Fig. 104, is in the position shown.

Immediately under the set screw is placed a lock washer, designed with lips or extensions opposite each other on the outside diameter. One of these is turned against the collar and the other is turned up against the side of the screw head. Bend back the lip which has been forced against the screw, and remove the set screw. As the lock washer will no doubt be broken or weakened in removing the starter, a new one must be used when replacing it. These washers may be obtained from the nearest branch.

Next, pull the Bendix assembly out of the housing, being careful that the small key is not misplaced or lost. Remove the four screws which hold the starter housing to the transmission cover, and pull out the starter, taking it down through the chassis. This is why it was necessary to remove the engine pan.

In replacing the starter, be sure that the terminal connection is placed at the top. If the car is to be operated with the starter removed, be sure to put the transmission cover plates in position. These plates may also be obtained from the nearest branch.

How to Remove Generator

If it is found necessary to remove the generator, first take out the three cap screws holding it to the front end cover, and by placing the point of a screw-driver between the generator and front end cover, the generator may be forced off the engine assembly. Always start at the top of the generator and force it backward and downward at the same time.

Plates may be obtained from the nearest branch to place over the time gear, if the engine is to be operated with the generator removed.

To Operate Engine; Generator Disconnected from Battery

If for any reason the engine is run with the generator disconnected from the battery, as on a block test, or when the battery has been removed for repair or recharging, be sure that the generator is grounded to the engine by running a wire from the terminal on the generator to one of the valve-cover stud nuts. A piece of wire 1/16″ or more in diameter may be used for this purpose. Be sure that the connections at both ends of the wire are tight. Failure to do this when running the engine with the generator disconnected from the battery will result in serious injury to the generator. Never ground the generator through the cutout.

Battery

This is a 6-volt, 13-plate "Exide," type 3-XC-13-1.

To Test Ford Generator

Clamp the generator lightly in a vise (Fig. 109). Turn the armature by hand to see if it revolves freely. If it does, attach one wire from a 6-volt battery to a bolt of the vise (one generator terminal is grounded), touch the other battery wire to the generator terminal to see if the generator will run as a motor.

If it does, and draws less than 6 amperes, the generator is probably in good condition.

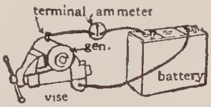
If it draws more than 6 amperes, take a piece of No. 00 sandpaper and hold it against the commutator until a bright surface is obtained. See page 491.

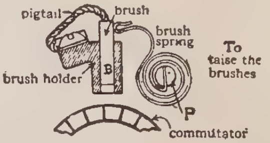
Installing New Generator Brushes

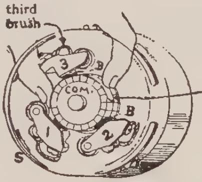
Examine the brushes and see that they are not too short and that they are clean and bear properly on the commutator. If loose, heat will be generated.

To fit new brushes, cut a strip of No. 00 sandpaper. Pull the spring back (Fig. 110) and pull the brush up by the pigtail, after which the spring is allowed to rest on the brush. Insert the sandpaper, sand side up (Fig. 111), and hold it so that it will conform to the commutator, and move it together with the commutator back and forth under the brush, the brush having been dropped on the sandpaper. Remove the brush and see if it is properly seated to the curvature of the commutator, and replace the brush.

Fig. 111 shows the method of sanding the third brush (3) and Fig. 112 shows the method of sanding the two lower brushes. (1) (2).







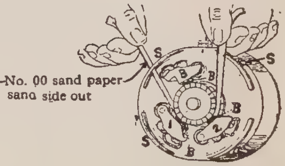


Fig. 109 (upper)
Fig. 111 (lower)

Fig. 110 (upper)
Fig. 112 (lower)

Setting Generator Brushes

The Ford generator uses the third-brush system of current regulation. When brushes seat properly, the lower brushes (1) (2) should be set on the **neutral point.** Start the lower and loosen the three upper screws (S) which hold the brush-ring to the head. Raise the third brush as in Fig. 110.

Connect the battery wire to the generator terminal. If the armature revolves, the brushes are not set on the neutral point. Turn the ring against the direction of rotation until the armature ceases to turn or until it revolves in the opposite direction. If it turns in the opposite direction, bring the ring back until the armature will not revolve in either direction, even when started by turning the shaft by hand. The brushes are now set on **neutral** point.

Tighten the screws which hold the ring to the head; lower the third brush (3) and try it for running.

If it turns over properly, drawing less than 6—preferably less than 4—amperes, the generator should be assembled to the engine, and proper connections made through the cutout to the battery.

Setting the Third Brush

The next operation is to set the third brush. The third brush may be moved back and forth on the brush ring. It is clamped to the ring by means of a bolt which is also used as a post (P) (Fig. 110) for the brush spring. To move the third brush, together with its holder, loosen the nut on this post until the holder may be moved back and forth. The third brush should be set in such a position as to give a charging rate of 10 to 12 amperes when the car is running at about 20 miles per hour on high gear. See also page 516.

Changes on Engine

The following changes have been made on engines of enclosed cars, to accommodate the starter motor and generator.

Transmission cover changed to take starter. Ford No. is 3376B.

Cylinder block changed. Ford No. 3000C.

Cylinder block front cover, changed. Ford No. 3009C.

Cylinder block front cover liner. Ford No. 3013.

Timing gear cover. Ford No. 3017.

Flywheel with ring gear. Ford No. 3269F.

The ring gear bolts to the flywheel and has teeth cut in it to take the starting-motor gear. See Fig. 105.

Price of Ford Coupé and Sedan

See page 1080.

Note. A complete instruction is devoted to the Ford electric starting and lighting system (see Instruction 45). See also pages 1125–1127, showing five two-color circuit-wiring diagrams.

FORD MODEL "T" ELECTRIC CIRCUIT WIRING DIAGRAMS INCLUDING FORD STARTING AND LIGHTING SYSTEM

The wiring diagram (Fig. 102, page 1120) is suitable for the repairman when installing new wires.

The circuit diagrams following show the different circuits, which are printed in red. These diagrams should give the repairman an idea of the wires in which any particular trouble might lie.

Wiring: The single-wire system, i.e., the metal part of the car, acts as the second wire, and is usually called the "ground." The frame is always connected to the (−) negative terminal of the battery.

There are eight circuits, each of which may be traced separately as follows:

1. Charging circuit (generator to battery as shown by the arrow points).
2. Starting-motor circuit.
3. Tail-lamp circuit.
4. Headlight circuit (bright).
5. Headlight circuit (dim).
6. Ignition from battery.
7. Ignition from magneto.
8. Horn circuit.

Electric Currents in Ford System

The generator delivers 6 to 8 volts direct current, with a maximum of 12 amperes.

The battery delivers 6 volts (direct current).

The starting motor requires about 225 amperes at 4 volts.

The magneto generates alternating current from 5 to 26 volts, with a maximum of 9 amperes.

The coil secondary current in the ignition circuit carries a current of extremely low amperage at 15,000 to 25,000 volts.

Tracing Trouble in Electrical Equipment

Trouble in the electrical system may be either **electrical** or **mechanical.**

Mechanical troubles very seldom occur, and when they do, they are located either by the resulting noise or during inspection for electrical trouble.

There are only four kinds of electrical trouble:

1. Weak source of current.
2. Open circuit.
3. Short circuit.
4. Crossed circuit.

The weak source may be the battery, the magneto, or the generator, and the trouble may be due to mechanical or any of the electrical troubles in that part.

An open circuit occurs where there is a gap in the wires of a circuit. This gap may be caused by a switch not functioning properly, a poor electrical contact between the wires and terminals, misplaced fiber insulators, dirty contact points, or a broken wire.

The importance of clean, tight contacts, particularly in the low-voltage circuits, cannot be too firmly impressed on the repairman's mind, as it is one of the most prevalent sources of trouble in an electrical system, often causing unnecessary drain on the battery when the system is apparently functioning properly..

A short circuit obtains when the current returns to its source without traveling through all the wires it is supposed to. This is caused by a bared wire coming in contact with some other uninsulated part of the circuit. These conditions may occur in the wiring or inside the separate devices.

Crossed circuits occur where the current from one circuit runs into another circuit through bared wires touching or wires misplaced in assembly.

The first thing to do in tracing trouble is to determine the circuit or circuits affected, and then, by breaking that circuit into several sections, the trouble may be located as being in one of them, which should be carefully inspected for the typical faults enumerated above.

If the trouble occurs in two separate circuits, it is reasonable to suppose that its source lies between the common connection and the supply of current. For instance, if upon trying the lights and the ignition on the battery, neither one will act, the trouble must lie between their common connection at the switch and the battery. If the horn will not sound and the car will not run smoothly with the ignition switch on the magneto side, the trouble probably lies between their common connection on the terminal block and the magneto.

Live Wires

In diagram I the wiring diagram of cars equipped with the starting and lighting system is shown; the wires shown in red are alive at all times (excepting when the battery is disconnected), and should be inspected occasionally to see that their insulation is in good condition and that the wires are in such a position that they will not chafe on any metal parts.

These wires are used on the other circuits as shown on pages 1125, 1126, 1127. However, if the batteries require recharging frequently, it is probably due to open circuits or a slight ground in these wires. As stated above, open circuits result from loose or dirty connections, as well as from parted wires.

If the top of the battery is allowed to become wet, dirty, or covered with acid spilled when testing, the current will leak across and gradually discharge the battery. The top of the battery should therefore be wiped occasionally with a rag moistened with household ammonia.

See Instruction No. 45 which gives complete details for testing all parts of the Ford electric system.

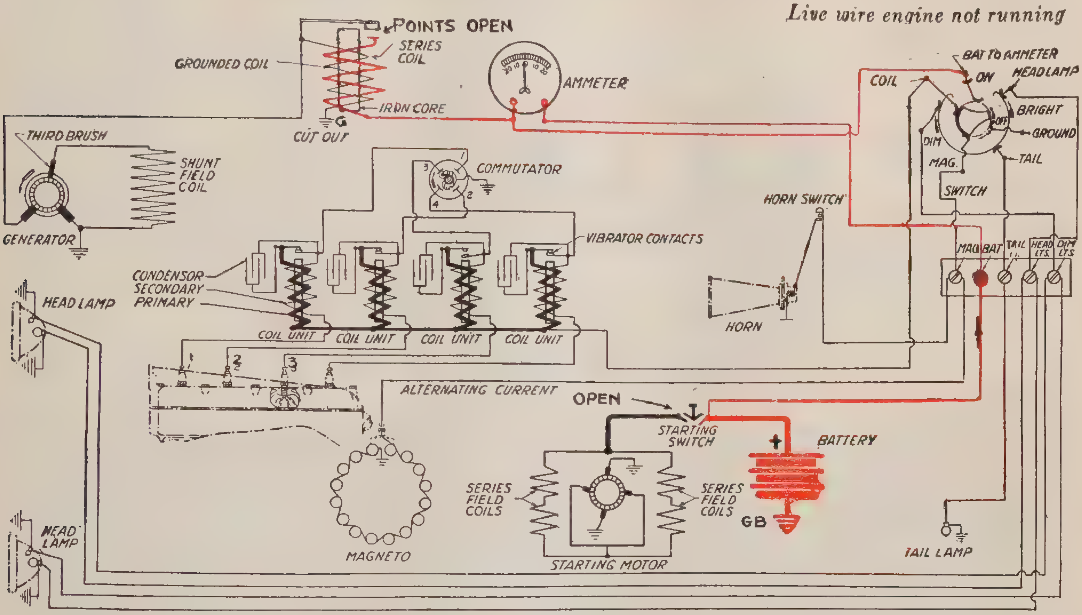

Live wire engine not running

Diagram I. **Live-wire circuit when the engine is not running** (see red wires). Note that the negative (−) terminal of the battery is grounded to the frame of the car at GB.

The red wires show the live wires, which is from the positive (+) of the battery to the terminal block (see also Fig. 102, page 1120). The circuit is then through the ammeter to the switch. Also note that one end of the cut-out series coil connects with the ammeter, but the other end is open at the open cut-out points. It will be observed that there is no complete circuit.

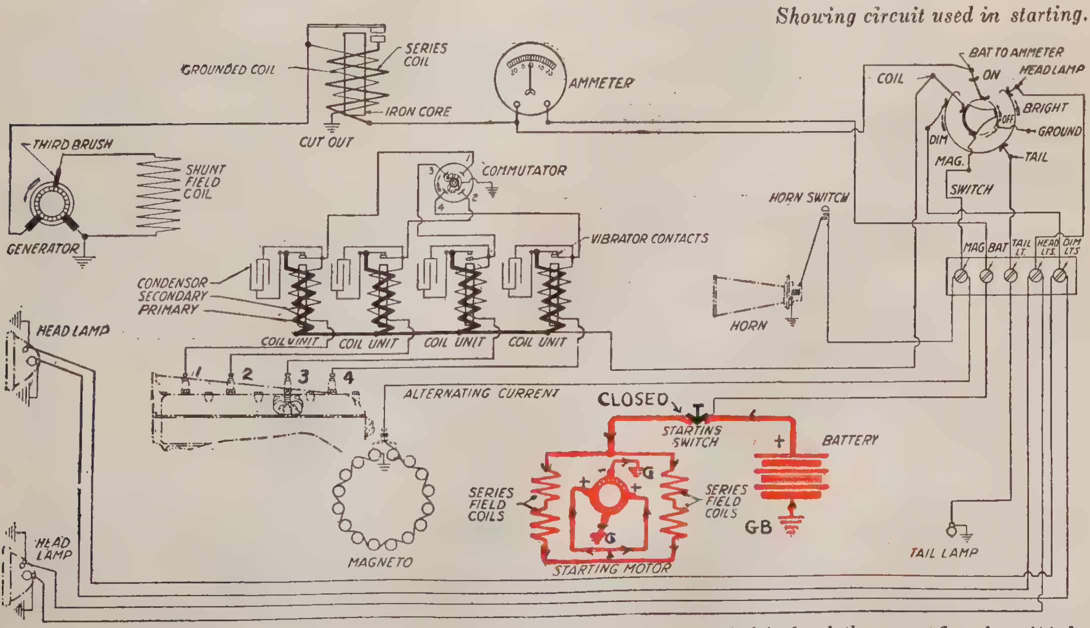

Showing circuit used in starting.

Diagram II. **Starting-motor circuit** (see red wires). When the starting-motor switch is closed, the current flows from (+) of the battery to the starting-motor field-windings, to the (+) brushes on the commutator of the armature, through the armature, out the (−) brushes, to ground (G), to the grounded (−) terminal of the battery (GB).

Charging Circuit

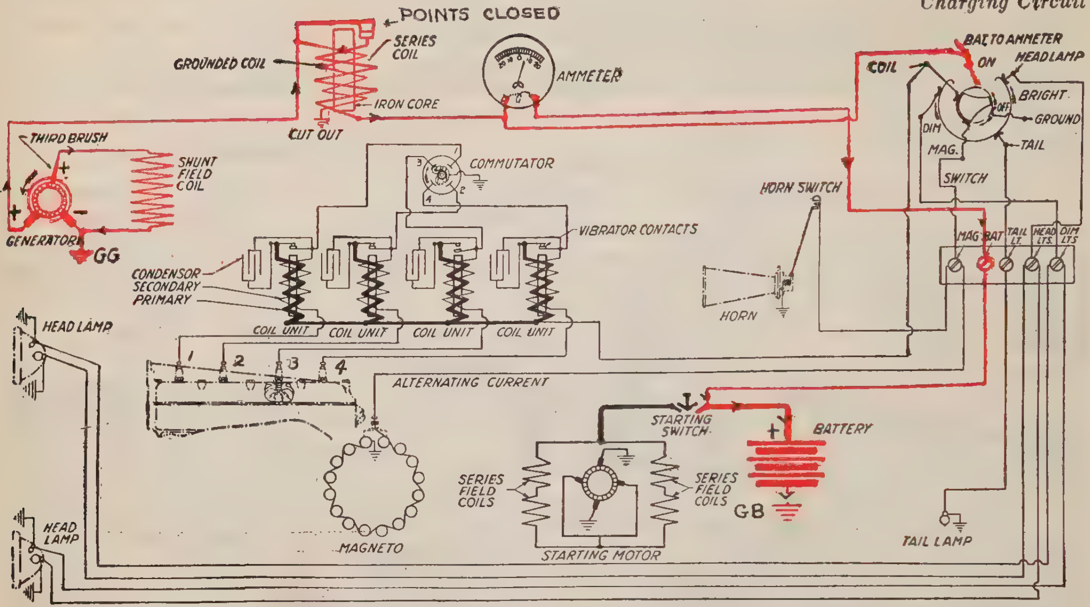


Diagram III. **Generator charging circuit** (see red wires). When the engine is running at sufficient speed (above 10 m.p.h. car speed, see instruction on Ford, page 511), the cut-out points close. The reason they close is that the current from the (+) brush of the generator passes through the shunt winding (grounded coil) on the cut-out, to ground, thence back to the (−) grounded brush of the generator (GG).

The charging current then passes from the (+) brush of the generator, through the cut-out points, through the series coil winding of the cut-out, through the ammeter, to the terminal block, to the (+) terminal of the battery, through the battery, to the (−) grounded terminal (GB) of the battery, to the (−) grounded brush of the generator (GG).

The ignition circuit, of course, must be on during this time, but is not shown in colors. If the ignition switch is on the battery side of the switch (BAT. see Fig. 108, page 1122) and the generator is charging the battery, then the ignition current would be taken from the generator ahead of the ammeter, where it is connected.

If, however, the generator is not charging the battery and the engine is running slow and the cut-out points are open, and the switch is on the battery side, then the current for ignition would be taken from the battery, first passing through the ammeter.

If the switch was on the magneto side (**MAG**; see Fig. 108, page 1122), then current for ignition would be taken from the magneto, as shown in Diagram IV.

Showing Ignition and Horn Circuits, the Ignition Switch being on the Magneto Side

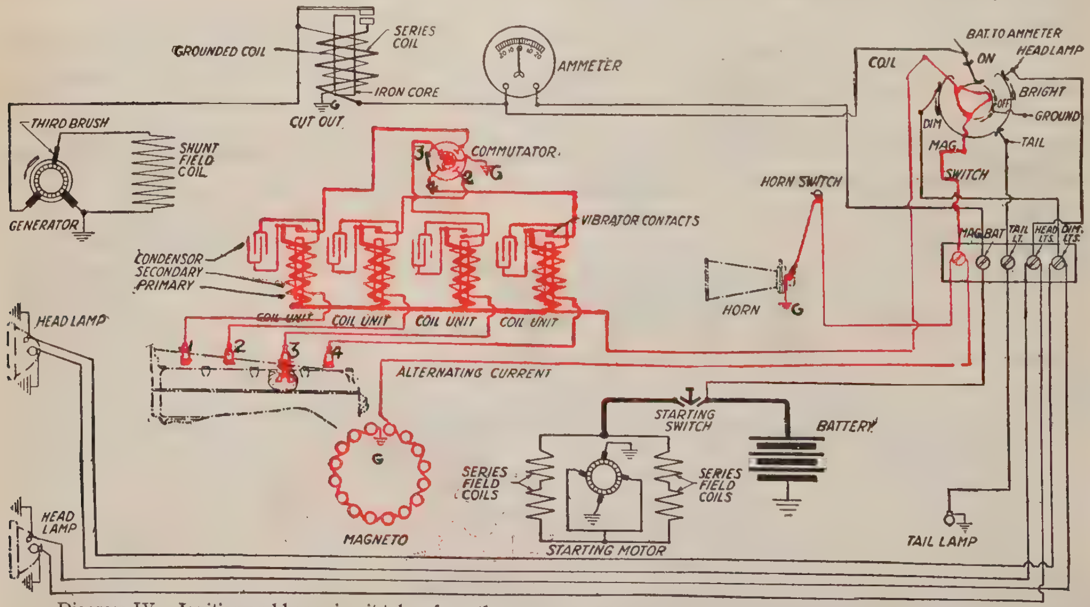


Diagram IV. **Ignition and horn circuit taken from the magneto:** The magneto ignition circuit is from the magneto terminal, to the terminal block, to the ignition switch which is now on the magneto side, to the primary coil winding (large red wire on coil), through the coil vibrator points, to the commutator segment (the one on which the roller is on contact), to ground (G) of the commutator, to ground (G) of the magneto.

The secondary current would be from the small red wire on the coil, to the spark plug (say No. 3 is firing), to ground of the engine, to ground of the commutator (G), to the secondary, where it is connected at one end of the right contact point.

Bright Head Lights and Tail Light

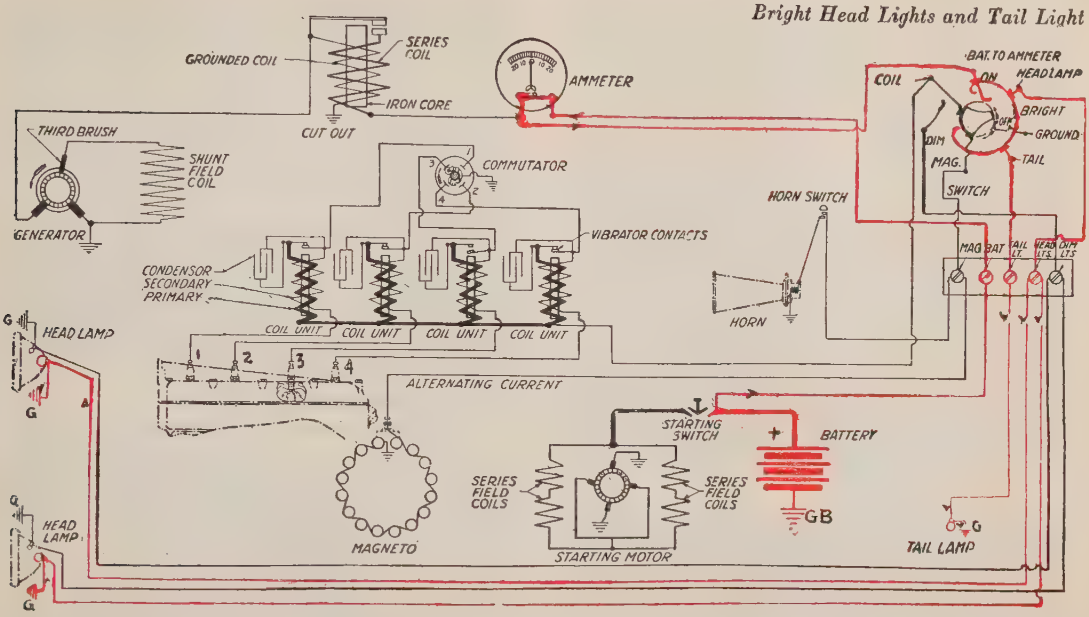


Diagram V. **Headlight (bright) and tail-light circuit** (see red wires): In this example, the generator charging circuit is open, and the engine could be running at a very slow speed or not at all, and the lighting switch lever is turned to "on" (see external view of switch, Fig. 108, page 1122); then the headlights (bright) and tail-light circuit take current from the battery, starting at (+) of the battery, to the terminal block, to the ammeter, to the switch, to the headlamps and tail lamp, to ground (G), to ground (GB) of the battery.

If dim headlights are desired instead of bright headlights, the lighting switch lever is turned to the "dim" side, which cuts out the 18-candlepower bright lamp filament and cuts in the 2¾ candlepower dim lamp filament (for double-filament lamps see page 433.

If the generator is charging the battery, the lights would be taken from the generator just ahead of the ammeter.

FORD CARBURETORS

The carburetor is located on the right side of the engine as shown in Fig. 50, page 1102. The external connections are shown in Fig. 7, page 105.

Two types of carburetors are furnished on Ford cars: the Holley, made by Holley Bros. Co., Detroit, Mich., and the Kingston, made by Byrne, Kingston & Co., Kokomo, Ind. There is very little difference in the adjusting of these two carburetors, but there is considerable difference in their repair, so they are here considered separately.

Dash Carburetor Adjustment

Both Holley and Kingston carburetors are of the automatic type, having but one adjustment. The carburetor adjustment knob (now a wire rod) is on the dash (Fig. 113). Turning this to the right—or in a clockwise direction—tends to give a weaker mixture and to save gasoline. But turning this knob to the left opens the spray nozzle and gives a richer mixture, which makes starting easier. In Fig. 113 the different positions are shown at (A) (B) and (C).

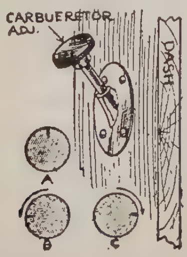


Fig. 113. **Carburetor dash adjustment.** A—is the position for correct mixture; B—for rich mixture; C—lean mixture. Adjustments in this direction save gasoline.

Carburetor Needle-Valve Adjustment

After the new car has been thoroughly worked in, a file mark or notch should be made on the face of this knob, so that the driver can determine the setting. (A) indicates the position at which the engine runs most satisfactorily. In cold weather, it will probably be necessary to turn the knob at least a quarter-turn to the left, as at (B)—especially when starting.

As gasoline vaporizes more readily in warm weather, the driver will find it economical to reduce the quantity of gasoline in the mixture by turning the carburetor adjustment to the right (as far as possible without reducing speed), as indicated at (C). This is particularly true when taking long drives where conditions permit a fair rate of speed being maintained, and accounts for the excellent gasoline mileage obtained by good drivers.

Carburetor Adjustment

This subject is treated separately for the Kingston and the Holley carburetors.

Starting the Engine in Cold Weather

The usual method of starting the engine when cold is to turn the carburetor dash adjustment one quarter-turn to the left in order to allow a richer mixture of gasoline to be drawn into the cylinders; then hold out the priming rod, which projects through the radiator, and turn the crank from six to eight quarter-turns in quick succession.

Another method of starting a troublesome cold engine is as follows: Before throwing on the magneto switch, (1) close the throttle; (2) hold out the priming rod and give the crank several quick turns, then let go the priming rod (being careful that it goes back all the way); (3) place the spark lever in about third notch and advance the throttle lever several notches; (4) throw on the switch (being sure to get it on the side marked "Magneto"); (5) give the crank one or two turns, and the engine should start.

After the engine starts, it is advisable to advance the spark eight or ten notches on the quadrant and to let it run until thoroughly heated up. If you start out with a cold engine, you will not have much power and are liable to "stall."

The advantage of turning on the switch last, or after priming, is that when you throw on the switch and give the crank one quarter-turn, you have plenty of gas in the cylinders to keep the engine running, thereby eliminating the trouble of the engine starting and stopping. After the engine is warmed up, turn the carburetor adjustment back one quarter-turn.

When cars are equipped with a starter, and difficulty is experienced in getting the engine started, do not run down the battery by continually using the starter, but follow the method outlined above.

To Facilitate Starting

Some drivers make a practice of speeding up the engine by opening the throttle just before stopping, by turning off the coil switch. This leaves the cylinders fully charged with gas.

Pulling out the priming ring, and thus causing a very rich mixture to be drawn into the cylinders, is another method of stopping the engine that will make it easier to start in cold weather but is bad practice, as the raw gasoline will be drawn into the cylinders and will work its way to the crank case and thin the lubricating oil. It is necessary to prime in this manner when starting, as then the gasoline will be likely to be ignited.

The Kingston carburetor is shown in sectional view on page 105. This shows how the gasoline enters the carburetor, is vaporized in a current of air, and then passes through the inlet manifold to the engine in the form of an explosive mixture, which gives the power. This general layout also applies to the Holley carburetor.

The hot-air pipe from the air intake of the carburetor to the exhaust manifold (as shown in Fig. 7, page 105) is useful in summer as well as in winter with poor gasoline.

THE KINGSTON CARBURETOR

The Kingston model "Y" carburetor is shown in Fig. 114. It was used on the 1913 and 1914 Ford. It differs from the model "L-1" used in 1915 and 1916 and from the "L-2" used from 1916 to 1920 in that in the model "Y" the air supply was regulated in a different manner.

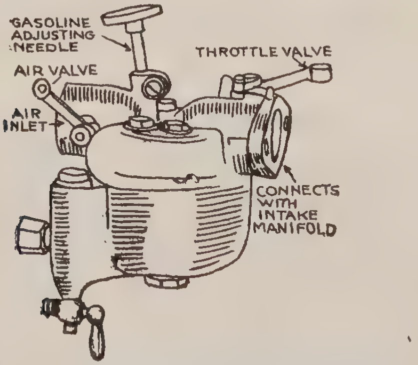


Fig. 114. Kingston model "Y" carburetor. See also Fig. 7, page 105 (this model is not now manufactured).

Description of Kingston Carburetor "L-2" and "L-1"

Fuel enters the carburetor from the tank at connection (**A**) (Fig. 116) and is maintained at a constant level (as shown), through the agency of the float acting on the needle valve (**K**).

The pool of gasoline formed in the base of the tube will always be present when the motor is not running, and is for the purpose of positive starting. When the motor starts, this pool is quickly lowered to the point of adjustment of the needle valve, and continues to feed from this point until the motor is stopped.

Let us follow the course of the air through the carburetor until it enters the cylinder, as a perfect mixture. To appreciate thoroughly what occurs in this carburetor, we must follow the course of the air and the atomized gasoline throughout its entire range.

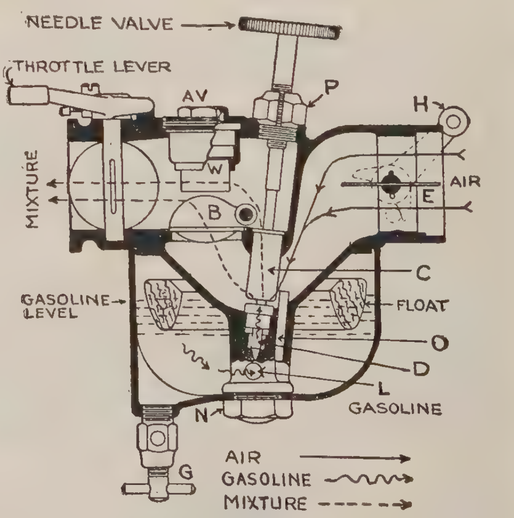


Fig. 115. Side sectional view of model "L-2" Kingston carburetor. The "L-1" is similar.

When the engine is running slowly, air valve (**B**) rests lightly on its seat, allowing no air to pass this point; consequently all air must pass through the low-speed tube (**C**). Since the lower end of this tube is close to the spray nozzle and all the low-speed air has to pass this point, the atomized gasoline drawn from nozzle (**D**) becomes thoroughly mixed with air in its upward course, and is carried in this state to the engine.

Let us now open the throttle slowly and see what occurs. The engine now requires a greater volume of mixture. Air valve (B) slowly leaves its seat, permitting a small volume of the mixture to pass by. At this point a change in operation occurs. The low-speed tube still continues to deliver a perfect mixture, but is being assisted by the air valve opening. The air being drawn by the air valve must pass across the spray nozzle between it and the low-speed tube.

As the engine speed is increased up to its maximum, the air valve continues to rise higher and higher, admitting more and more air, which, having to pass across the spray nozzle with an ever-increasing velocity, becomes thoroughly impregnated with the atomized gasoline producing a perfect mixture throughout the entire range.

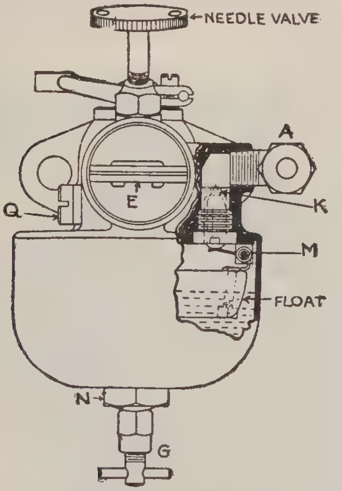


Fig. 116. End and partial sectional view.

(A)	Gasoline inlet elbow.
(AV)	Air valve cap.
(B)	Air valve.
(C)	Slow speed tube.
(D)	Spray nozzle.
(E)	Choke throttle.
(G)	Drain cock.
(H)	Choke throttle lever.
(K)	Inlet needle valve.
(L)	Gasoline inlet hole.
(M)	Float mechanism.
(N)	Float chamber nut.
(O)	Overflow tube.
(P)	Needle valve clamp nut.
(Q)	Air valve shaft.
(W)	Air valve weight.

This list refers to Figs. 115 and 116.

To start an engine at any time depends upon getting a combustible mixture in the cylinders: that is, proper proportions of air and atomized gasoline thoroughly mixed. Difficult starting in cold weather is the result of two inherent properties of gasoline. It does not vaporize as readily in cold weather as in warm, nor does it flow through the needle-valve adjustment as easily; consequently we cannot get as much by the adjustment in cold weather as we can in warm. This is why opening the needle valve slightly makes starting easier and keeps the engine running, which otherwise would have a tendency to stop when the load was thrown on.

In the Kingston model "L-2" this extra amount of gasoline for starting and warming-up period can be obtained by opening the needle-valve adjustment at the dash, or by the use of choke throttle (E), placed in the air passage.

When starting with a cold motor, choke throttle can be closed by pulling wire connected to (H). This cuts off nearly all the air supply and produces a very strong suction at the spray nozzle, which causes gasoline to jet up and be carried with the incoming rush of air to the cylinders.

A drain cock (G) is placed at the lowest point in the bowl, and should be opened from time to time to free the bowl of all water and foreign matter.

Note. A new design is the Kingston model "L-4," its most noteworthy feature being an automatic accelerating jet.

To Adjust Models "L-2" and "L-1" Kingston Carburetor

Retard the spark fully. Open the throttle about five or six notches on the quadrant on the steering post.

Loosen the needle valve clamp nut (P) on the carburetor until needle valve turns easily.

Turn the needle valve (with dash adjustment) until it seats lightly. Do not force it. Adjust away from its seat one complete turn. This will be slightly more than necessary, but will assist in easy starting.

Start the engine and open or close the throttle until the engine runs at fair speed (not too fast), and allow it to run long enough to warm up to service conditions.

Now make the final adjustment. This carburetor has but one adjustment—the needle valve. Close the throttle until engine runs at the desired idling speed. This can be controlled by adjusting the stop screw in the throttle lever.

Adjust the needle valve slowly toward its seat till the engine begins to lose speed, thus indicating a weak or lean mixture. Now adjust the needle valve away from its seat very slowly until the engine attains its best and most positive speed. This should complete the adjustment. Close the throttle until the engine runs slowly, then open rapidly.

The engine should respond strongly. Should acceleration seem slightly weak or sluggish, a slight adjustment of the needle valve may be advisable in order to correct this condition.

With the adjustment completed, tighten the binder nut until the needle valve turns under tension.

Float Level Adjustment of Kingston

In the **model "Y" Kingston,** used on 1913-14 Ford cars, the float should be set to show a clearance of 9/32″ from the top of the float to the top or face of the cup casting (the same is true of model "L," 1915 and early 1916).

Model "L-2": The action and the float setting of this carburetor are entirely different from those of the other two models. The float is hinged directly to the body, instead of in the cup, as in models "Y" and "L." To test the level of the float, turn the body upside down, and, when properly set, it should show a clearance of 7/16″ from the machined surface on the top casting to the top of the float, at a point directly opposite the point where the float is fastened to the body of the carburetor.

Miscellaneous Adjustments of Kingston Carburetor

The float chamber is removed and the float is repaired, as explained for the Holley carburetor.

The inlet needle-valve seat at (K) is removed and replaced, as in the Holley carburetor. Do not, however, replace it with the Holley valve or seat, as these parts are not interchangeable.

Before replacing the float chamber, see that the air-vent hole and gasoline feed holes (L) are clear. The chamber should be replaced with the drain cock (G) toward the inlet manifold. See that the float-chamber gasket is in place, and that the nut (N) is drawn up tight.

The spray-nozzle seat at (D) is integral with the mixing chamber, and should it become badly worn or scored, the entire mixing chamber must be renewed; however, it is seldom that this is necessary.

To remove the needle valve:

1. Unscrew the needle-valve clamp nut (P).
2. Screw out the needle valve.
3. When replacing, see that the point of the needle valve enters the taper of the spray-nozzle seat, as there is considerable play in the threads.

To remove the air valve:

1. Unscrew and remove the air valve cap (AV), thus exposing the weight (W) with its sleeve. On top of the weight is a small fiber disk which deadens the sound of the weight striking the cap. There is also a fiber ring between the shoulder of the weight and the sleeve which also is for the purpose of deadening sound.
2. Remove the weight and sleeve, thus exposing air valve (B).
3. Unscrew the air-valve shaft (Q) and remove.
4. Remove the air valve through the opening of the air-valve cap. There is a fiber gasket secured to the air valve, which acts as a sound deadener.
5. Inspect the valve for cracks between the ball and the shaft bearing.
6. When the air valve has been replaced and the shaft inserted, tilt the carburetor to see that the ball falls freely back and forth. If it requires a jerk to cause this, either a new shaft or valve must be used.
7. See that all gaskets are in place when assembling.

THE HOLLEY CARBURETOR

The model "G" Holley carburetor was used on Fords up to January, 1920. The later Holley carburetor model "NH" was installed in January, 1920, the main difference between the two models being that in the later model, the passage of air is in a straight line, thus decreasing air friction.

Holley Model "G" Carburetor

This carburetor is shown in Figs. 117 and 118. The distinguishing feature of Holley carburetors is the small number of moving parts.

From the float chamber, the gasoline passes through the ports (E) to the nozzle orifice in which is located the pointed end of the needle valve (F) (Fig. 117).

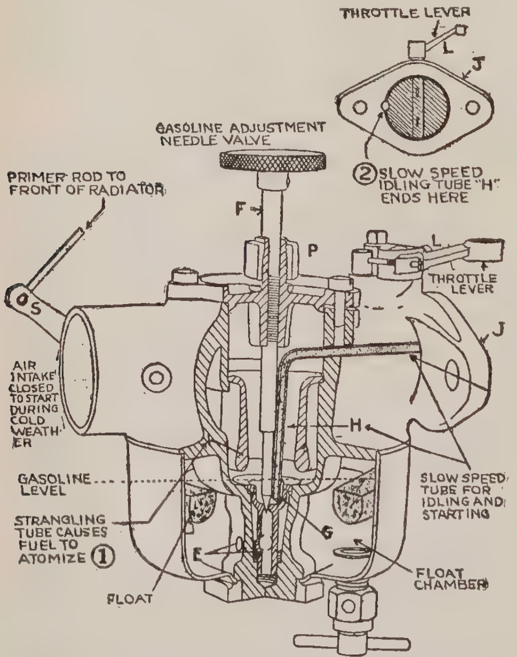

THROTTLE LEVER
L
J
GASOLINE ADJUSTMENT NEEDLE VALVE
PRIMER ROD TO FRONT OF RADIATOR
② SLOW SPEED IDLING TUBE "H" ENDS HERE
F
P
L
THROTTLE LEVER
S
J
AIR INTAKE CLOSED TO START DURING COLD WEATHER
H
GASOLINE LEVEL
SLOW SPEED TUBE FOR IDLING AND STARTING
STRANGLING TUBE CAUSES FUEL TO ATOMIZE ①
G
E
FLOAT CHAMBER
FLOAT

Fig. 117. Side sectional view of Holley (Ford) carburetor model "G."

A drain valve is provided for the purpose of drawing off whatever sediment or water may accumulate in the float chamber.

The float level is so set that the gasoline rises past the needle valve (F) and sufficiently fills the cup (G) to submerge the lower end of the small copper tube (H). Drilled passages in the casting effect communication between the upper end of this tube and an outlet at the edge of the throttle disk (see 2).

The tube and passage give the starting and idling mixtures.

The strangling tube (1) gives the entering air stream an annular converging form, in which the lowest pressure and highest velocity occur immediately above the cup (G); thus it is seen that the fuel issuing past the needle valve (F) is immediately picked up by the main air stream, at the point of the latter's highest velocity. This is termed the venturi principle. This gives thorough atomization of the fuel and results in a very economical and powerful performance. The lever (L) operates the throttle.

For facilitating starting in extremely cold weather a disk attached to lever (S) at the air intake opening, with a spring return, is connected to a priming rod. By closing this, an excess of gasoline is drawn into the cylinders.

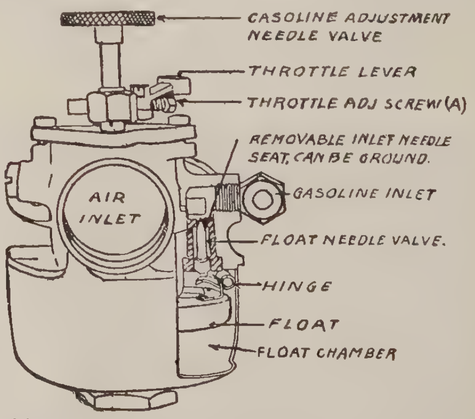


Fig. 118. End view of Holley model "G" carburetor.

Holley Model "NH" Carburetor

A sectional phantom view of the Holley "NH" carburetor is shown in Fig. 119.

Gasoline from the gasoline tank enters at the gasoline inlet passage (D), passes through the float-controlled valve (FS), and then into the float chamber (V). As a result of the suction of air caused by the engine piston, it rises in spray nozzle (**N**), where it is mixed with air from the primary air passage **T**).

When the engine is idling, this mixture is drawn through the low-speed fuel passage (**J**), and thus passes by the closed throttle plate (**H**) and thence into the engine. An air bleeding hole (**AB**) is provided in the low-speed fuel passage in order to cut down the suction, and consequently the amount of gasoline, when the throttle is completely closed.

As the throttle is advanced, a suction occurs at (**AB**), which increases the flow of gasoline through the low-speed fuel passage (**J**).

As the throttle is further advanced, the suction ceases through the low-speed fuel passage and passes to the choke in the center of the carburetor, thus causing the primary mixture to rise through the needle-valve passage (as shown in Fig. 119) and to become more thoroughly mixed with air before it enters the engine.

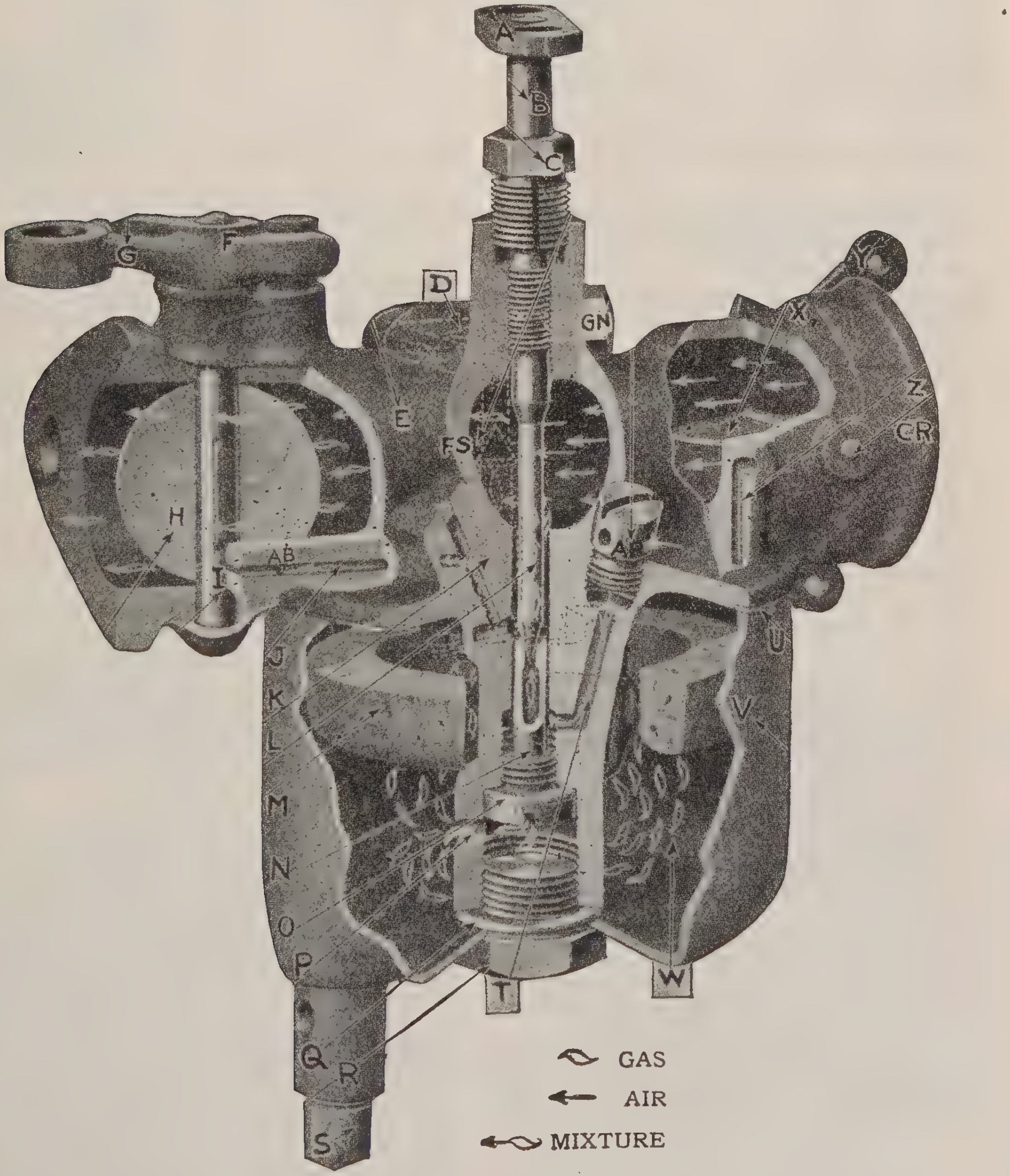


Fig. 119. A sectional phantom view of the model "NH" Holley (Ford) carburetor.

(**A**) Spray-needle head.
(**B**) Spray-needle body.
(**C**) Spray-needle clamp nut.
(**D**) Gasoline inlet passage.
(**E**) Mixing chamber body.
(**F**) Throttle-lever assembly.
(**G**) Throttle lever.
(**H**) Throttle plate.
(**I**) Throttle rod.
(**J**) Low-speed fuel passage
(**K**) Float valve.
(**L**) Spray-needle point.
(**M**) Float.
(**N**) Spray nozzle.
(**O**) Spray-nozzle gasket.
(**P**) Fuel passage.
(**Q**) Mixing-chamber body gasket.
(**R**) Mixing-chamber body screw.
(**S**) Drain valve.
(**T**) Primary air passage.
(**U**) Float-chamber gasket.
(**V**) Float-chamber bowl.
(**W**) Float chamber.
(**X**) Choke-valve plate.
(**Y**) Choke-valve lever.
(**Z**) Float-chamber vent.
(**AB**) Air bleeding hole.
(**AP**) Air-passage vent plug.
(**CR**) Choke-valve rod
(**FS**) Float-valve seat.
(**GN**) Gasoline-inlet elbow pack nut.

To Adjust the Holley Carburetor

This adjustment applies to both the models "G" and "NH." The usual method of regulating the carburetor is to start the engine, advancing the throttle lever to about the sixth notch. The flow of gasoline should now be cut off by screwing the needle valve (A) (Fig. 119) down to the right until the engine begins to misfire; then gradually increase the gasoline feed by opening the needle valve until the engine picks up and reaches its highest speed, and until no trace of black smoke comes from the exhaust. After determining the point where the engine runs at its maximum speed, the needle-valve clamp nut (C) should be tightened to prevent the adjustment from being disturbed. For average running, a lean mixture will give better results than a rich one.

The following indicate a lean mixture: To correct, turn the adjusting rod counter-clockwise.

1. The engine starts hard.
2. The engine backfires through the **carburetor** when the throttle is opened suddenly.
3. The engine will not idle.

The following indicate a rich mixture: To correct turn the adjusting rod clockwise.

1. Spark plugs foul quickly.
2. Exhaust gas causes the eyes to burn.
3. Black smoke from the muffler.
4. The engine operation is uneven, causing the rear axle to have an uneven hum which is distinctly heard at 13 m.p.h.

Holley Carburetor Needle-Valve Troubles and Remedies

Carburetors may leak from the following causes:

1. Sediment in the fuel lodging on the needle valve seat, preventing the needle from closing.
2. The inlet needle or seat damaged or worn.
3. The fuel level too high, flooding the nozzle.

These troubles may be overcome as follows:

1. Thoroughly clean the fuel tank, pipe, and carburetor, removing all sediment. After cleaning the fuel system, filter the fuel through a clean piece of chamois.
2. **Damaged float-inlet needle:** The inlet needle and seat should be replaced if a ridge is worn on the tapered point, or if the seat is scored; but in no case should a needle be replaced without a new seat, or vice versa.

   To remove the detachable seat, unscrew the float-chamber nut at the bottom of the carburetor, take off the float chamber containing the float and lever and inlet needle, then insert the socket wrench, as shown in Fig. 120.

   When installing new seat, do not turn it up too tight, as this may leave a burr inside which will interfere with the movement of the needle. After installing the seat and new needle, see that the latter works freely before attaching the float.

Adjusting of Fuel or Float Level on Model "G" Holley Carburetor

Attach the carburetor to the manifold and then take off the mixing-chamber cap by taking out the screws. This will enable you to see the nozzle and fuel level. Connect the fuel line to the carburetor; turn on the fuel; note where the level comes. The level should be as shown in Fig. 121.

Level too high, flooding the nozzle: Remove the float chamber and pry up the lever, as shown in Fig. 121 until the level is correct. The gasoline level should be from 1/16″ to ⅛″ lower than the top of the nozzle (Fig. 121).

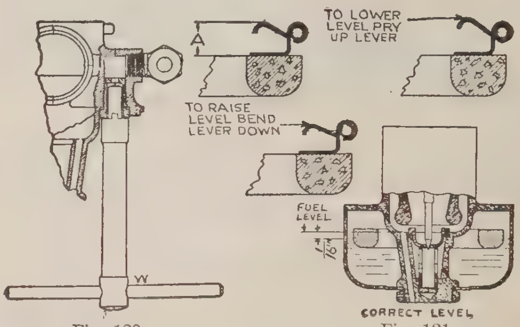


Fig. 120 Fig. 121

Fig. 120. Removing float needle-valve seat.

Fig. 121. Adjusting float level.

Fuel level too low: Should the level be lower than shown in Fig. 121, bend the tab on the float lever (that the needle rides on), down toward the float, as shown in Fig. 121 (upper sketch). It is best to detach the float and lever for this operation, by drawing out the float lever pin. The distance from the machined flange on the mixing chamber to the top of the float lever should be about ½″ when the float valve is closed.

Caution: It requires a bend of only 1/32″ on the float lever in order to change the gasoline level ⅛″. **When setting the float,** try to keep the part opposite the float lever at an angle, so that the pressure of the gasoline will assure a tight fit.

Adjusting of Fuel or Float Level on Model "NH" Holley Carburetor

Remove the float chamber bowl (V) (Fig. 119) by taking out the mixing-chamber body screw (R). When measuring at a point opposite to the float hinge, the distance from the flange, on which the gasket (U) fits, to the float should be ¼″ to 5/16″ when the float valve is closed. (For metal floats, the distance should be 3/16″ to ¼″.)

To Coat the Cork Float

(Applies to all Ford carburetors)

The float is impregnated with a composition to prevent it from becoming gasoline soaked. Sometimes this filler breaks down, destroying the buoyancy of the float, allowing too rich a mixture to enter the cylinders, or in extreme cases, causing the carburetor to flood. This condition may be noted by lack of luster on the surface of the cork, when the gasoline has dried from it. The float should be removed, by withdrawing the hinge pin, and it should be dried in a warm place, and then dipped into a thin shellac. A heavy coat of shellac will make the float so heavy that it will be impossible for it to control the gasoline supply. While the shellac is drying, the float should be suspended by a hook or string passed through the hinge. Nothing should be allowed to touch it until it is thoroughly dry.

Inspect the float to see that the cork is not cracked and that no pieces have been chipped out of it. See that the hinge is tight. If it is not, replace the float with a new one. While it is possible to tighten the hinge by peening the rivets, the chances of breaking the cork make this repair impractical.

Removing Spray Nozzle on Model "G" Holley Carburetor

First remove the small screws at the top of the carburetor and take off the plate into which the needle valve screws. Now remove the strangling tube, thus exposing the spray nozzle which may be removed with a socket wrench.

Removing Spray Nozzle on Model "NH" Holley Carburetor

Remove the float-chamber bowl, thus exposing the spray-nozzle seat, which may then be removed by a large screwdriver.

MORE MILES PER GALLON

There are three ways of obtaining more miles per gallon of gasoline: (1) by increasing the efficiency of the engine; (2) by reducing engine and running gear friction; (3) and last, but not least, by skilful driving.

The efficiency of the engine can be increased by careful carburetor adjustment, which must be changed frequently, if the best possible results are to be obtained. Worn carburetor parts waste gasoline and should be replaced. Either an attachment for leading hot air to the carburetor, or a special manifold, which heats the vapor mixture after it leaves the carburetor, should be used to insure complete vaporization of the fuel and give higher efficiency.

Carbon cuts down the efficiency of the engine and **should be removed occasionally.** Poor oil tends to form carbon, so good oil should be used, as it also causes less friction and wear.

Loss of compression, due to leaky piston rings or leaky valves, will cause a steady loss of power, which must be compensated for by opening the throttle wider, thus wasting gasoline. Scored or worn cylinders will have the same effect. And the valve tappets should be remedied, to provide the proper clearance, as given on page 1105.

Idling, or running the engine while the car is at rest, or racing the engine unnecessarily, tends to waste fuel.

Good ignition is another essential in making the most out of the fuel. Driving with a retarded spark tends to waste the power of the engine and causes overheating also.

Gasoline leaks from the tank, pipe line, or carburetor sometimes waste considerable gasoline and as the fuel evaporates as fast as it drips, this loss of fuel is not always quickly noticed.

The most economical driving speed is about 20 miles an hour.

Auxiliary Air Valves for Carburetors

The high cost of gasoline and the low cost of air has made many owners of cars wish that they could burn air instead of gasoline. While this is, of course, impossible, it is still quite true that a much greater mileage per gallon of gasoline can often be obtained by burning the gasoline vapor more completely in the presence of additional air.

Complete combustion occurs when there is sufficient air mixed with the fuel to furnish enough oxygen to combine with all the fuel particles. When complete combustion is obtained, no smoke or carbon will be formed. Thus the use of auxiliary air valves may reduce the amount of carbon deposited in the cylinders.

The mixture of gasoline and air as it comes from the carburetor is often full of little drops of almost pure gasoline. These drops are simply burned in the cylinder, instead of forming an explosive mixture, as they would if the mixture were more perfectly vaporized. The admission of air into the side of the stream of gasoline vapor often serves to form whirlpools which churn the gasoline particles into a more perfect mixture with the air.

If the carburetor mixture is perfect then the air valve is unnecessary. Unfortunately, most carburetors are far from perfect, and the air valve under the control of the driver compensates for carburetor deficiencies. The air valve, in most instances, increases the efficiency of any carburetor, if properly applied.

To determine if the auxiliary air valve is required, close the throttle and retard the spark until the engine runs as slowly as possible. Then adjust the carburetor until the engine runs smoothly and evenly on the least possible amount of gasoline.

Now take the car out on the road and, with the spark advanced and the car traveling at about twenty or twenty-five m.p.h., attempt to reduce the amount of gasoline by turning the carburetor dash-adjusting knob.

If the amount of gasoline can be reduced without greatly affecting the power and speed of the engine, the fitting of an auxiliary air valve will be advantageous.

Types of Air Valves for Carburetors

The type of air valve fitted should be one that supplies additional air at high speeds. But if, on the contrary, the engine requires a richer mixture at high speeds, when the carburetor is adjusted for good running at low speeds, then that type of air valve should be fitted that supplies air at low speeds, but is drawn closed by the suction at high speeds.

Correct adaptation of the air valve to the eccentricities of the particular engine and carburetor is necessary to get good results.

To obtain the best results from the auxiliary air valve, it should be easily controlled, preferably from the steering column. If it is operated from the dash, it will be little better than the carburetor adjusting knob, which is already provided. In fact, the idea of the air valve is to bring the carburetor more completely under the control of the driver.

Perhaps the **simplest form of auxiliary air valve** is that made by threading a **Ford oil cup** into a hole in the side of the intake manifold (see Fig. 122).

A strip of brass about ½" wide should be soldered to one side of the movable part of the oil cup, thus forming a lever by means of which the opening and closing of the air valve may be controlled. A hole may be drilled near the end of this lever, and a wire connected to the lever, this wire running through copper tubing, or a Bowden wire arrangement, to the steering column. The end of the wire may end in a loop or be connected to a small lever to suit the convenience of the driver.

Bowden wire is small, flexible, metallic tubing, with a strong but flexible wire running through it. It can be obtained from motorcycle agents, as it is used on the control system of many motorcycles.

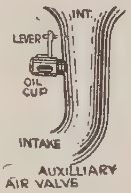


Fig. 122

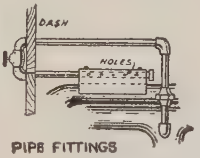


Fig. 123

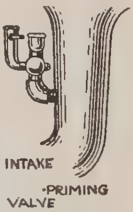


Fig. 124

Another simple form of air valve, which is more nearly airtight when closed, consists of a priming valve, screwed into an elbow attached to the intake manifold, as shown in Fig. 124. A hole can be drilled through the handle of this priming valve for the attachment of the wire to the steering-column control.

This air valve has the advantage that it can be used for priming in cold weather, or for introducing water or kerosene for loosening carbon deposits.

In winter, it is preferable to inject warm, rather than cold air into the manifold, and for this purpose it is often well to fit a soft copper pipe (which can be wrapped around the exhaust pipe) to the air valve.

An air valve made of standard quarter-inch pipe fittings and valve is shown in Fig. 123. The end of the intake pipe is covered with a sheet-iron sleeve, so that hot air will be drawn from the top of the exhaust manifold.

Another form of air valve, which eliminates the use of moving parts, is as follows: One end of a copper tube is fastened, by means of a brass coupling, to a hole in the side of the intake manifold. The tube is then given four turns around the exhaust manifold near the point where the exhaust pipe is connected. The copper tubing is then led along the dash and up the steering column, ending in an air valve directly under the steering wheel. Of course, this device can be used for priming the engine or injecting carbon-softening solutions.

When first installed, this device made a whistling sound when the air valve was opened, but this was overcome by rounding off the edges of the air valve, and since then has given entire satisfaction.

The auxiliary air valve is most useful in hilly country, for then conditions vary most widely. It is possible to use the air valve to make the engine act as a brake when coasting down hill. The admission of the air tends to cool the engine, so that the next hill will be climbed more easily. Opening the air valve also breaks the suction in the cylinders and keeps the oil from being drawn up and fouling the spark plugs when the engine is used as a brake on long hills.

A Primer

For extremely cold weather a method of priming is shown. Take off the inlet pipe and drill a hole for a 1/8" pipe tap, and fit a priming cock, as shown in Fig. 125.

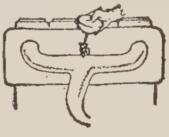


Fig. 125. Primer.

To operate: (1) turn off the switch; (2) pour about a tablespoonful of gasoline into the intake through this cock; keep an oil can filled for the purpose; (3) close up the cock; (4) crank three or four times with the switch off; (5) now turn on the switch, open the throttle, and the engine will start (see also page 1082).

Gasoline Tank Gauge

The method of constructing a gasoline tank gauge is explained on page 1082.

Control of Carburetor Mixture

A saving in gasoline: All Ford users are acquainted with the peculiarity of the Ford carburetor, in which variation of the strength of the mixture is obtained by altering the size of the jet, the alteration being effected by screwing a vertical needle up or down. This needle is tapered at its lower end, and the tapered portion enters the jet orifice; consequently, as the needle is lowered, the jet is closed; as the needle is lifted, the jet is opened and the size of the hole increased. This alteration is controlled by the driver through the medium of a rod which projects through the dash (Fig. 113). The top end of the rod is fitted with a suitable device, for convenience when handling; the lower end is forked, and the two prongs of the fork fit into suitable holes in a disk (on late models, a bar has been substituted) on the top of the needle already mentioned. (See holes in (A) Fig. 119.)

If you are a motor-wise driver, you set that disk differently for varying conditions, turning it counter-clockwise for starting, clockwise when you have started, and still further clockwise when you have been running for, say, 15 minutes. As the cool of the evening comes on, you will probably find it advantageous to turn the disk back again a little. In other words, you keep the disk set as nearly as possible for maximum efficiency of the mixture under all conditions.

The jet should be opened slightly so that sufficient gasoline is available for fast running, while at the same time the mixture would be too rich when running slow.

On the other hand, as the spark is advanced, the jet should be slightly closed and the mixture weakened.

The increase of fuel for an increased throttle opening is not much; it is just sufficient to allow of the correct proportions of gasoline and air being provided when the engine is demanding its full supply of gas. It is a known fact that a weak mixture can be readily fired by a spark when fully advanced. The result is an ecomony of fuel.

The conditions are always varying, and you cannot always be bending forward to twiddle that disk, and if you could, your adjustment would not be fine enough, and it means fine adjustment to keep the mixture just right. If it is not just right, you will be simply wasting gasoline instead of using it economically as an ingredient in an efficient explosive mixture.

This device provides an accessible control which will enable you to set the disk anew whenever conditions indicate the need, and to set it to a really fine point of adjustment, so that the mixture will not be in the nature of a compromise.

A method employed by an experimenter who is fond of tinkering is similar to devices used on some of the other makes of carburetors, and is nothing more than a hand control placed on the steering post as in Fig. 126 next column.

A steering column control is utilized, together with wire and casing. A small lever is riveted and soldered to the carburetor dash-control adjustment.

The fitting of the parts should be careful and accurate, so that there will not be the slightest play or lost motion.

If this device is used in conjunction with the throttle, as explained above, it is claimed that a saving of gasoline will be obtained, together with a cooler and smoother running engine. There are suitable graduations for different driving conditions, which the driver will soon learn, and the mixture can be made richer or weaker as required by the road driving conditions. Do not trouble, however, to experiment with this device unless you are a "fine point" driver, as it will be of little assistance unless you study out the principle and know when and how to regulate the adjustment.

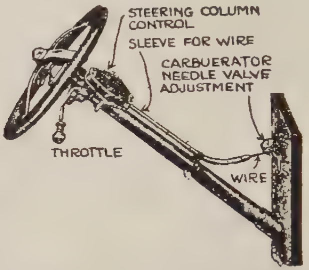


Fig. 126. Handy carburetor adjuster.

How to Save Gasoline

The illustrations below point out where care should be exercised in order to prevent loss of power, by decreasing friction and waste. To gain power means a saving of gasoline. The illustrations show where, if parts are kept in proper order, there will be a saving of power. Excess of power and loss of gasoline would come from poor driving, too much flooding of the carburetor, keeping the windshield constantly up, dragging brake bands, etc. See the three illustrations (Figs. 127, 127**A**, 127**B**). (*Ford-Owner and Dealer.*)

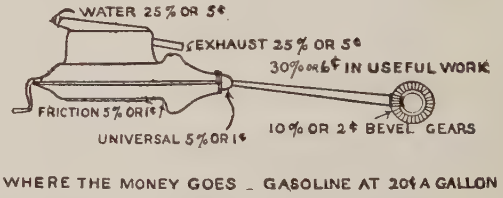


Fig. 127. **How the energy in a gallon of gasoline is distributed.** Note that if gasoline sells for 20c. a gallon, 30 per cent of it is consumed in useful work and 70 per cent in a loss, as follows: water 25 per cent, exhaust 25 per cent, bevel gears 10 per cent, universal joint 5 per cent, friction 5 per cent.

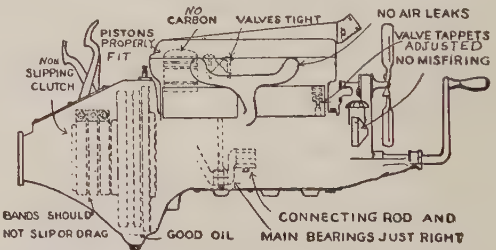


Fig. 127A. **In order to obtain the greatest percentage of power from the engine,** it is necessary to have properly fitted pistons and rings, tight cylinder-head-gaskets, no air leaks at inlet manifold, good carburetor mixture, no misfiring, properly seated valves, no air leaks at spark plugs or elsewhere, properly adjusted bearings, good oil, properly adjusted spark plug and coil, etc.

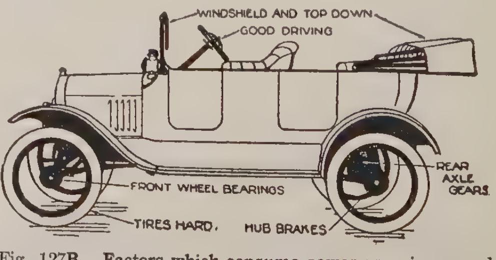


Fig. 127B. **Factors which consume power are:** improperly adjusted brakes that drag, improper lubrication, tires not fully inflated, wobbly wheels, improper use of spark and throttle control, windshield and top up, etc.

MISCELLANEOUS FORD TOOLS, TIME-SAVING DEVICES, AND ACCESSORIES

Device for Raising Rear End of Car

The illustration below (Fig. 128) shows the hook in position for raising the rear end of a car. By means of this device the rear end can be held up securely while removing or repairing the rear axle assembly or spring. In attaching the hook, place the clamps which are on the end of each bar on the frame; then bring the ends of the bars together, one bar resting in the safety clevis on the other bar. The links are then placed in the hook on the chain block, and the car is easily raised.

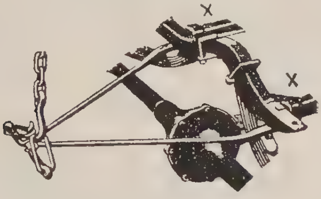


Fig. 128. Raising rear end of a Ford car.

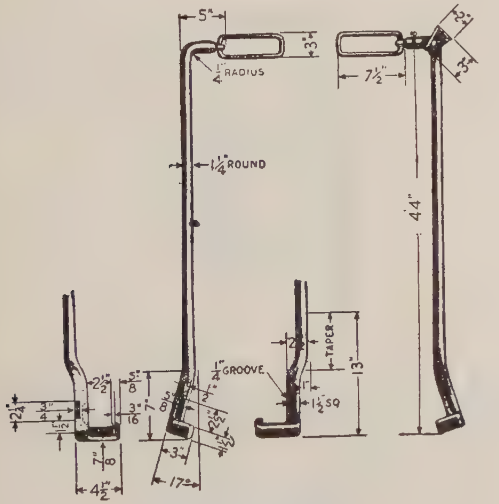


Fig. 129. Showing in detail with specifications the method of constructing the **rear-end hook.** This equipment can be made by local blacksmiths, and Ford agents will find it an efficient help in their repair work.

Device for Raising Front End of Car

The illustration (Fig. 130) shows a device in position for raising the front end of a Ford car while removing or repairing the front axle or spring. Each hook is placed on the fender iron below the nut on the end of the lamp bracket. The ring is placed in the hook on the chain-block, and the car is easily raised.

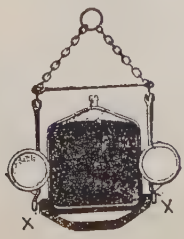


Fig. 130. Raising front end of a Ford car.

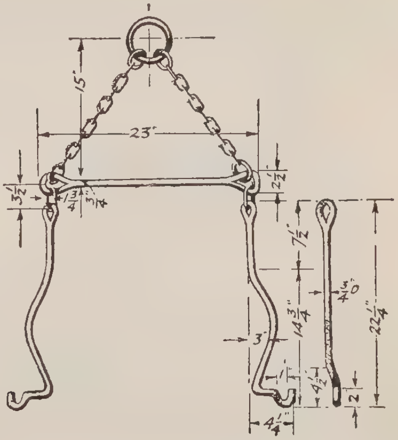


Fig. 131. Details of **front-end hoisting device.** Ford agents will be able to have this equipment made by local blacksmiths from the details and specifications shown. The front-end hook should be part of the equipment of every Ford repair shop. (*Ford Times.*)

Device for Raising Engine

An engine lifting hook, used in conjunction with a chain block, to remove the engine from the frame is shown in Fig. 132 below. It is in two parts, one U-shaped, and bent in the manner shown, having eyes to catch two manifold stud nuts; the other fastened to it, and bent to grab below the water jacket between the second and third cylinders. Ordinarily the manifolds, cylinder head, transmission-case cover, and crank-case base are removed, the illustration showing the application of the hook. When removed the engine will balance.

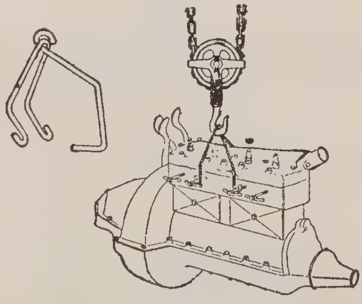


Fig. 132. Engine-lifting hook.

Towing in a Ford Car

When towing in a Ford car, when the differential happens to lock or the rear axle becomes defective, loosen the hub caps, remove the wheels, and withdraw the keys in the axle shafts. The wheels are then replaced, and the car can be towed in with the wheels turning free. Note: Grease well before starting.

Auxiliary wheels may be used for towing in a Ford that is disabled by having the rear axle broken near the hub. The device to be used is shown in Fig. 133.

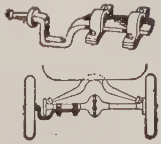


Fig. 133. **Auxiliary wheel for towing a disabled Ford.** A bar of steel about 3 ft. long and 1½ in. square is put in the lathe, and a standard Ford hub is turned on one end and fitted with the cones and locking nut. The other end of the bar is then forged out flat and bent to clear the rear brake band, after which the lower clamping straps are riveted on. The addition of the upper clamping straps and a standard Ford wheel makes the outfit complete. To use, the disabled car is jacked up and the auxiliary wheel clamped in place, permitting the car to be towed in. In the case of a front wheel the procedure is much the same, except that the cross-steering rod must be tied and the car towed very slowly. The device is not limited to use on the Ford, and has been used to bring in a 1-ton truck.

Valve Lifter

A tool for removing the valves may be made from a piece of steel ⅝" round and about 12" or 14" long, as shown in Fig. 134.

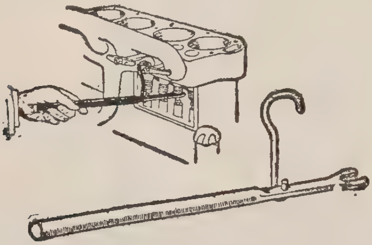


Fig. 134. **Ford valve lifter.** One end is flattened out for about 4", and is then drilled ¼", and the flattened end is then notched in the manner shown to permit insertion beneath the valve-locking washer. A piece of ¼" rod is then bent at both ends, one end passing through the ¼" hole in the lever, and the other being used to hook over one of the manifold studs. By the aid of this lifter the valve may be removed without removing either manifold.

Larger Valves

Valves, if made larger, will permit slightly more gas to enter and will increase compression and power, but heating will also be increased. In consequence, a circulating pump or a larger radiator may be necessary. A valve lift of 5/16" with a valve seat 3/32" measured across the slanting face would be about right.

Valves are now with a 1 5/16" outlet and 1½" diameter across the widest part, but for racing, valves of 1½" diameter outlet and 1 11/16" across the widest part would be better. The valve ports can be enlarged to this size by reaming and grinding. Tungsten valves of 1⅝" are sometimes used.

Circulating Pumps

Circulating pumps of unique and simple design are manufactured, by Giddings & Lewis, Fond du Lac, Wis.

Increasing Compression

This means that by reducing the space in the combustion chamber from the head of the piston to the inside top of the compression chamber of the cylinder—when the piston is in its uppermost position—the gas would be compressed tighter, and therefore a more explosive force would result when combustion takes place.

Opinions vary on this. For high-speed work it might possibly help—but the heating will increase, and a circulating pump or a larger radiator (special racing type—see Index) will probably be required. Refer to the discussion under "Compression."

The question was recently asked of a manufacturer of Ford parts:

Q.: Would you advise cutting the cylinder base down ⅛" to increase compression on the engine for racing?

Ans.: It is much easier to plane off the cylinder head. Another method would be to use special pistons to increase compression by ⅛ inch. We had an experimental machine fitted in this manner and found it satisfactory. This is no doubt the most practical way. Increased water capacity is necessary, and some form of circulating device, such as a pump, is advisable.

Right here the writer wishes to add that in a recent race tournament of Fords, not one of the engines had increased compression.

Miscellaneous Engine References

Piston clearance: See pages 809 and 811.

Remedying pumping of oil by the piston: See page 168.

Ford oversize pistons, etc.: This is treated under "Pistons." See page 812.

The piston pin is 47/64" in diameter by 3½" long.

Piston-pin bushings (pairs) are of phosphor bronze, 15/16" in diameter by 1 7/32" long.

Standard oversize pistons are supplied by the Ford Motor Co. Pistons of .0025" can be used in worn cylinders without reboring, but necessitate careful lapping. See page 811.

If a cylinder is out of round, reboring is necessary. Cylinder reboring tools can be secured of the Universal Tool Co., Inc., 435 Woodward Ave., Detroit, Mich., or of K. R. Wilson, Buffalo, N.Y. See also page 821 under "Enlarging cylinders."

Aluminum pistons: See page 807.

Ford Carburetor Wrench

A specially made wrench for tightening the carburetor to the inlet manifold is shown in Fig. 135.

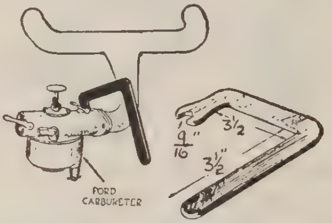


Fig. 135. **A special wrench for tightening the carburetor to the inlet manifold can be made of flat metal.** Dimensions are shown in the illustration.

Priming Cups

To fit priming cups to a Ford cylinder head, replace four of the cap screws with studs drilled as shown in Fig. 136.

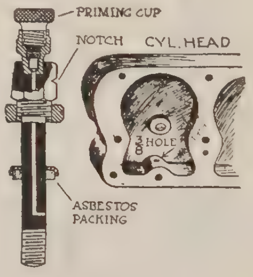


Fig. 136. Home priming bolt for the Ford car.

The cylinder-head bolts are removed, and the heads drilled as shown; that is, four ⅜" holes are drilled through the cylinder head. The special bolts are then inserted and permit the engine to be readily primed.

Priming Spark Plugs

Some spark-plug manufacturers make a spark plug with priming cup attached (Fig. 137). The old plug is removed and the priming plug is installed without making any changes on the engine. Priming is accomplished by pouring gasoline in the cup and then turning the pet cock on the cup, thus permitting the gasoline to flow into the cylinder.

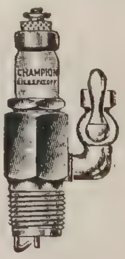


Fig. 137. Priming spark plug for a Ford car.

Pointers on Replacing Transmission and Cleaning a Clogged Engine Oil Pipe

The illustrations (Figs. 138 and 139) explain the method of replacing the transmission and of cleaning a clogged oil pipe.

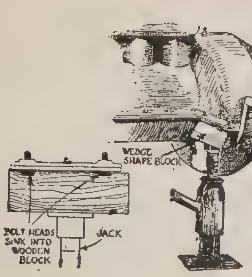


Fig. 138

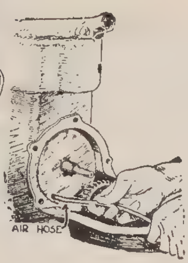


Fig. 139

Fig. 138. **The four bolts on the front of the Ford transmission can be replaced** by one man working alone, by inserting the bolts from under the car, laying a block of wood on top of a jack, and lifting the jack till the heads of the bolts are pressed into the wood. This keeps the bolts in place and prevents them from turning while the nuts are put on.

Fig. 139. **When the oil pipe of a Ford engine is clogged,** remove the radiator and take off the front gear plate. The cam gear is then removed with a puller. This will expose the end of the pipe. An air hose is connected to it and air is turned on, blowing the clog out. This saves tearing the engine down. If the pipe is clogged, the gears will be noisy. (*Motor World.*)

Oil-Level Gauge

A glass gauge oil-level indicator, when screwed into the engine crank case, will indicate the amount of oil at a glance (see Fig. 140). It is advisable to place a stock cock between the gauge and the crank case, and to keep it closed; open only when testing—to prevent loss of oil if the gauge breaks.

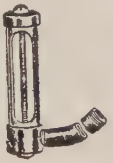


Fig. 140. Oil-level gauge for Ford engine.

Drill Press to "Run in" Ford Bearings, etc.

Ford main bearings, connecting-rod bearings, or oversize pistons can be run or worn in by bolting the cylinder block to the drill-press table, with the cylinder head removed and with four ½" pieces under the corners between the head and the table to give clearance to the pistons (See Fig. 141).

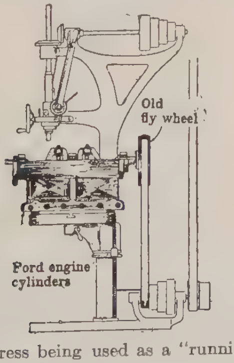


Fig. 141. Drill press being used as a "running-in" machine.

A flywheel of the bolted-on type is drilled to fit the flange of the Ford crank shaft, and is bolted on.

The table is turned so that the flywheel lines up with the drive pulley of the drill press, and is then belted up. An elevating screw is used to tighten the belt. See Index under "Running-in bearings."

Aligning Reamer

A reamer designed to ream all three main bearings simultaneously saves much time in scraping and refitting bearings. (See Fig. 142.)

The unequal distribution of weight and driving strain on the crank shaft of a Ford engine naturally causes unequal wear in the main bearing. It can be seen that tightening up only on the bearing caps will spring the shaft out of line and throw additional strain on the bearings, causing them to wear loose again very rapidly. This reamer will bring all bearings to proper size and perfect alignment An allowance of .0025" is made for wear of the crank shaft.

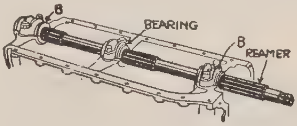


Fig. 142. Main bearing aligning reamer.

This reamer can also be used for reaming the connecting-rod lower bearings, as they are of the same diameter as the main bearings. (Stevens Co., N.Y.) See page 789, 714: "Align-reaming main bearings."

Running-in and burning-in Ford bearings is fully treated elsewhere in this book. See pages 787, 789.

Clutch Spring Tool

A device for compressing the Ford clutch spring is shown in Fig. 143.

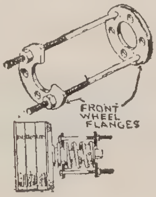


Fig. 143. **A device for compressing the Ford clutch spring.** The end plates are Ford front-wheel flanges, one being cut away, so that it may be inserted over the shaft, behind the spring. Two bolts connect the plates, and by tightening the nuts, the plates are drawn together, compressing the spring. With this device, only one pair of hands is needed to remove the pin.

Special Ford Wrenches

Some speed wrenches to save time on rear-axle work are shown in Figs. 144, 145, and 146.

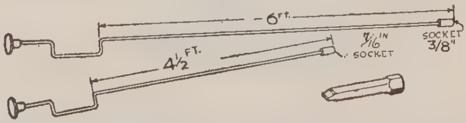


Fig. 144. The 6 ft. brace, with a ⅜" socket wrench is used for removing the **universal flange nuts** from the rear without having to get under the car. The 4½ ft. one, with a 7/16" socket, is used to remove the **torque tube retaining nuts** after the axle has been placed in the axle stand (Fig. 145).

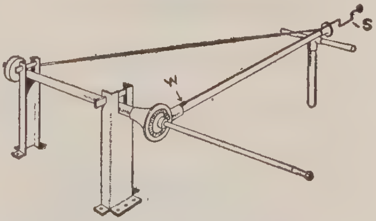


Fig. 145. Method of removing the torque-tube retaining nuts with a special speed wrench.

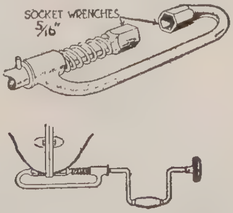


Fig. 146. Styled a "jew speeder wrench"; used in removing the 5/16" flange nuts and bolts holding the two halves of the axle housing together. (*Motor World.*)

A Home-Made Rear-Axle Stand

An axle stand designed for the Ford rear axle is shown in Fig. 147.

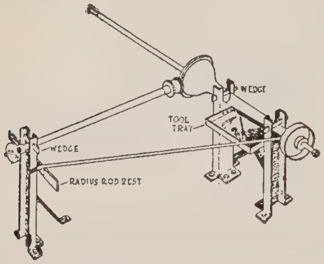


Fig. 147. **Rear axle stand** constructed of channel iron throughout. Each upright is laid out at a point of an L on the floor as shown. One half of the rear axle housing passes through, and is held by two of these uprights, the other upright holding the torque tube. A steel cross-piece is riveted to this latter upright, serving as a rest for the radius rods.

Special Reamers for Ford Car

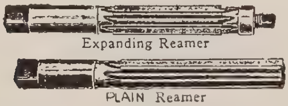


Fig. 148. Ford reamers.

An expanding reamer is shown in Fig. 148. A good set of reamers is very essential to the repairman. The particular reamer shown in Fig. 148 marketed by the Stevens Co., 375 Broadway, New York, is of an expanding type. They are ground .005″ undersize, and can be brought up to .005″ oversize. This is an added advantage.

Reamers are used for reaming out such parts as piston-pin bushings, steering-spindle bushings, transmission triple gear bushings, cam-shaft front and rear bushings, etc. In fact they are indispensable to the repairman.

A reamer for spindle-body and spindle-arm bushing is the 2-in-1 reamer for front-axle bushings. The 5″ section reams the spindle-body bushings in perfect alignment at one operation.

The 1″ section is for use in the spindle arm bushing.

A reamer for piston-pin bushing is used for reaming through both the piston-pin bushings to secure perfect alignment of the piston pins.

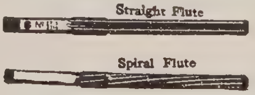


Fig. 149. **Reamers** are usually made with either straight or spiral flutes (see Index under "Reamers"). The Stevens Co., 375 Broadway, New York, furnishes reamers.

A spindle-bushing remover is shown in Fig. 150. The knurled end is inserted through either bushing and pulled through until the expander slips over the inside end of the bushing. Then by tapping on the knurled end of the tool with a hammer, the bushing is readily removed. By reversing the tool, the opposite bushing is readily removed. Made of carbon steel, spring hardened. (G. H. Dyer, Cambridge, Mass.)

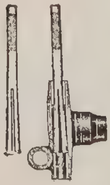


Fig. 150. Ford spindle-bushing remover.

Data on Overhauling a Ford Car

Fair charges for overhauling a Ford car are given elsewhere in this book. See page 758.

What constitutes an overhaul is described elsewhere in this book. See page 758.

Lights from Magneto

The "St. Louis Evenlite" is a device (Fig. 151) that controls the current from the magneto, and is for the purpose of producing lights that have the same degree of brilliancy at all engine speeds when the lighting current is taken from the magneto. It produces the full candlepower of the lights at 10 miles per hour, and will afford a full, clear light at 6 or 7 miles per hour with a very slight decrease from highest speed. It is made in two models, one to go on the dash under the hood; the other, to go on the steering post, includes a horn, a push button, and a switch with which the lights can be turned on, dimmed, or cut off. The device can be installed in thirty minutes. (Can be secured of A. L. Dyke, Granite Bldg., St. Louis, Mo.)

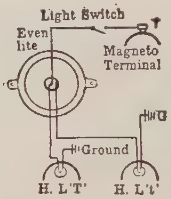


Fig. 151. Wiring diagram of the "St. Louis Evenlite."

The Atwater Kent Ignition for Ford Cars

This system is not the standard or regular equipment for a Ford car, but is a good ignition system to be installed on this car, especially when overhauling. With this system, only one coil is used, which is of the non-vibrating type. See Index under "Atwater Kent type CC ignition coil and distributor." (Atwater Kent Co., Philadelphia, Pa.)

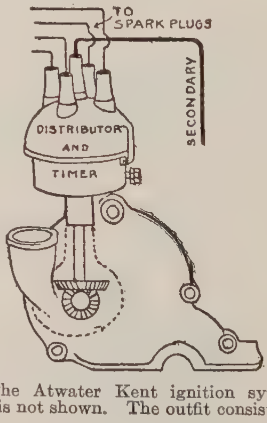


Fig. 152. The Atwater Kent ignition system for Ford engines. Coil is not shown. The outfit consists of the following parts:

1 No. 3079 Type CC 4 cylinder Unisparker with adjustable advance lever and mounting bracket attached.
1 No. 3071 coil adapter unit for primary circuit.
1 No. 3074 cap screw, 4 ⅛″ long.
2 No. 1049 cap screws, 1 ½″ long.
1 No. 3076 primary lead.
1 No. 1046 lock washer.
1 No. 1044 bevel gear.
1 No. 1910 complete set of secondary wiring.
1 No. 1048 advance rod.
4 No. 3075 spacing washers.
1 No. 1524 switch connection.
1 No. 187 wood screw, U. B. 71.

The Kemco Electric System for the Ford

Generator: Consists of a direct-current generator (13 lbs.), driven from the crank shaft by a Whittle V belt. It is mounted in the fan and charges a 6-volt battery which supplies current for lights, ignition, and the starting motor.

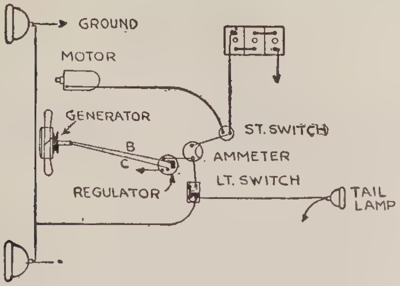


Fig. 153. The Kemco wiring diagram.

The starting motor is geared back 16 times. It is a series-wound motor, and starts the engine through a roller chain connecting with a sprocket on an over-riding clutch connected to the crank shaft. (Kemco Electric Co., Cleveland, Ohio.)

A Battery Charger

A battery charger illustrated in *Ford-Owner and Dealer* is shown in Fig. 154. With this device the alternating current is rectified to direct current. The magneto is intended to supply the current for charging. The rectifier and battery are placed in a battery box on the running board. The manufacturers are Warnerlite Products Co., Davenport, Iowa. Another rectifier of a different design is manufactured by Double EE Co., 2307 Bosworth Ave., Chicago, Ill.

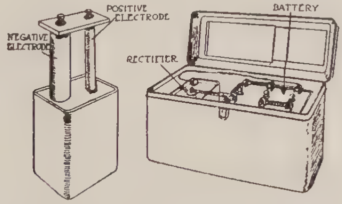
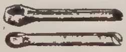


Fig. 154. **Warner battery charger for Fords,** for the purpose of charging storage batteries for the lighting system with current generated by the magneto.

Cotter Pins for Ford Cars

There is a total of 95 cotter pins used throughout the Ford car, and 6 different sizes, as enumerated in Fig. 155.



5—3/32 x ½″ No. 66
33—3/32 x ⅝″ No. 88
27—3/32 x ¾″ No. 753
4—3/32 x 1″ No. 421
11—1/16 x ½″ No. 544
15—1/8 x 1″ No. 82

Fig. 155. Ford cotter pins.

Tires

Two Ford cars may be so changed that each has the same size tires all around, without extra expense except for a set of 31″ x 3½″ tires. One will have 31″ x 3½″ tires, and the other will have 30″ x 3½″ tires.

Remove the wheels without hubs from the front of one car and the rear of the other. Place 30″ x 3″ rims all around on one car, and 30″ x 3½″ rims on the other. Put 31″ x 3½″ tires on the car with 3″ rims, and 30″ x 3½″ tires on the other car. This gives equal size tires all around, and extra size.

Spokes and rims can be had complete from the Ford Motor Co., ready to assemble to fit in the hubs.

Extra oversize tires: The 30″ x 3″ front rim on a Ford will take a 31″ x 3½″ or a 32″ x 4″ tire.

The 30″ x 3½″ rear rim will take a 31″ x 4″ or a 32″ x 4½″ tire. The 4″ and 4½″ tires, of course, will fit tight and are not recommended, but they can be put on by lapping the beads slightly.

Demountable Rims and Wheels

The advantages of demountable rims are explained on page 597. Rims for 30″ x 3½″ tires all round will make riding easier, will give longer life to the tires, and one has only one size of tire and tube to bother with. The Firestone Tire and Rubber Co., Akron, Ohio, makes this equipment for Ford and Chevrolet cars. The outfit consists of 5 rims for 30″ x 3½″ tires, 4 being applied to the wood wheels, and 1 spare; 24 hub bolts, and a socket wrench.

Visor Windshield Protector

To keep rain and snow off the windshield, a straight piece of fiber or thin sheet metal (6″ to 10″ wide) should have the corners bent at right angles, as shown by the dotted lines in the sketch (Fig. 156). These side flaps keep the snow from blowing in at the sides, and help to support the front edge of the visor. The rear of the visor should be fastened to the lower side of the front bow of the top, by means of a number of small, round-head wood screws and washers. (*Fordowner and Dealer.*)

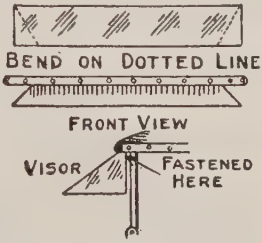


Fig. 156. Windshield protector.

Starting-Crank Rattle

This is prevented by the means shown in Fig. 157.

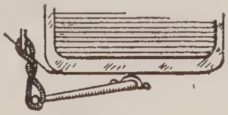


Fig. 157. A twisted spring will keep the starting crank from rattling. A screen door spring is often used.

Tool Box

A device showing how the door on a Ford car can be utilized as a tool box is shown in Fig. 158.

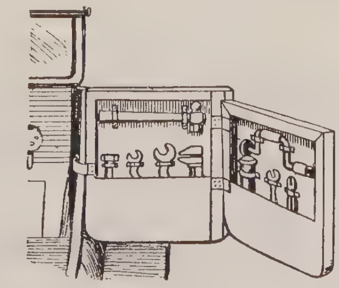


Fig. 158. **A tool box on the door.** The front door is arranged with a light door of strips of wood properly braced, the hinges screwed to a strip of wood placed up and down behind the metal door lock; the inner door-spring catch fits nicely in the notch left by removing the center cross-brace next the leather stop. Then a pocket made of canvas or leather is fastened in the lower portion of each door with a strap or two to keep the tools in place. Replace the door lining and put new strips of gimp, tacking with black-headed tacks as it was before. (*Motor World.*)

Power from Rear Wheels

This is unusual, but has been done, as shown in Fig. 159.

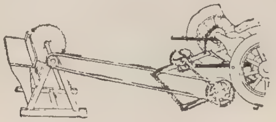


Fig. 159. Power from rear wheels. The device shown is self-explanatory.

Broken Speedometer Shaft

A simple method of repairing the speedometer shaft is shown in Fig. 160.

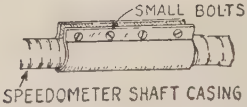


Fig. 160. To repair a broken speedometer-shaft casing, a sleeve is used as shown. A layer of tape is applied first.

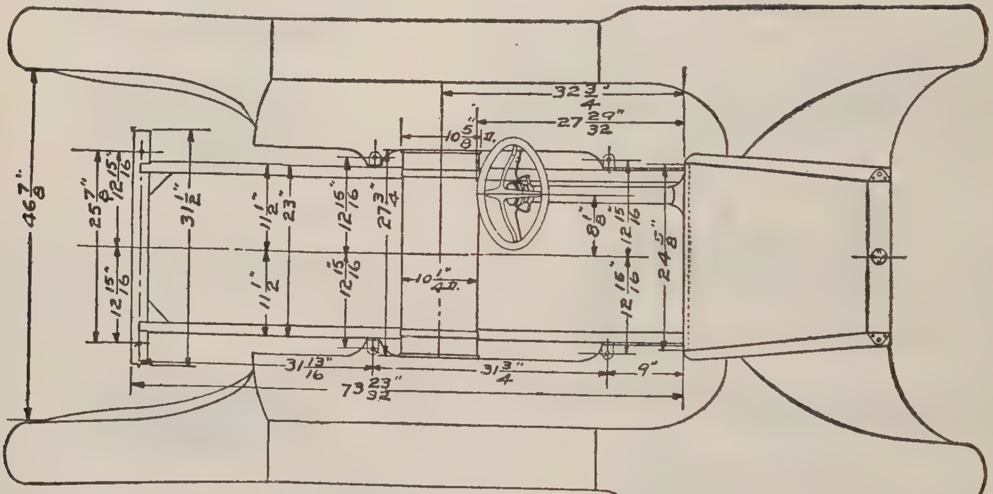
Muffler and Cut-Out

The construction of the Ford muffler and a method of attaching one type of cut-out is shown on page 49. The outside diameter of the exhaust pipe of a Ford is 1½"; therefore a cut-out would be required which would fit over it.

COMMERCIAL APPLICATION OF THE FORD MODEL "T" CHASSIS

The Ford is being rapidly adapted to a variety of commercial uses.

The illustrations (Figs. 1 and 2) show the principal dimensions of the side view (Fig. 2) and top view (Fig. 1) of the model "T" Ford chassis. These dimensions will be of value when figuring measurements for bodies for commercial use which can be applied to the model "T" Ford chassis.



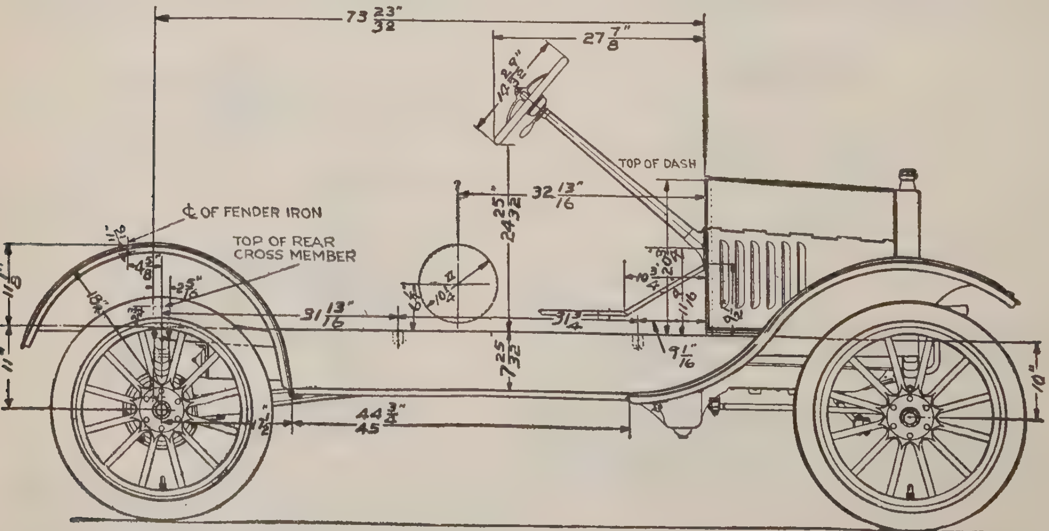


Fig. 1 (upper). Top view of Ford model "T" chassis.
Fig. 2 (lower). Side view of Ford model "T" chassis.

In the illustrations above, an assembly drawing of the model "T" chassis, with the principal dimensions for commercial body designing is shown. These dimensions apply regardless of the type of body to be installed.

The Ford Motor Co. does not recommend that the model "T" chassis with standard rear axle be used for truck use. The Ford truck with a special worm-driven rear axle (see Index) is furnished for this purpose. However, as there are many owners who desire to convert the Ford model "T" for commercial use, the following information may be of assistance.

See page 913: "Ford truck" for dimensions of the Ford truck chassis.

Combination Bodies for Model "T" Ford Chassis

The illustrations (Figs. 3 to 9) show how **several different types of bodies for commercial use can be made** from the lot of detachable parts illustrated in Fig. 10.

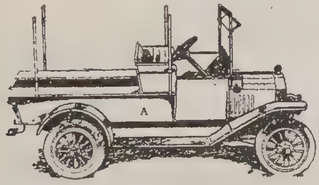
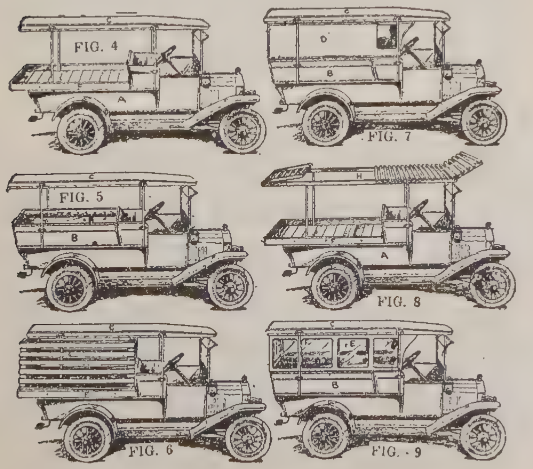


Fig. 3 shows the chassis with the base (A) fixed thereto, which forms the ground work of all the variations. The base (A), it will be noted, includes the seat for the driver and his companion.

In certain cases individual pieces of parts shown in Fig. 10 have more than one use, for instance, the upright for the canopy top of the wagonette (Fig. 5) and the station omnibus (Fig. 9) is used to support the rack of the hay and straw wagon (Fig. 8), though when the last-named is used, an additional pair of supports can be fitted.

The station omnibus body has double doors, for the base carries permanently a half-door at the back. The upper half for the omnibus use is attached to the detachable panels; the half-doors are bolted together in use, so as to form a single unit.

The seat backs used for the wagonette (Fig. 5) and the station omnibus (Fig. 9) also form a part of the sides of the closed van (Fig. 7), and for the latter, the same canopy and upright are used. Instead of the upper half-door and rear panels of the station omnibus, the van has a back panel hinged at the top, two supports being provided to hold it open when required.



Figs. 4 to 9, showing different body constructions which can be assembled from the parts shown in Fig. 10.

The parts in Fig. 10 will make the following:

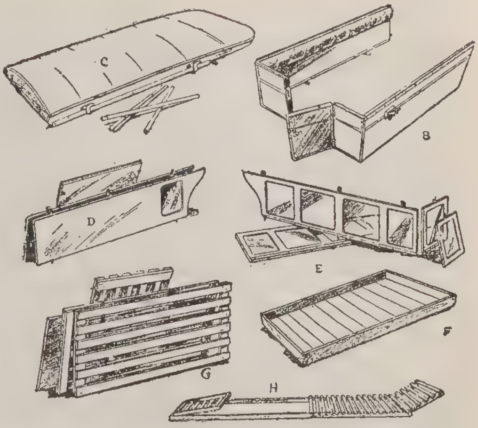


Fig. 10

Fig. 4. **The Flat Lorry** is made up of the base (A) (as on Fig. 3), the float (F), and the uprights and the canopy (C) (Fig. 10).

Fig. 5. **The Wagonette** is made up of base (A) (Fig. 3), and the parts (B) and (C) (Fig. 10).

Fig. 6. **The Live-Stock Dray** has a lattice (G) (Fig. 10), placed on base (A) (Fig. 3), and float (F) (Fig. 10).

Fig. 7. **The Closed Van** for perishable goods is made up of the base (A) (Fig. 3) with parts (B) (C) and (D).

Fig. 8. **The Hay and Straw Wagon** is made up of base (A) (Fig. 3) and parts (F) and (H) (Fig. 10), with canopy uprights.

Fig. 9. **The Station Omnibus** is made up from base (A) (Fig. 3), with sides (B), glass sides (E), and canopy (C).

Trailers[1]

Trailers are divided into two general classifications: the two-wheeled, or cart type; and the four-wheeled, or wagon type. The two-wheeled type is of course much simpler, and does not require any steering gear, being simply attached to the rear by a tongue and flexible connection. The attachment is usually made to the center of the rear cross-member of the chassis frame, where the spring is fastened—the spring clip bolts often being used to fasten the trailer connection.

On level country roads, Ford cars are sometimes used to pull from two to three of the light, two-wheeled trailers. When much used for pulling trailers, it is advisable to change the bevel gear and pinion in the rear axle, so that a gear ratio of 4 to 1, or as high as 6 or 7 to 1, can be obtained. This lessens the strains on the engine, transmission, and other parts of the power plant.

The capacity of the two-wheeled trailer is usually about half a ton, although some are made of a three-fourths ton capacity.

The capacity of the four-wheeled type of trailer is usually one ton or more. But a one-ton trailer is about as large as should be used in connection with a Ford car.

The speed, with trailer attached, is but little below that of usual touring-car speed. Twenty miles an hour is the usual speed.

Load distribution on two-wheeled trailers should be divided evenly in front of and behind the axle. Otherwise, severe strains will be placed on the connection between the car and the trailer, and the car may have to carry part of the load.

The coupling, or connection, between the car and the trailer should be quickly detachable, and should be provided with a cushion spring to asborb jerks and shocks when starting and stopping.

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[1] See also page 952: "Trailers."

INSTRUCTION No. 86

THE LIBERTY ENGINE: History; Construction. GNOME ENGINE

BRIEF HISTORY

At the declaration of war, Mr. H. E. Coffin, and soon thereafter, Mr. E. A. Deeds, were called upon to organize the production of aviation equipment.

J. G. Vincent, Chief Engineer of the Packard Motor Car Co., and E. J. Hall of the Hall-Scott Co., of Berkeley, Cal., were called into conference at Washington, May, 1917. On May 29, these two men started the design of an 8-cylinder aviation engine to develop approximately 200 h.p., and a 12-cylinder engine to develop 300 h.p. The first engine, an 8-cylinder, was delivered to the Bureau of Standards, Washington, July 4, 1917, and ran successfully.

The Engine Production Department, a section of the Division of the Signal Corps, was created in August, 1917, with Lieut. H. H. Emmons in charge as Chief Engineer of the Engine Production Department.

The horsepower of the 12-cylinder engine was increased to 440 h.p., and in spite of many difficulties, more than 15,000 engines were produced by November 29, 1918, or within eighteen months after work began—certainly a marvelous accomplishment.

OILING SYSTEM

The oil supply for the Liberty engine is carried in a reservoir which is cooled. This reservoir is mounted somewhere in the vicinity of the engine, and from it oil is led to the connection on the right side of the oil-pump body, which is marked "oil in."

There are two oil pumps: a delivery pump and an oil-return pump. See Fig. 1.

Oil-return pump: Immediately above the oil-delivery pump is located the "oil-return pump" consisting of three gears, and driven by the same shaft as the delivery pump. The function of this oil-return pump is to draw the excess oil out of the crank case and return it to the oil reservoir. One half of this pump draws oil from the oil sump at the propeller end of the crank case, and the other half draws oil from the sump at the distributor end of the crank case. Both halves of the pump deliver oil to the connection on the left side of the oil-pump body marked "oil out," from which point it returns to the oil reservoir.

The oil-delivery pump takes the oil and delivers it under pressure to a distributor pipe (**C**) running the entire length of the crank case.

There is a pressure regulating valve between the pump and the distributing pipe which holds the pressure so that it does not exceed 50 lbs. per sq. in.

The oil-gauge pressure, after about 3 minutes of running at 600 to 800 r.p.m., should show about 5 lbs. pressure, and at 1,600 r.p.m. up to 30 lbs.

From the distributor pipe, there are pipes (**P**) leading to the main crank-shaft bushings. The crank shaft is hollow, and in the center of each main bearing there is a radial hole drilled through the shaft into the hollow center. A passage leads from each hollow main bearing to the adjacent crank pin, which is also hollow. A radial hole is drilled through each crank pin and carries the oil out on the surface of the pin.

There are oil grooves and passages in the connecting-rod bushings to insure proper lubrication for both the forked and plain connecting rods.

The oil spray thrown off by centrifugal force from the ends of the connecting rods lubricate the piston pins and cylinder walls.

A part of the oil conducted to the crank-shaft main bearing at the propeller end of the engine goes through a passage around this bearing and up through pipe leads (F) and (E), to the propeller end of the cam-shaft housings. From the end of the cam-shaft housing it is led around the end of the cam-shaft bearing through a passage drilled diametrically through the bearing midway of its length.

Once in every revolution of the cam shaft, a hole drilled through the cam shaft into its hollow center registers with the oil passage through the bearing.

Thus once in every revolution of the cam shaft a small quantity of oil is forced into the hollow cam shaft.

The oil is led through the cam shaft and out through holes drilled in it to each cam-shaft bearing.

The excess works out of the ends of these bearings and collects in small reservoirs to a depth of about ¼". The cams, in revolving, dip into this oil and splash it over the cam rollers.

The excess oil eventually finds its way to the gear end of the cam-shaft housings, over the gears, and down the drive-shaft housing into oil chamber (**O**), just above the oil pump.

The excess oil thrown off in the crank case by the connecting rods collects in this same chamber when the engine is inclined, so that the propeller end is high. If the propeller end of the engine is low, this oil collects in the oil pump or chamber at the propeller end of the crank case.

Starting Engine

Block wheels securely. With the ignition switches "off," turn the propeller forward five or six revolutions to distribute oil over the cylinder walls.

Set throttle slightly open, at a point which will run the engine at 600 to 800 r.p.m. Set spark at fully retarded position.

Prime engine (fill priming cock twice), and with ignition switch "off," turn engine forward two revolutions. Turn one (either one) ignition switch "on" and start the engine by pulling steadily down on the propeller blade. When the engine starts, turn on both switches and advance the spark halfway, leaving the throttle approximately in starting position, and allow the engine to run at idling speed (about 800 r.p.m.) for five or ten minutes until warmed up. At the same time test the crank-case temperature with your hand. The crank case should be warm by the time the temperature of the water has increased to 150° F. Accelerate and slow down the engine occasionally to throw oil up into the cylinders. When the engine is well warmed up, the throttle may be opened wide (wheels blocked), and the speed of the engine noted. The tachometer should show 1,550 to 1,600 r.p.m. on the ground.

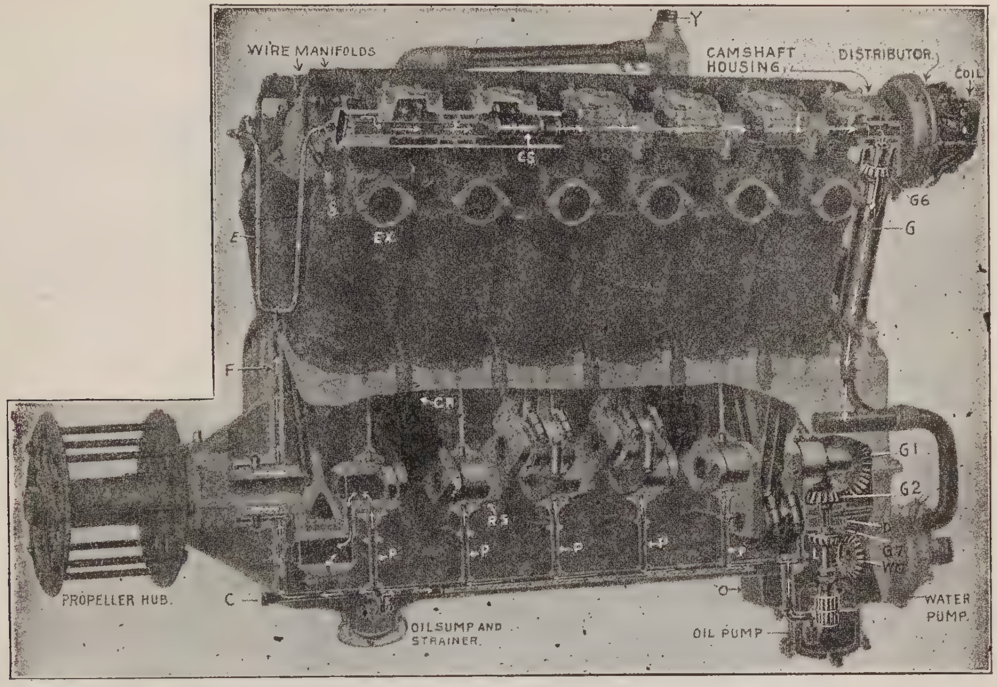

Fig. 1. (**Ex**) exhaust ports; (**CS**) cam shaft; (G6) cam-shaft drive gear; (G) drive-shaft housing; (G1), (G2), (G7), (L) (D) correspond with Fig. 5; (O) oil chamber above oil pump; (**WG**) water-pump gear; (C) oil-distributor pipe; (**CR**) connecting rods; (**RS**) crank shaft.

GENERAL CONSTRUCTION

The Liberty engine used in the De Haviland and other land planes and many seaplanes is a 12-cylinder "V"-type, with overhead valves and overhead cam shaft. It **weighs** approximately 890 lbs., and the **horsepower** ranges between 350 and 400 in the army type with the high-compression pistons, and between 320 to 340 in the navy type with low-compression pistons.[1]

The rated fuel consumption is 0.54 lb. a horsepower, or 36 gal. an hour with wide-open throttle at 1,700 r.p.m. Under service conditions about 30 gal. an hour is a fairly representative consumption.

The oil consumption is 0.03 lb. a horsepower-hour, or 1½ gal. an hour with wide-open throttle at1,700 r.p.m.

The horizontal flying speed of the engine is 1,700 r.p.m., and the ground speed is 1,600 to 1,625 r.p.m.

Cylinders

Cylinders: The design follows the practice used in the German Mercedes, English Rolls-Royce, French Lorraine-Dietrich, and Italian Fraschini before the war and during the war.

The cylinders are made of drawn-steel inner shells surrounded by pressed-steel water jackets welded to the cylinders and at their own seam. Each cylinder has one inlet and one exhaust valve and two spark plugs.

Angle between cylinders: In the Liberty the included angle between the cylinders is 45°; in all other existing 12-cylinder engines it is 60°. This feature is new with the Liberty engine, and was adopted for the purpose of bringing each row of cylinders nearer the vertical and closer together, so as to save width and head resistance. By the narrow angle greater strength is given to the crank case, and vibration is reduced.

A disadvantage of this angle, if used for automobile work, would be the resulting uneven firing impulses, which would be noticeable at low speeds. Under these conditions, in the course of the distributor brush rotation, the sparks first occur close together (22½)° and then far apart (37½°).

With the airplane engine, however, where the speed is usually high and constant, the uneven impulse is not noticeable.

The bore is 5″ and the stroke is 7″, the same as on the Hall-Scott "A-5" and "A-7" engines, and as used on the Hall-Scott 12-cylinder engine. The **piston displacement** is 1,649.34 cu. in.

An engine in all respects identical with the Liberty airplane engine, but having cast-iron cylinders, is used in "tanks."

Pistons

The pistons are of aluminum, and are of the Hall-Scott design.

There are two designs of pistons used, one for the army and one for the navy.[1]

The army type of piston has a crowned head which gives an 18 per cent compression space.

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[1] Engines required for different classes of work were: (1) elementary training planes; (2) advanced training planes; (3) combat planes. For (1) Curtis "OX", 90 h.p. engine, and Hall-Scott "A-7A." 100 h.p. engine, were used. For (2) the Gnome 110 h.p. engine, made by the General Vehicle Co., Long Island, N.Y., and the Le Rhone (similar), of 80 h.p., made by the Union Switch and Signal Co., Swissvale, Pa., and the Hispano-Suiza, 150 h.p., by the Wright-Martin Co., New Brunswick, N.J., were used. For (3) the Liberty engine was used. It was estimated that 22,500 would be required for the army and navy.

[1] The navy type usually works at low altitudes and the army type at high altitudes, hence the reason for low and high-compression pistons.

The navy type of piston has a flat head which gives a 20.5 per cent compression space.

The pistons are 5″ long, and have three rings of the eccentric type, all at the top of the piston. These piston rings are assembled with a gap between the ends of the rings not less than .025″. The pistons of the engine weigh 3 lbs. 3 oz. and are fitted with a clearance of .018″ to .020″.

Piston Pin

This is a seamless steel tube, the tube being a drive fit into the bosses on the aluminum piston. The tube is 1¼″ in outside diameter and is surrounded by a bronze bushing upon which the upper end of the connecting rod bears.

Crank Shaft

The design follows the standard 12-cylinder practice, except as to oiling.

The crank shaft is a drop-forged 7-bearing crank shaft 2⅝″ in diameter, the longer being at the propeller end.

The shaft carries a propeller hub at its forward end, and at the rear end carries a bevel gear for driving the valve mechanism.

A double-row thrust bearing at the propeller-hub end of the crank shaft takes the end thrust on the shaft.

The shaft is drilled for oil passage, the openings being drilled through the crank cheeks through the crank pins.

Connecting Rods

The forked or straddle-type connecting rods of I-beam type are used. This type of connecting rod was first used on the French De Dion car, and on the Cadillac in this country. The length is 12″ between centers. Both crank shaft and connecting rods are made of chrome nickel steel.

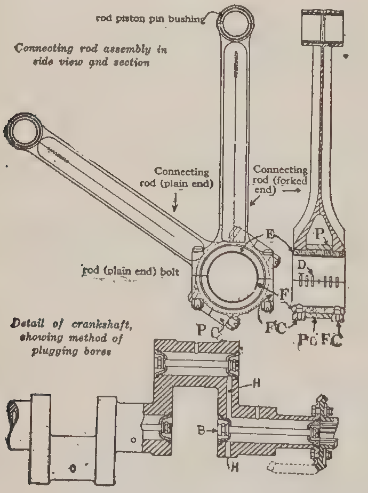

rod piston pin bushing
Connecting rod assembly in side view and section
Connecting rod (plain end)
Connecting rod (forked end)
E
P
D
rod (plain end) bolt
F
Detail of crankshaft, showing method of plugging bores
P C
FC
P C
FC
H
B
H

Fig. 2. Note that the lower part of the plain end **connecting rod** is placed between the forks of the forked end rod. (P) shows a section of the lower end of the plain rod over the bearing bushing (E), which is the upper half of the bearing bushing, and (F) is the lower half. The plain rod has one cap (PC) and the forked rod, two caps (FC). The left rods are forked, and the right are plain.

The clearance between crank pin and lower connecting rod bushing varies from .003″ to .004″.

Clearance between the plain rod and the back of the bushing is .005″.

The bushing carried by the forked rod should have from .010″ to .020″ side play on the crank pin.

The plain end rod should have from .004″ to .008″ side play in the forked rod.

Crank Case

The crank case is in two pieces, both of which are aluminum castings.

The crank-shaft bearings are on a line with the split in the crank case, the lower halves of the crank-shaft bearings being held in the lower half of the crank case and the upper halves in the upper half of the crank case.

The two halves are tied together by long bolts or studs (S) (Fig. 3), which pass through the upper half of the crank case, through bosses, the nuts being at the top of the upper half of the case. This gives an accessible construction which is at the same time rigid.

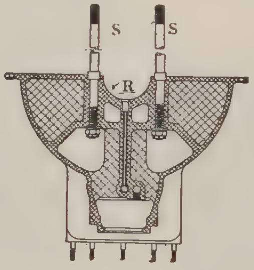


Fig. 3. Cross-section through lower half of crank case.

A careful joint is made between the two halves of the crank case in order to secure the desired alignment at the main bearings, the joint being lapped.

Cooling System

Cooling water is circulated through the Liberty engine by a centrifugal pump running at one and a half times the engine speed.

The capacity of this pump is 100 gal. a minute at 1,700 r.p.m. The cooling system from the pump inlet to and including the water outlet header will hold 5½ gal. of water, or 46 lbs.

Cold-Weather Instructions

Anti-freezing preparations are not used. The cooling system is filled with boiling water.

Hot lubricating oil is put into the crank case. Oil can be heated in an open-top container set in boiling water.

The engine is primed to start at slow speed. It is then run on the ground until the oil has been thoroughly distributed.

The plane is not taken from the ground until the water temperature is 160° F. The engine should not remain stationary more than 10 minutes at a time, as it will get cold again. The temperature of the water should not exceed 200° F., and should average about 180°.

After finishing a test flight, all oil and water should be drained before the engine cools.

The spark plugs should be removed from the engine and kept in a warm place, if the engine is to stand idle over night or for a long period.

Propeller

The propeller is 9 ft. in diameter; the blade is 9″ in width. The difference in pitch between the two blades is 1/16″ in 9 inches. The Hall-Scott propeller hub was adopted.

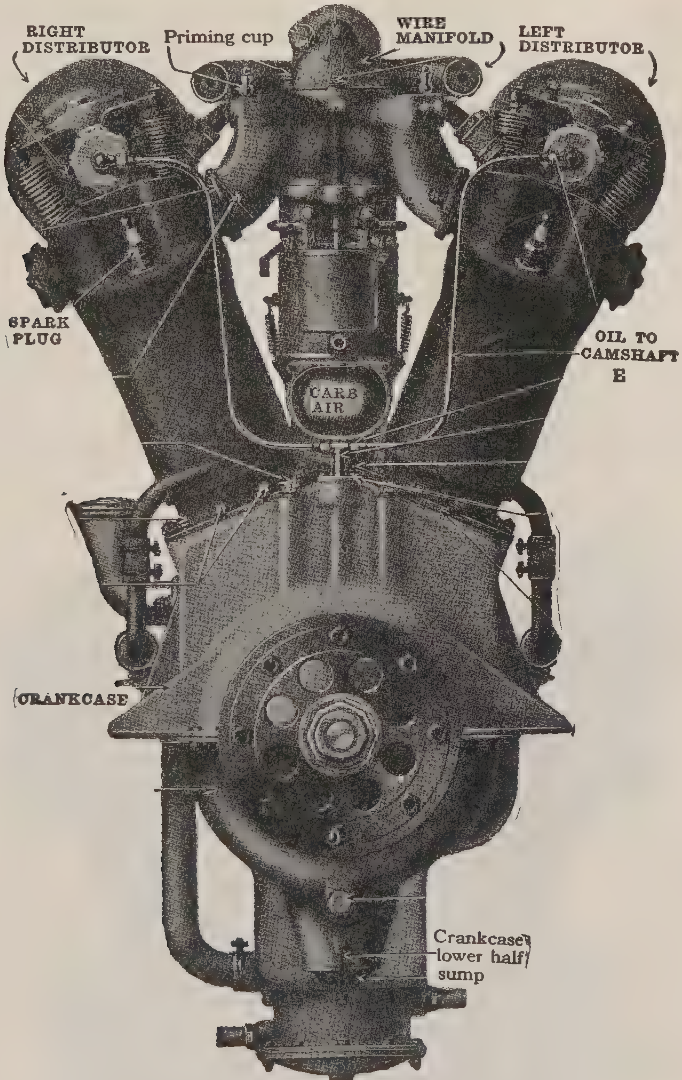


Fig. 4. Propeller end view of Liberty "12" engine.

Valves

The valves are mounted in the heads of the cylinders and are inclined at an angle of 15° to the center line of the cylinder, so that the angle made by the center lines of the two halves is 30°.

The valves are of the standard mushroom type with a 45° seat. The cylinder heads are bushed for the valves, and the valve springs are of the double concentric type.

The intake manifold passes between the two rows of cylinders, and the carburetors in most of the installations are mounted in the "V."

The entire valve drive is housed above the cylinders and can be readily removed without tearing down the engine.

The valves are operated from the cam shaft by roller cam followers, which actuate the rocker shaft and in turn the valve rocker arm or lever.

To adjust valve clearance: Turn the tappet screw (see Fig. 14, page 1151).

Cam-Shaft Drive

The cam-shaft drive was copied almost entirely from the Hall-Scott engine. In fact, several of the gears used in the first sample engines were supplied by the Hall-Scott Motor Car Co. This type of drive is used by the Mercedes, Hispano-Suiza, and others.

By referring to Fig. 5, on next page, the drive system can be seen.

Drive-Gear System

(G1) is the main drive gear on the end of the crank shaft; **(G2)** drive gear for lower oil and water-pump shaft; **(D)** bearing assembly; **(G7)** drive gear for water pump; **(N)** oil plug; **(L)** oil-pump shaft (runs at 1½ times the engine speed); **(G3)** driven gear for upper shaft; **(G4)** drive gear for the two inclined shafts (through **G5**), which drives the right and left overhead cam shaft.

The inclined shafts revolve at 1½ times the engine speed; **(G6)** is the gear (one on each inclined shaft) to drive the cam shaft; the **cam shaft** revolves at one-half the engine speed; the **distributor rotor** or brush, is driven from the cam shaft, at cam-shaft speed.

Tachometer drive and gun synchronizer: Provision is made for mounting a mechanically driven air pump on the distributor end of the engine crank case and for driving it by means of a splined shaft fitting into the crank-shaft gear. An extension of this shaft carries a double adjustable cam designed to operate a machine gun. The over-all length of the unit is 6″.

The tachometer is driven from the generator shaft.

Valve Pointers

One method for testing gas tightness of a valve: This can best be done by inverting the cylinder with the valves in place and pouring a small quantity of gasoline in the cylinder. Watch for seepage around the valve. If the valves show any leak, they should be carefully ground in. The cylinder, for this operation, should be **held in position** by means of the flange at the bottom.

Valves should not be ground any oftener than is absolutely necessary; and then only enough to "clean up" the seat. If a valve is pitted or warped to such an extent that it is necessary to grind it heavily, care should be taken that any ridge or shoulder formed on the edge of the valve seat be dressed down with a fine mill file. The abrasive should be carefully washed off the valve, the seat, and the inside of the cylinder. Test the seating of the valve with Prussian blue.

The exhaust valve spring exerts a pressure of 45 lbs. when compressed to a length of 2¼″. The intake-valve spring exerts a pressure of 23½ lbs. when compressed to a length of 2¼″.

Piston Pointers

Examine the piston for scores. It is very likely that the pistons will show scratches which were

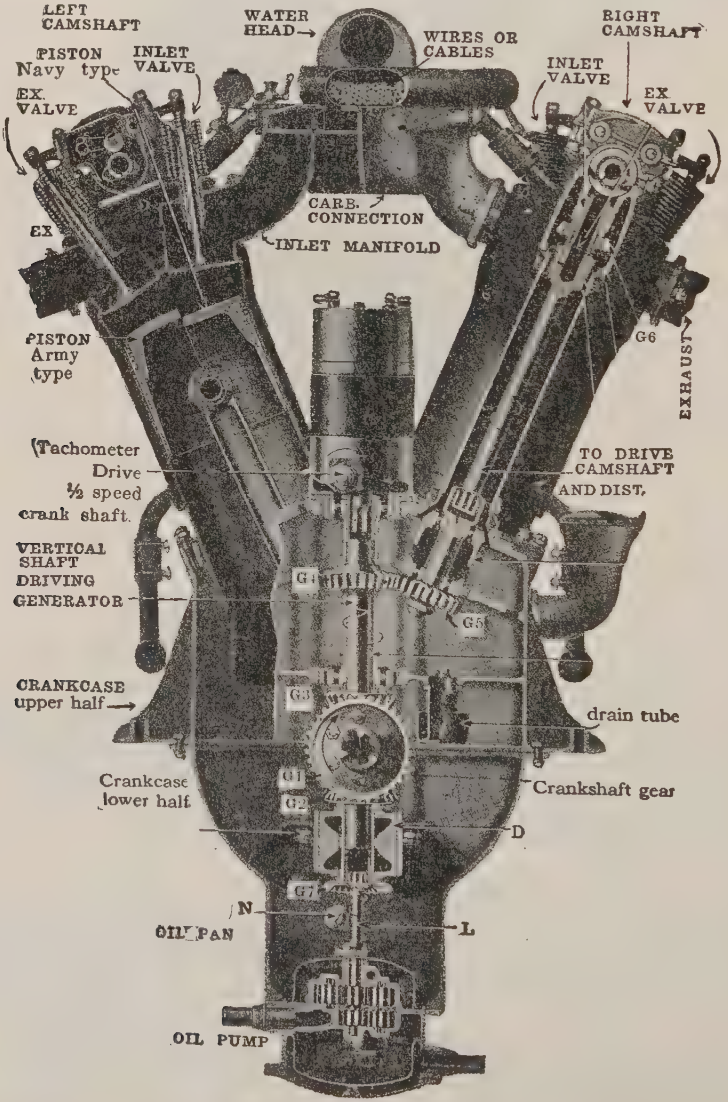


Fig. 5. Transverse section, **from distributor end,** showing how the **oil and water pump, generator and cam shaft are driven,** and also the valve action.

caused during the first run-in of the engine. It is difficult to draw a line of distinction between what is termed a scratch and a score. A piston should not be discarded unless the scores extend past the piston rings and seem to be of recent origin.

Examine the piston for even bearing on its outside surface. If any piston shows excessive wear on one side at the bottom and not at the top, it is an indication that the connecting rod is twisted or bent. This rod should be straightened up before assembling.

Piston Rings

Examine the piston rings for even bearing on the outside surfaces. The ring should be a free fit in the grooves, and should not be so loose that any shake is noticeable.

Inspect the condition of the ring grooves through the ring gap as to carbon deposit. If the carbon is soft and not of great amount, it may be wiped out with a soft rag over a splinter of wood inserted through the gap in the ring. If the amount of carbon is excessive and caked hard, the ring should be taken off.

Ring grooves should be wiped out with a soft cloth moistened with gasoline, and any carbon caked in these grooves may be scraped out with a piece of wood.

It is preferable to put back the old rings, if the wear has not been too excessive, than to fit new rings which have not been run in.

The gap between the ends of the ring should not be less than .025″ when the ring is fitted in the cylinder.

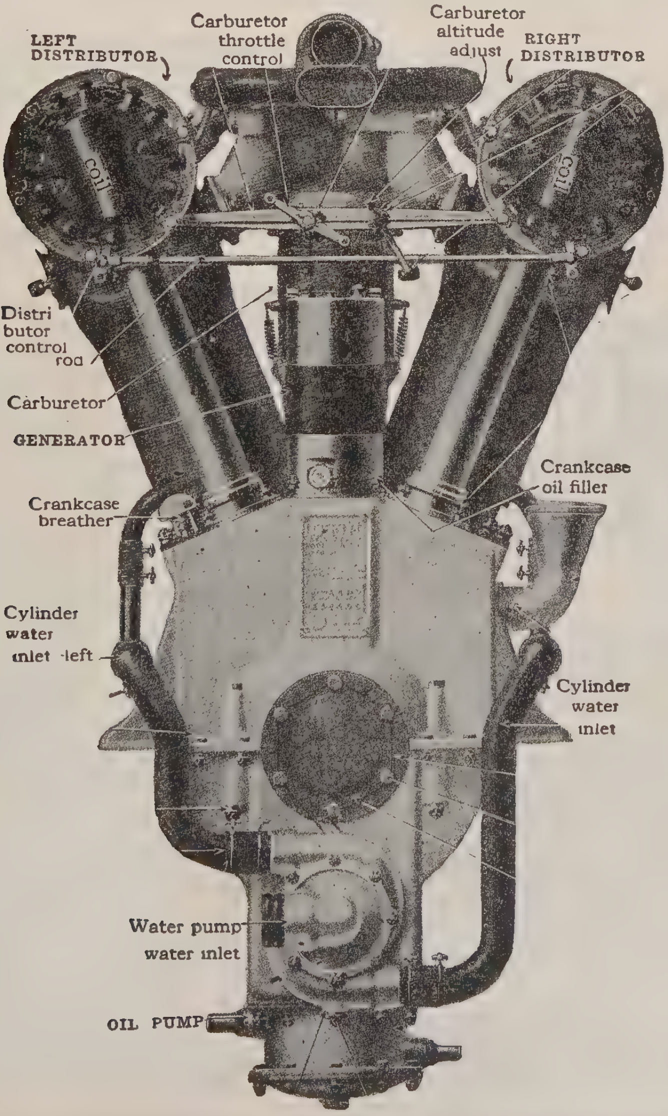


Fig. 6. **Distributor or rear-end view** of Liberty "12" engine. Note that the **high-tension ignition coils are an integral unit of each distributor,** being placed on their front. Note, too, that **all controls** are at this end of the engine.

Connecting-Rod Bearings

If the bearing has been damaged or shows wear to such an extent that it is advisable to replace it, the new bushings should first be fitted in the forked end rod. Be sure that bushing seats properly in rod and dowel does not hold it away at any point.

The caps of the forked end rod should be put in place and drawn up tightly.

Examine the joints between the cap and the rod and between the two halves of the bushings. Caps and bushings should bear equally hard at the joints.

The bushing should then be scraped to a free fit .003″ to .004″ larger than the crank pin.

The ends of the bushing should be dressed off with a fine mill file, and a sufficient amount should be removed to permit from .010″ to .020″ side play. Touch up the radius at each end of the bushing with a scraper until it clears the fillet of the crank pin. Test this point by coating the crank pin and each fillet lightly with red lead or Prussian blue.

After fifty hours of running, the engine should undergo a thorough inspection.

CARBURETION AND FUEL SYSTEM

Two Zenith duplex carburetors are used. This is equivalent to four single carburetors, each one supplying three cylinders of the engine.

Each duplex carburetor consists of a single float chamber (Fig. 7) and a single air inlet joined to two separate and distinct spray nozzles, venturi and idling devices. See also page 131.

Each of the two barrels of each carburetor is fitted with a throttle valve of the butterfly type. The two pairs of throttles are operated simultaneously by a shaft provided with an adjustment at each end by which the pairs may be synchronized.

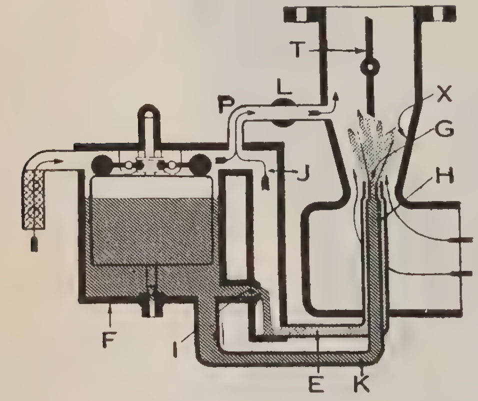


Fig. 7. Zenith carburetor.

An altitude adjustment is incorporated in this Zenith airplane type of carburetor, the purpose of which is to adjust the gasoline supply to the changed conditions met with at higher altitudes.

If a carburetor is adjusted to deliver a properly proportioned mixture at sea level, it will supply an increasingly "rich" one as the machine mounts to higher altitudes, owing to the fact that the air is lighter and less dense in the higher altitude.

The principle of the altitude adjustment, shown in Fig. 7, is as follows: The float chamber is open to the air through two screened air inlets.

The well (J) is in open communication at its top with the float chamber.

A passage (P) is provided from the float chamber to the carbureting chamber below the throttle valve; this passage is fitted with a stop cock (L), which is manually operated from the pilot's seat.

Under normal conditions, that is, on the ground, the stop cock (L) should be closed and the gasoline in the float chamber will be subjected to atmospheric pressure through the screened-air inlets.

When the engine is running, the partial vacuum produced in the throat or choke (**X**) will draw the gasoline out of the nozzle (**G**) and (**H**) in proper proportions.

At an altitude of about 6,000 feet, the aviator will begin to open the valve (**L**), thus drawing air from the float chamber and establishing therein a partial vacuum, which depends on the degree of opening of stop cock (**L**); this partial vacuum will impede the flow of gasoline through the jets, and the mixture will be made more lean.

The altitude valve should be opened as far as possible consistent with obtaining the greatest number of r.p.m. of the engine.

The float level is set so that the gasoline level is ⅛″ below the main cap jets.

Gasoline System

The air-pressure feed is used from the main gasoline tank. The initial pressure (3 lbs.) is obtained from the hand pump (Fig. 8). After the engine is running, the air pressure is obtained from the power air pump on the engine.

The auxiliary gravity feed tank, located overhead, is filled by pressure from the main tank. See Fig. 8, for further details.

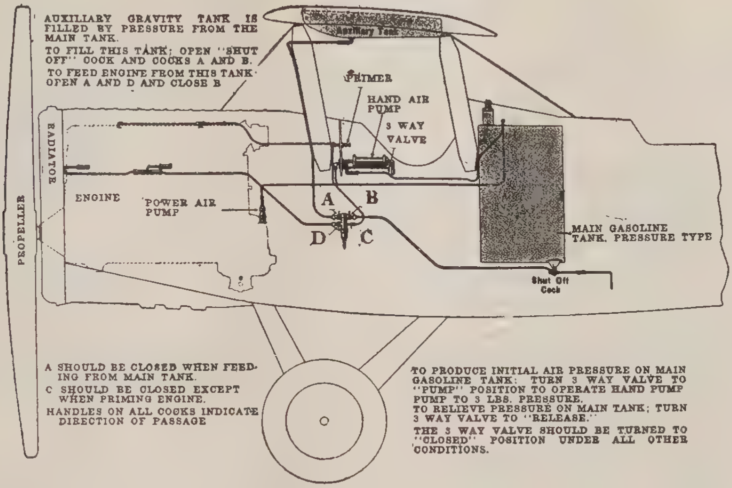
The engine-driven air pump with its regulator is designed to hold the pressure on the gasoline tank to approximately 3 lbs. In order to determine whether or not the pump is functioning properly, screw **down** the pressure-regulator adjusting screw. This should cause the pressure in the tank to rise, if the pump is operating as it should. Now screw the regulator adjustment **up** until the pressure is held steadily at 3 to 4 lbs.

Gasoline recommended: Specific gravity; 58 to 65 Baume; initial boiling point, 102° F., not higher than 120°; final boiling point 350° F.

Fuel consumption is .54 lbs. per horsepower-hour, or 36 gal. per hour with wide-open throttle at 1,700 r.p.m.

The gasoline pipe is annealed copper tubing ⅜″ inside diameter from the tank to the T between carburetors. From this T to each carburetor, the pipe is 9/32″ in diameter.

The air-pressure pipe is 3/16″ inside diameter, copper tubing.



AUXILIARY GRAVITY TANK IS FILLED BY PRESSURE FROM THE MAIN TANK.

TO FILL THIS TANK; OPEN "SHUT OFF" COCK AND COCKS A AND B.

TO FEED ENGINE FROM THIS TANK OPEN A AND D AND CLOSE B

A SHOULD BE CLOSED WHEN FEEDING FROM MAIN TANK.

C SHOULD BE CLOSED EXCEPT WHEN PRIMING ENGINE.

HANDLES ON ALL COCKS INDICATE DIRECTION OF PASSAGE

TO PRODUCE INITIAL AIR PRESSURE ON MAIN GASOLINE TANK: TURN 3 WAY VALVE TO "PUMP" POSITION TO OPERATE HAND PUMP PUMP TO 3 LBS. PRESSURE.

TO RELIEVE PRESSURE ON MAIN TANK; TURN 3 WAY VALVE TO "RELEASE."

THE 3 WAY VALVE SHOULD BE TURNED TO "CLOSED" POSITION UNDER ALL OTHER CONDITIONS.

Fig. 8. Fuel system.

LIBERTY ENGINE ELECTRICAL SYSTEM

Ignition

The ignition system (Delco) used on the Liberty "12" is of the battery type with two independent breaker and distributor mechanisms, mounted on the ends of the cam shafts, identical in every respect and each one firing all twelve cylinders.

These distributors are supplied with electrical energy from two sources: For starting and idling speeds up to 650 r.p.m., current is drawn from the specially constructed 4-cell storage battery which has sufficient capacity to ignite the engine at full speed for 3 hours and is so constructed that it will function properly upside down (8-volt, 11 ampere-hour capacity).

The generator builds up so that it takes up the load at 650 r.p.m.

Two main contact-breakers connected in parallel are located in each distributor box, and the two circuit-breakers are timed to operate simultaneously. The two contact-breakers are furnished in duplicate, as a precautionary measure. The breaker cams have 12 lobes.

Auxiliary contact-breaker is to prevent the production of a spark when the engine is turned backward or "rocked." This auxiliary breaker (Fig. 9) is connected in parallel with the other two through a resistance unit which reduces the amount of current flowing through it. The breaker is so timed that it opens slightly **before** the other two when the engine is turned in a forward direction. The opening of the main breakers then results in the production of a spark.

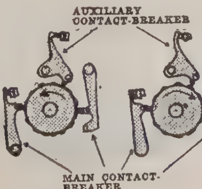


Fig. 9. Auxiliary ignition contact-breaker.

When the engine is turned in a **backward** direction, the two main breakers open first and no spark is produced owing to the fact that the current continues to flow through the coil through the auxiliary breaker, but in diminished quantity, because of the resistance unit. By the time the circuit is opened at the auxiliary breaker, the intensity of the magnetic field of the coil has weakened to such an extent that no spark is produced.

A coil is incorporated in the cover of each distributor head (see Fig. 6, page 1147).

Generator

In addition to the battery, a positively driven generator, mounted at the rear of the engine (Figs. 5 and 6), is provided, so geared that it runs at 1½ times crank-shaft speed. It is a 4-pole shunt-wound machine.

As stated above, electrical energy for starting and idling speeds is supplied by the battery. As the engine speed is increased, the generator "builds up" and its output grows greater until at about 650 r.p.m., the generator voltage equals that of the battery.

The maximum generator output exceeds the requirements for igntion, so that, at speeds above 650 r.p.m., the direction of flow of the current is reversed and the excess output of the generator goes to recharge the battery.

Regulation: The generator is controlled by a "voltage regulator," mounted on the cowl of the plane. It consists of an iron core on which are wound three coils, the connections of which are shown in Fig. 15. The regulator prevents the output exceeding a predetermined figure. In view of this fact, the generator will supply **current for ignition** indefinitely, without the battery, so long as the engine speed is not allowed to drop below 500 r.p.m. It is not possible to crank the engine fast enough to start it on the generator, however.

Switch

A duplex ignition switch, mounted on the cowl of the plane (Fig. 16, page 1151) is provided which will permit of either one or both distributors being turned "on." This switch is so constructed that either set of igntion alone can be used without connecting in the generator.

In starting, only one side should be used as, with both switches "on," the generator is connected to the battery. Under these conditions the discharge from the battery through the generator before the engine is started would be an excessive drain on the battery. It is essential that both switches be "on" at all flying speeds.

When operating at a speed under 650 r.p.m., only one switch should be used, as with both switches on, the generator is in the line and working as a motor. The result is, with both switches on, the pull on battery is about 12 amperes. With one switch on, the draw is 4 amperes, which is the ignition load.

Idling at 650 r.p.m. for an hour, with both switches on, will discharge the battery.

The ignition switch has an ammeter incorporated in it, and this ammeter should be watched occasionally as it indicates the amount of current flowing to or from the storage battery.

If the ammeter shows a discharge at any speed above 650 to 700 r.p.m. with both switches "on," it is an indication that something is wrong with the generator circuit and that all electrical energy is being supplied by the storage battery.

If the ammeter stands at zero under the same conditions, it indicates that the storage battery is not receiving a charge, but that the ignition is being carried by the generator.

There are two ignition resistance units mounted on the back of the ignition switch (see Fig. 15, page 1151).

Storage Battery

The storage battery is charged at .7 amperes for 70 hours if discharged. It is an 8-volt 4-cell battery.

Spark Plug

There are two spark plugs per cylinder to the Liberty "12."

One airplane type of spark plug (Splitdorf) is illustrated in Fig 10.

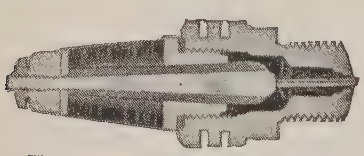


Fig. 10. Airplane type of spark plug.

The spark plugs are subjected to a pressure of 90–110 lbs. The gap distance is .015" to .018". The life of a plug of this type is 25 to 100 hours.

The parts of the Splitdorf plug (Fig. 10) **are as follows:** Brass terminal, mica washers, lateral wound mica, steel center rod, 98 per cent pure nickel electrode point, carbon steel from brass terminal to electrode, and carbon steel shell.

The AC Titan, one-piece porcelain spark plug is used on the Liberty 12-cylinder engine.

Firing Order and Valve Timing

Valve timing: Inlet opens 10° after top dead center; closes 45° after bottom dead center; exhaust opens 50° before bottom and closes 10° after top. Note that if the spark is fully advanced the spark will occur 30° before top dead center on the compression stroke. See Fig. 13 for valve-timing diagram.

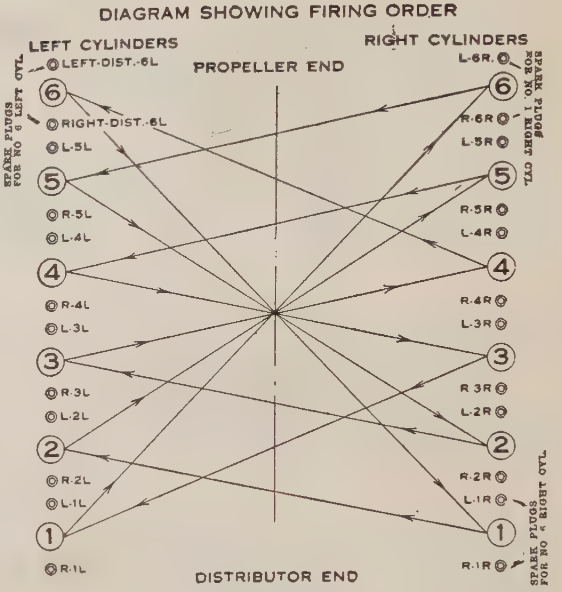


Fig. 11

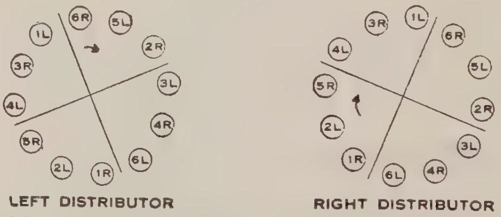


Fig. 12. **Order of firing**—Standing at the distributor end of the engine and looking toward the propeller, the groups of cylinders are designated as "Left" and "Right" respectively and are numbered 1, 2, 3, 4, 5 and 6 beginning at the distributor end. The order of firing is as follows:

1	2	3	4	5	6	7	8	9	10	11	12
1L	6R	5L	2R	3L	4R	6L	1R	2L	5R	4L	3R

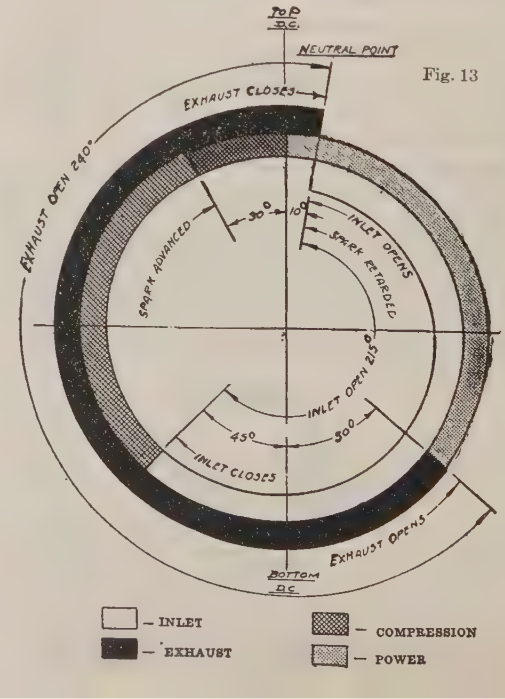


Fig. 13

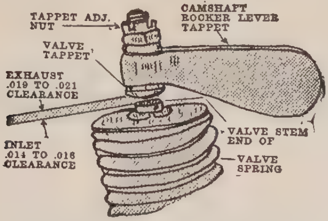

TAPPET ADJ. NUT
CAMSHAFT ROCKER LEVER TAPPET
VALVE TAPPET
EXHAUST .019 TO .021 CLEARANCE
VALVE STEM END OF
INLET .014 TO .016 CLEARANCE
VALVE SPRING

Fig. 14. Valve-clearance adjustment on Liberty engine.

Electric Wiring and Ignition System

Electric wiring: For low-tension work, No. 14 stranded cable for a distance of 10 feet or less, or No. 10 for a distance up to 25 feet, well insulated with rubber and braid. Wires taped and shellaced where clipped to the fuselage. See Fig. 15, wiring diagram. A single-wire grounded-return (G) system is used.

The spark-control advance and retard at the distributor is 10° after dead center "retarded," and 30° before dead center "advanced" (see Fig. 13, page 1150).

The contact-breaker (timer) gap, when the breaker is wide open, should be .010″ to .013″.

The spark-plug gap: .015″ to .018″ of an inch. Defects in all spark plugs are most apparent when the plugs are hot.

Timing: When the engine is set on the firing point of No. 1L cylinder, in other words, with No. 1L crank set 10° past top of "compression" dead center, the carbon brush in the end of the distributor rotor should bear on the brass contact marked 1L on the distributor head.

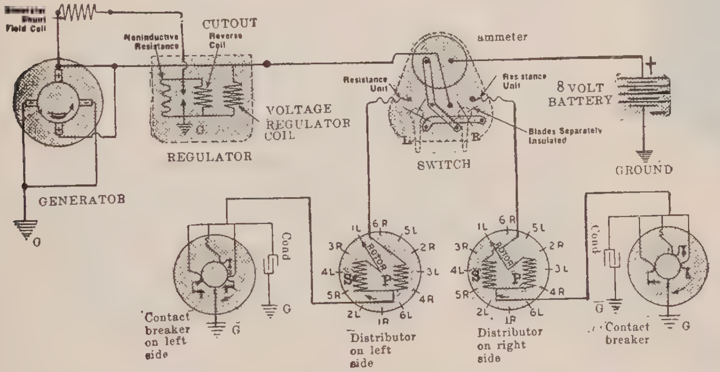


Fig. 15. Wiring diagram of Liberty engine.

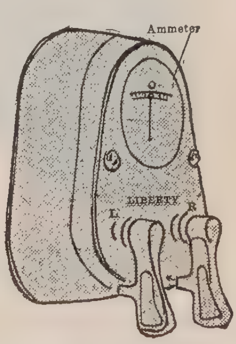


Fig. 16. Duplex ignition switch.

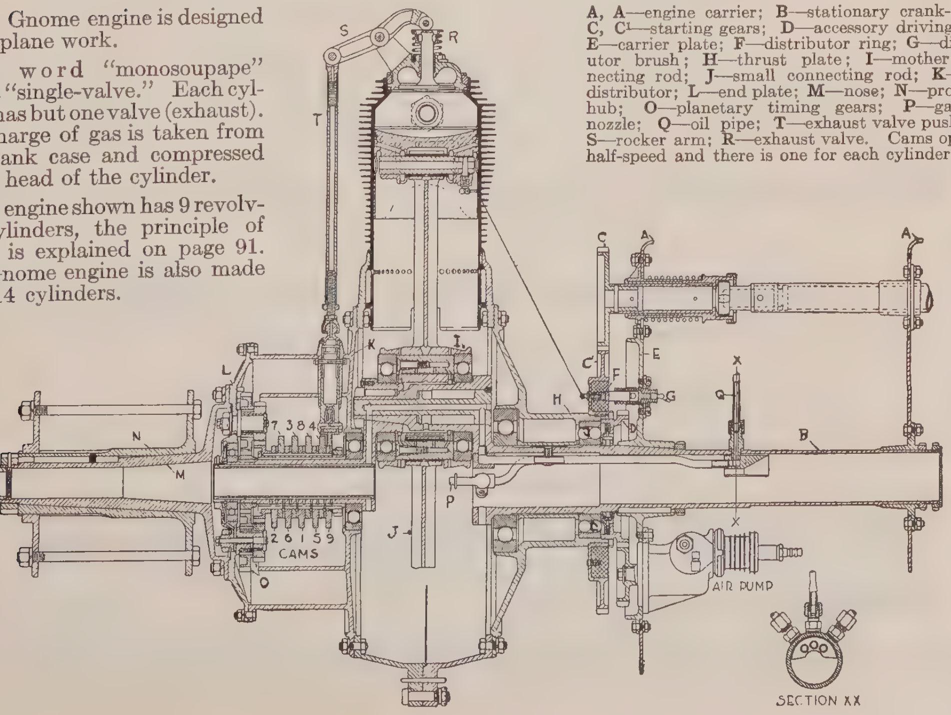
GNOME MONOSOUPAPE REVOLVING CYLINDER ENGINE

The Gnome engine is designed for airplane work.

The word "monosoupape" means "single-valve." Each cylinder has but one valve (exhaust). The charge of gas is taken from the crank case and compressed in the head of the cylinder.

The engine shown has 9 revolving cylinders, the principle of which is explained on page 91. The Gnome engine is also made with 14 cylinders.

A, A—engine carrier; B—stationary crank-shaft; C, C¹—starting gears; D—accessory driving gear; E—carrier plate; F—distributor ring; G—distributor brush; H—thrust plate; I—mother connecting rod; J—small connecting rod; K—cam distributor; L—end plate; M—nose; N—propeller hub; O—planetary timing gears; P—gasoline nozzle; Q—oil pipe; T—exhaust valve push rod; S—rocker arm; R—exhaust valve. Cams operate half-speed and there is one for each cylinder.



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GENERAL INDEX

Instructions how to use the Index: This Index is prepared so that a student, a novice, an expert, or an instructor can readily find any subject in the book. It is advisable, therefore, to take a few minutes' time to study the Index and to follow the instructions given herein before starting to study the book.

The subjects are alphabetically arranged, but classified as **major, minor,** and **miscellaneous** subjects.

Major subjects are: *Assembly of the Automobile, Principles, Troubles, Adjusting, Testing, Repairing, and Timing.* These subjects are indexed in **black face type.** For example, if you desire to find the Fundamental Principle of any subject, first look under *"Principle of."*

Likewise, if you desire to find how to Diagnose or to Test for a Trouble, first look under *"Troubles"* and then under *"Testing."*

If you desire to find how to adjust any part of a car, first look under *"Adjusting."* If what you are looking for is not found, then look under the part to be adjusted, such as *"Clutch"* or *"Carburetor,"* etc.

If you desire to find how a certain car, truck, or tractor is constructed, look under *"Specifications,"* pages 1056, 966, 996.

If you desire to find how to adjust the axle, carburetor, clutch, or some other part of a certain make of car, truck, or tractor, and do not know the make or type used on that car, first look under *"Specifications of Passenger Cars, Trucks, or Tractors,"* then turn to that page and find the make or type of axle, carburetor, clutch, etc.; then turn to the Index for the part of that particular make; or if the make is not given, the type will be given; then turn to the page whereon it is described.

For example: Suppose you wished to find the method of adjusting the clutch on an Auburn car; first turn to the specifications where you would find that the clutch used was a Borg & Beck; now turn to the Index under *"Borg & Beck clutch adjusting,"* and if not found, turn to *"Clutch, adjusting (Borg & Beck)."*

Measurements: Before the student can clearly understand valve timing, ignition timing, and the many other subjects treated in this book, it is advisable for him to turn first to the Index and to find such subjects as *"Decimals," "Thousandth Part of an Inch," "Degrees,"* etc., and to learn fully their meanings.

Terms, Symbols, and Index Review: Likewise the student should study the meaning of words and terms in the Dictionary, and also refer to the Index for *"Glossary of storage battery terms," "Glossary of gear contacts,"* and also *"Electrical symbols"* and *"Symbols of degrees, feet, inches, and seconds,"* all of which can be found by referring to the Index.

Table of Contents: In the first part of this book a brief digest of subjects is given, together with the page number and instruction number. It is advisable to read it carefully first.

If you don't find what you want under one heading, stop and THINK—what other heading it could be under. For instance, if you are looking for the *"Adjustment of floats of carburetors,"* it may be under *"Carburetor float adjustment,"* or *"Adjustment: carburetor float,"* or *"Floats for carburetors."*

Subjects, as a rule, are cross-indexed in three ways:

(1) Part, Operation, Make.
(2) Part, Operation, Make.
(3) Make, Part, Operation.

For example: "Clutch adjusting (Borg & Beck)" can be found in three ways:

(1) Clutch (part); adjusting (operation); Borg & Beck (make).
(2) Adjusting (operation); clutch (part); Borg & Beck (make).
(3) Borg & Beck (make); clutch (part); adjusting (operation).

The Ford is indexed under *"Ford," "Ford truck," "Ford tractor."*

Note: Where there are hyphens between figures, as for example 865–867, all pages between these pages are included.

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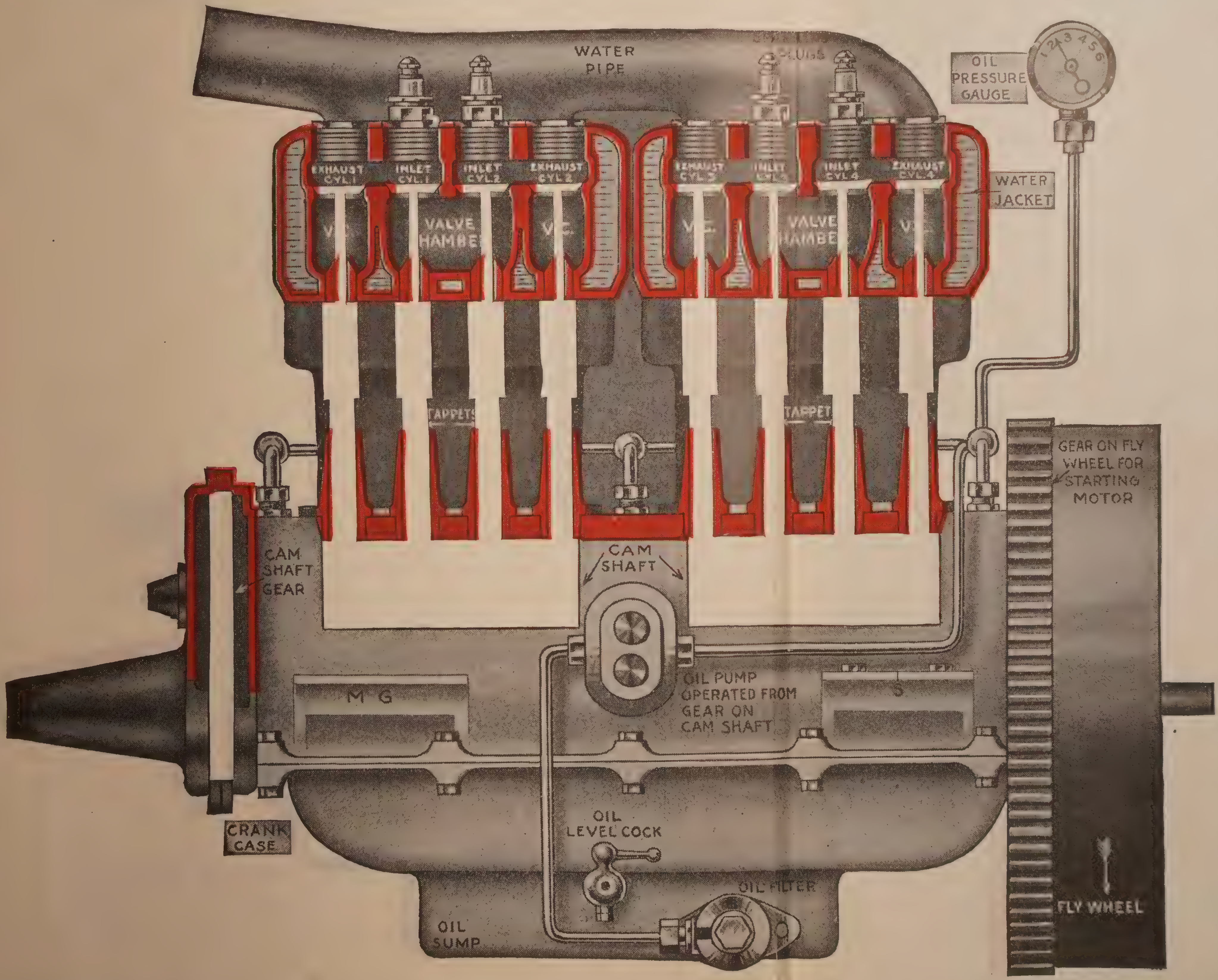
VALVE AND CAM SIDE OF FOUR-CYLINDER ENGINE. (Draw in the Parts.)

Draw in the other side first (shown on the reverse side of the sheet); then draw in the parts on this, the valve side of the engine.

Valves: Draw in the valve head in its seat or slightly raised where necessary, taking it for granted that No. 1 piston is just starting down on the power stroke. The firing order, we will say, is 1, 2, 4, 3.

Valve springs come next; then the valve-spring retainers.



Cam gears should now be drawn; then the **cam shaft** with its eight cams. Place the cams in position, as near as possible as if No. 1 piston was just starting down on the power stroke; No. 2 just starting up on compression; No. 3 just starting up on exhaust, and No. 4 just starting down on the suction stroke.

Valve guides are drawn next, then the **valve tappets**; on the upper part of the valve tappets place adjustment nuts.

The lubrication system of the forced-feed principle can now be outlined—the oil pump being operated from the cam shaft. Show arrows pointing in the direction of the flow of oil.

Ignition: A magneto of the high-tension type can be installed, or a battery and coil system, as desired.

If a battery and coil system is decided upon, place the ignition unit on the generator, and place the generator on the bracket (MG). Chains usually run the generator—but in this case we will use gears.

Connect up the wires from timer to battery (place a battery below somewhere); connect cables from the distributor to the spark plugs for a firing order of 1, 2, 4, 3.

Starting motor: Place a starting motor, using a Bendix drive on the bracket (S); connect this starter with the battery and switch.

INSERT NO. 1. Four-Cylinder Engine Drawing Diagram.

(Copyrighted, 1922, by A. L. Dyke, St. Louis, Mo.)

PISTON AND CRANK SIDE OF FOUR-CYLINDER ENGINE (Draw in the Parts.)

In order to understand more clearly just where the parts of an engine are located and their purpose, this illustration and the one on the back have been provided. If the reader cares to, he may take his pencil (a soft one) and **draw in the parts** as enumerated below. This will assist very materially in gaining a practical knowledge of the parts involved.

Crank shaft: Draw this first. Bear in mind that the stroke of the piston is approximately 1⅛"; therefore the "throw" of the crank shaft must be one-half of this, or 9/16". The crank shaft is an 180° crank.

The pistons are next. They are approximately ¾" diameter. The length should be approximately ⅞". There is a slight clearance.

Piston rings: Place three on the piston for No. 4 cylinder.

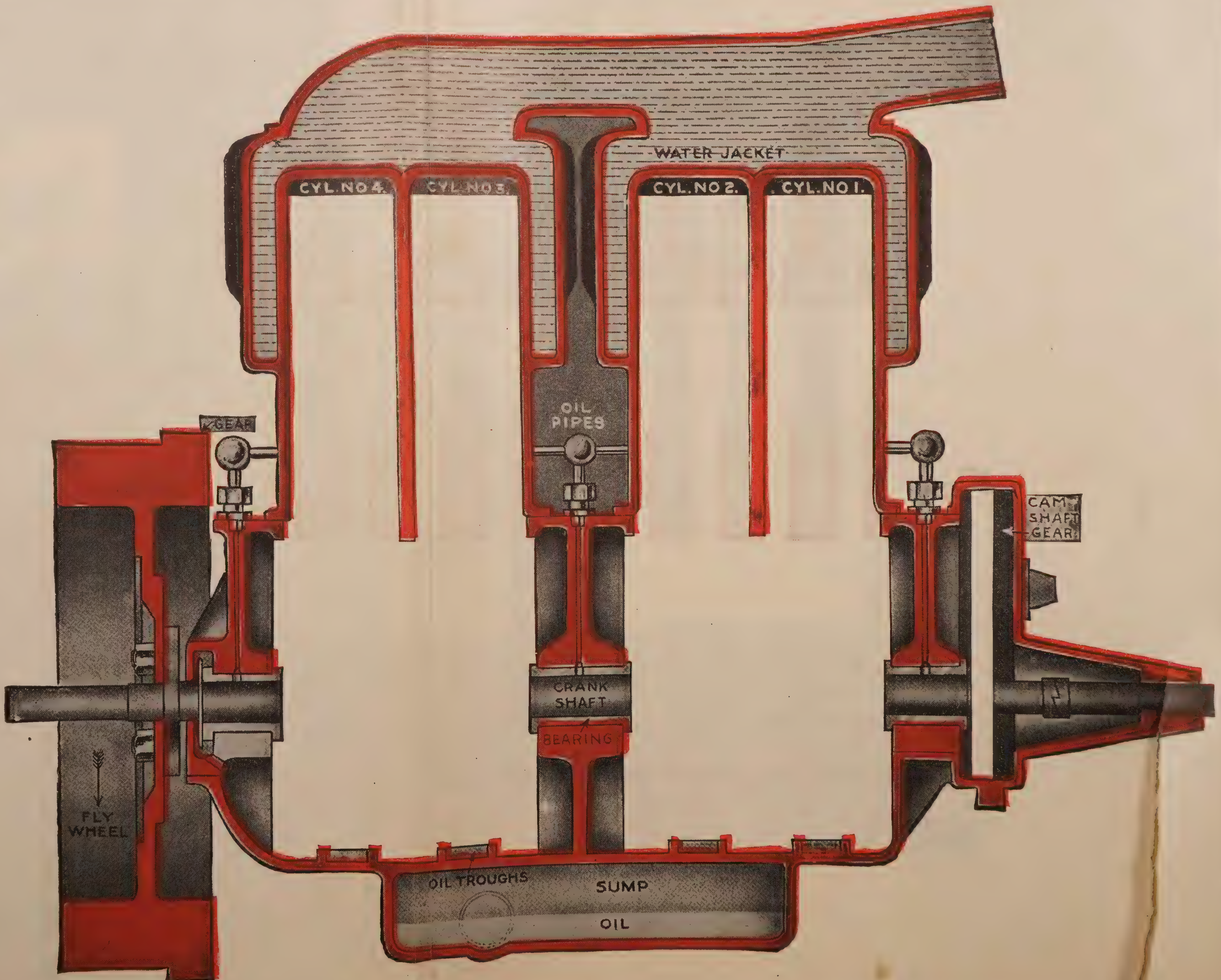
The wrist pin is next; the piston for No. 3 cylinder should be drawn in section so as to show it. Draw pistons for cylinders No. 2 and No. 1 in like manner.

Connecting rods (with the lower bearing split and bushings provided and shims between the upper and lower parts) should be drawn next. The **oil scoop** or dipper is to be provided on the lower end of the connecting-rod cap.

Timing gears: The crank-shaft timing gear is one-half the size of the cam-shaft timing gear.

The cam shaft is drawn in next. Bearings are not provided, but can be indicated.

Clutch: Draw a cone or plate clutch (in section) in the flywheel. It will be necessary to taper the inner face of the flywheel rim for a cone clutch, and to re-design it for a plate clutch.



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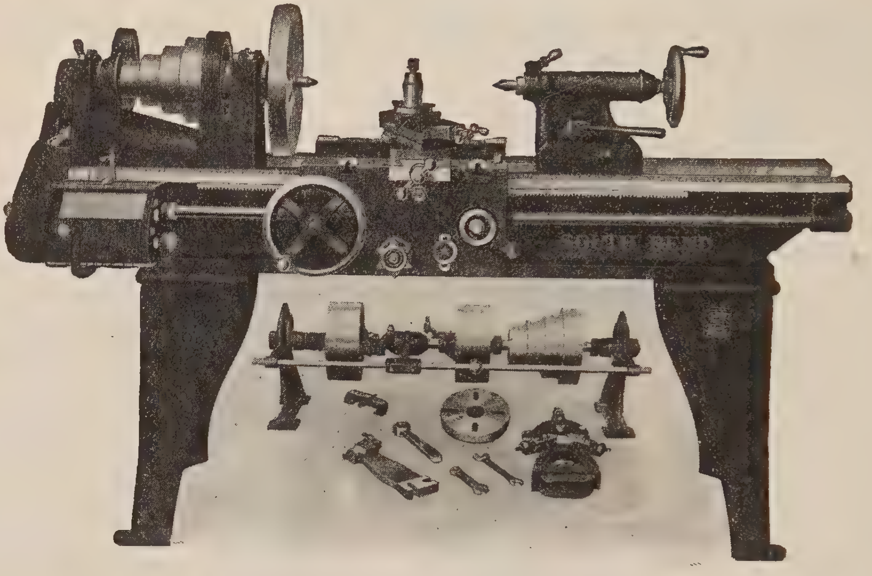

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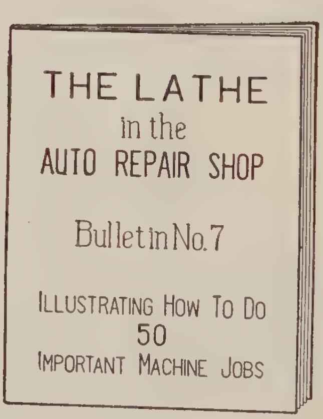

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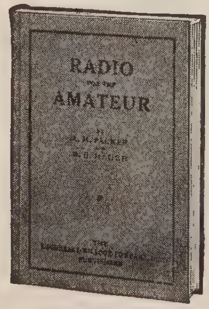

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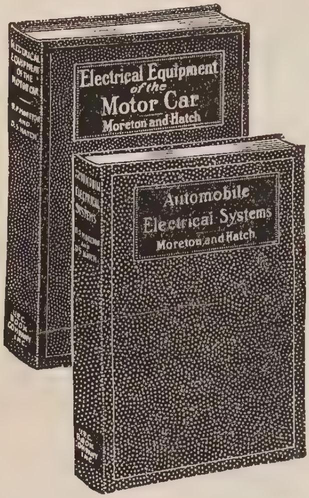
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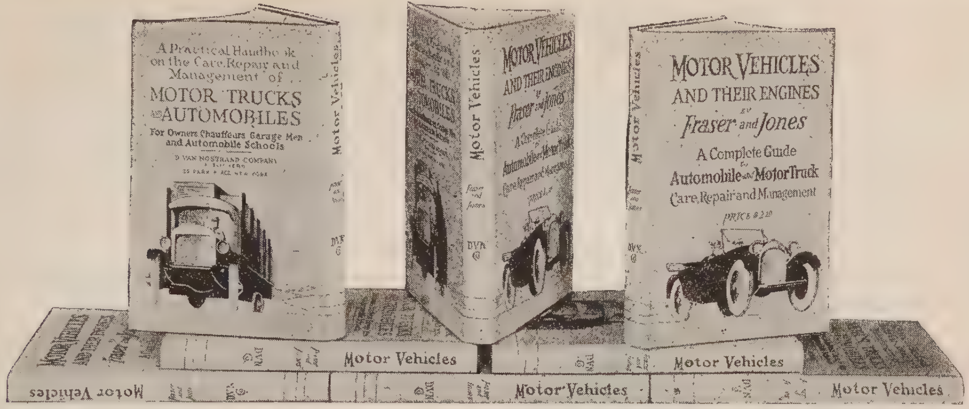
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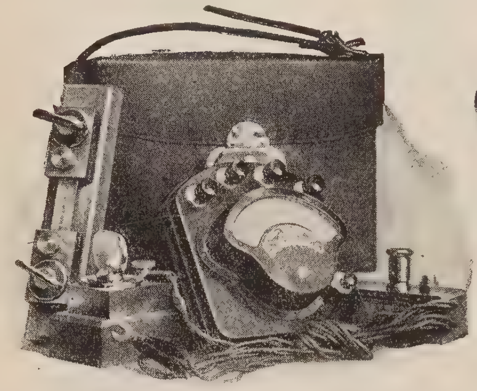
ELECTRICAL TESTING INSTRUMENTS

For Automotive Electrical Repairmen

The most profitable work of automobile repairing is that of electric work. After studying the subjects of the different electrical systems in this book, and the principle and construction of the Weston meter as shown on page 464, then how to test on pages 475 to 520 and 545 to 555, then how to diagnose troubles on pages 454 to 462 and 556, anyone ought to be able to test, diagnose and remedy almost any electrical trouble—**if equipped with the proper Testing Instruments, Wiring Manual and Data for making the tests.** The Instruments shown below are recommended and the Wiring Manual and Data book is described in the advertising section elsewhere of this book.



Weston Model "280" Combination Volt-Ammeter

This instrument can be used to make all average tests the electrical repairman will be called upon to do (see page 464) **and it will also make cadmium tests,** as the scale (fig. 7, page 548) is now provided without extra cost. Weston cadmium test points and test cables (fig. 8, page 548) are $5.00 extra. Ambu cadmium test points and test cables $2.25 extra. Either can be used.

Price Weston Model "280" Volt-Ammeter with three shunts; 3, 30 and 300 ampere and test cables and book of instructions—$41.25 (case $7.00 extra).

Ambu High Rate Battery Discharge Tester

This tester provides an accurate, reliable means of testing the performance of a storage battery under discharge, without removing the battery from the car. Simply place the two sharp prods; one on the positive, and other on the negative post of each cell, and the voltmeter flashes the condition of battery instantly.

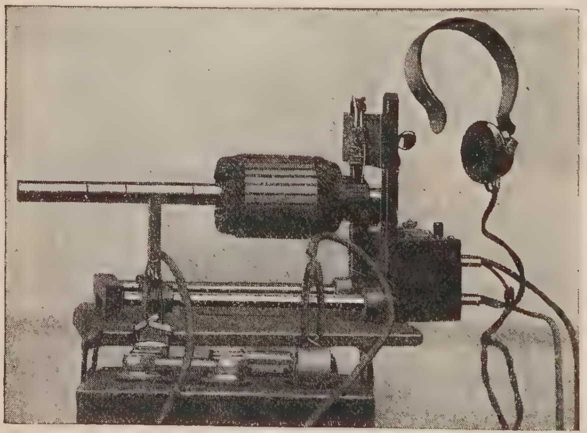
The **voltmeter** has a range of 2 volts on each side of the center zero. The readings are easily made during tests.

The **prods** are made of heavy ⅜" square nickle-plated steel driven into a large wooden handle. The **shunt** is made of heavy Nichomre metal. Size 4" x 11½" high.

This tester in your shop will be invaluable as an aid in securing repair work and selling new batteries when the old battery is found to be "shot." **Price** complete with voltmeter **$6.75.**

Coil Tester and Remagnetizer

See page 223 for an **ignition coil tester** and pages 312 and 1118 for a **magnet remagnetizer.**



Testing Method: First the operator raises the sliding panel and places the armature to be tested in position, as shown. Lowering the panel then brings four contact arms to bear on the commutator bars. The operator puts on the special telephone receiver, turns on power, and tests by rotating the armature and listening in the receiver. As the armature is rotated, current from the center test points passes through each consecutive pair of bars, while the outer test bars draw a shunted current off two bars equally distant from the bar at which the current enters. This current passes through the primary of a transformer, the secondary of which is connected to the telephone receiver. The transformer develops the slightest variation in current strength into a marked change in the receiver's buzzing note. These changes indicate every fault in the armature.

Ambu Armature Tester

This new patented armature tester is priced low enough to be within the reach of the smallest shops and does the work of a "growler" or transformer test, "drop of potential" test and the telephone receiver test combined, and in less time than any of them.

It is designed for use with a 6 volt storage battery. Connecting a bank of lamps in series with it, equips the Tester to work on any ordinary direct or alternating current. Maximum current is ½ to 1 ampere.

The testing method is explained under illustration. So long as the armature coils are in good condition, the receiver gives a uniform loudness. An **open circuit** is indicated by a sudden, marked **increase** in loudness, and a **short circuit** is indicated by an equally pronounced **decrease** in loudness. **Reversed connections** between the coils and commutator are indicated by a loud tone every **second** pair of bars.

When one rotation has been completed, a small switch is thrown, and a second rotation tests for grounds. In every kind of trouble—open circuit, short circuits, grounds, and reversed connections—the Tester picks out the bars to which the faulty windings are connected. Each coil is tested against several others, and the **entire test requires only five minutes.**

Price Tester complete (wt. 15 lbs. packed) **$30.00**